International Journal of Science Education
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713737283

Eyeballs in the Fridge: Sources of early interest in science

Adam V. Maltese[a]; Robert H. Tai[b]
[a] Indiana University, USA [b] University of Virginia, USA

First published on: 11 June 2009

To cite this Article Maltese, Adam V. and Tai, Robert H.(2010) 'Eyeballs in the Fridge: Sources of early interest in science', International Journal of Science Education, 32: 5, 669 — 685, First published on: 11 June 2009 (iFirst)

To link to this Article: DOI: 10.1080/09500690902792385

URL: http://dx.doi.org/10.1080/09500690902792385

International Journal of Science Education
Vol. 32, No. 5, 15 March 2010, pp. 669–685

RESEARCH REPORT

Eyeballs in the Fridge: Sources of early interest in science

Adam V. Maltese[a]* and Robert H. Tai[b]
[a]*Indiana University, USA;* [b]*University of Virginia, USA*

This paper examines the experiences reported by scientists and graduate students regarding the experiences that first engaged them in science. The interviews analysed for this paper come from Project Crossover, a mixed-methods study of the transition from graduate student to PhD scientist in the fields of chemistry and physics. This analysis involved review of 116 interviews collected from graduate students and scientists and focused on the timing, source, and nature of their earliest interest in science. The majority (65%) of participants reported that their interest in science began before middle school. Females were more likely to report that their interest was sparked by school-related activities, while most males recounted self-initiated activities. Our findings indicate that current policy efforts (which focus on high school science reform) to increase the numbers of students studying in the science fields, may be misguided.

Keywords: *Attitudes; Career interest; Gender-related; Qualitative research; Science education*

There has been a good deal of public attention paid to science and science education in the past few years. In his 2006 State of the Union address, President Bush discussed his plans for the *American Competitiveness Initiative*, a plan to keep America at the forefront of the global economy (Bush, 2006). This speech followed the publication of *Rising above the Gathering Storm*, a report by the National Academies (2005) that discussed the condition of science and technology in the USA and stressed the importance of science education for maintaining the technical workforce. Understandably, corporations are also concerned, especially with the impending retirement of baby-boomer scientists over the next 10 years.[1] However, the USA is not the only country concerned about these issues; the European Union issued a major report

*Corresponding author. Department of Education, Indiana University, W. W. Wright Education Building, Rm. 3054, 201 North Rose Avenue, Bloomington, IN 47405, USA. Email: amaltese@indiana.edu

ISSN 0950-0693 (print)/ISSN 1464-5289 (online)/10/050669–17

DOI: 10.1080/09500690902792385

concerning the need for more scientists to achieve the desired economic growth (European Commission, 2004).

These reports extol the importance of having more students proficient in science and more scientists in the workforce, yet the causal link between the two seems tenuous. Reports like the ones mentioned often seem to imply that improving student proficiency in science will eventually lead a country to a globally competitive position in research and development. However, it seems logical that factors other than achievement influence students' decisions to persist in their study of science. While persistence is critical to the production of scientists, it is equally important to know what types of experiences lead to that initial spark of interest in science. To investigate these issues, this study analysed the stories from those who have actually progressed to advanced levels of education (i.e., graduate training) or are practising academic and industrial scientists to gain an understanding of the experiences that led to their initial interest in science.

There are plenty of anecdotal reports of famous scientists becoming interested in science at an early age; however, little research exists regarding the prevalence of this phenomenon and its importance in developing scientists. A recent investigation was completed to examine the role that students' interest in science plays in college degree completion. Tai et al. (2006) recently completed an analysis using data from the National Education Longitudinal Study of 1988 (NELS:88), where eighth-grade students were asked to indicate the career they desired at age 30. In 2000, NELS:88 collected a final round of data that included college transcripts for approximately 12,000 of the students surveyed in the eighth grade. The researchers employed a logistic regression model with science vs. non-science college major as the outcome variable. After accounting for differences in background and academic history, the results indicated that students reporting an interest in science careers in eighth grade were three times more likely to obtain a college degree in a science field than those who did not show that interest.

In England, the prestigious Royal Society (2004) initiated a study to investigate the effect of role models in the choices of individuals who pursued careers in science, engineering, and math. As part of the study, the Society conducted a web survey of scientists and engineers, where respondents were asked when they first considered a career in the science and engineering fields. Out of more than 1,100 respondents, 63% indicated that they had such thoughts by the age of 14. The study found that, on average, the female participants reported a first interest in science a few years later than the men in the study, but no further details about these experiences were collected.

Investigating factors involved with student persistence, Lindahl (2007) recently reported findings from her longitudinal study of 70 Swedish students tracked from age 12 to age 16. Using a combination of interviews and questionnaires, her results indicated that students were thinking about potential careers in science as early as age 12. An additional finding reported by Lindahl was that students claim "interest" as the most important factor in choosing to follow science in school. Lyons (2006) reviewed three qualitative studies (including work by Lindahl) that investigated student experiences in science classrooms in Sweden, England, and Australia. One conclusion from these studies was that students are often not engaged by the “autocratic” way science is represented in their classes. Additionally, students often reported that the science they were taught in their classes was usually disconnected from the natural world they experienced on a daily basis. These feelings often resulted in students deciding not to continue their enrolment in science classes.

Cleaves (2005) completed a study in the UK to investigate the formation of students’ choices to enter into a science field in college; he selected students from six schools in a small city of approximately 100,000 people. A total of 69 students were interviewed four times in three years beginning in Year 9 and ending in Year 11. Cleaves separated student trajectories into five categories: directed (early and specific career goal), partially resolved (less focused idea of career), funneling identifier (narrowing of ideas over time), multiple projector (constantly changing), and precipitating (little focus, uncommitted). Interestingly, many of the students planning to continue study in the science, technology, engineering, and math (STEM) fields reported on experiences that they did not enjoy in secondary school science. Students often reported being bored, not having a good sense of the career options in science fields, or simply enjoying other classes more. However, because of some vision of the career they wanted, or the flexibility that study in STEM would give them, these students planned to continue in science. The students who did not plan to continue in STEM reported similar educational experiences, but for this group, the experiences were strong enough to deter them from wanting to continue study of science and mathematics at an advanced level.

Seymour and Hewitt (1997) used interview and focus group data from over 400 college students to assess reasons why the students remained in STEM or switched from majors. The researchers uncovered a number of reasons that contribute to student attrition from STEM majors. The finding most relevant to this study is that the students who remained in STEM majors were more likely to claim that they received motivation from strong intrinsic interest in the field than those students who switched majors. The results from this study, as well as from Lindahl (2007) and Cleaves (2005), provide a better picture of the issues involved with students remaining on the pathway toward careers in science, but do not address issues related to how students developed their initial interest in the field.

Osborne, Simon, and Collins (2003) completed a detailed review of research involving student attitudes toward science. One of the major conclusions of this review was that science teachers play a major role in student attitudes toward science and persistence. Osborne et al. state that even though this link is found throughout the literature, little research has been done to investigate these factors from the students’ perspective.

While the studies mentioned here touch on aspects of student persistence in science such as the timing of initial interest (Royal Society, 2004) and personal reasons for staying in or leaving from science (e.g., Cleaves, 2005; Seymour & Hewitt, 1997), none of the studies investigated the combination of these factors using the same participants. More importantly, although previous studies have touched on student interest in science, few involved populations that had actually matured to working age and pursued careers in science. Said another way, there is not much published research involving qualitative data on early interest in science from those who have actually gone on to work in science. Given this record of research, we sought to answer the following three important questions with this analysis:

Among graduate students and scientists in chemistry and physics:

(1) What was the timing of their initial interest in science?
(2) Who was responsible for sparking their interest?
(3) What was the nature of the initial experiences?

Although it is interesting to know when and how scientists first became interested in the field, assessing the role of educators in initiating student interest is the main focus of this analysis. The significance of these results may help guide educators and administrators in the development of curriculum or programs to help generate early interest.

Framework

This analysis is based on our belief that student aspirations are developed from a combination of intrinsic interest and extrinsic experiences; what Lent, Brown, and Hackett (1994, 2000) call Social Cognitive Career Theory. Lent et al. believe that aspirations and career choices are a result of the complex interplay of person, environment, and behavior. The importance of career aspirations in student persistence in science has been discussed elsewhere (e.g., Mau, 2003; Wang & Staver, 2001), but, as the name implies, these studies involve the intentions of students, not actual distal outcomes. This study is different—by analyzing the reported stories of practicing graduate students and scientists we hoped to gain an understanding of the experiences that sparked their interest in science. In turn, the results of this analysis may present educators with a clearer picture about the types of experiences that may initiate student interest in science.

Methods

The data included in this analysis resulted from the qualitative part of a mixed-method investigation: Project Crossover. Focusing on the fields of physics and chemistry, Project Crossover set out to study the transition from graduate student to scientist—from a consumer of knowledge to a producer of knowledge. As part of this study, interviews were collected from individuals with experience in a PhD program in either chemistry or physics. The interviews focused on graduate school, but also included early educational history, and relevant research and employment experiences. This study focuses on participant responses to questions about their earliest experiences in science.

Practicing and retired scientists, as well as graduate students were solicited from across the USA to participate in the study. Individuals were contacted by email and phone and asked to participate in the research project. In an attempt to maximize the variety of experiences of our participants we contacted individuals from different fields, work settings (i.e., academic institutions, industry, government), and experience levels (from new graduate students to Department Chairs and Nobel Laureates). In addition, we sought to increase the ethnic and regional diversity of the sample by soliciting scientists from groups traditionally underrepresented in the physical sciences. Those who participated in interviews often provided contacts for their colleagues and mentors, who we also solicited. While this method of sampling restricts the generalisability of the results it is often the best option when pursuing a representative sample of a population, which is not easily defined (Rodrigues et al., 2007).

To answer the research questions proposed for this analysis, we used transcripts from 116 completed interviews, collected mainly from scientists and graduate students between September 2005 and September 2006. The majority of interviews were collected over the phone, with approximately 25% of the interviews completed in person. The interviews followed a semi-structured format. However, since the interviews were meant to explore all of the issues involved in the transition from student to scientist, interviewers were encouraged to ask probing questions and follow all leads. Because of this, not all interviews touched on exactly the same material. Each interview was recorded using a digital recording device. The recordings were transcribed and transcriptions were sent to the participants for member-checking of their statements. To supplement the interview data, text copies of autobiographies were obtained for two of the scientists included in the sample. In a few cases, clarification was sought from participants regarding their interview responses. In these cases, the e-mail communications were included in the data file and made available for coding and analysis.

Once approved by the interviewees, transcripts and other documents were imported into QSR *NVivo 7*, a software package that enables computer-assisted qualitative data analysis. Every file was associated with a set of attributes for each participant indicating gender, field and position.

Because of the time required to complete all transcriptions, data coding was completed in two phases based on the availability of approved interview transcripts. The first batch of transcripts included approximately 40 interviews and the second batch an additional 76. As a result, the batches were coded as an exploration sample and a confirmation sample before being combined for analysis.

For the exploration sample, the first step of the coding process involved data reduction. To reduce the data we made an initial read through the interviews and used open coding on the transcripts, specifically seeking references to early interest in science. To provide context to the coded sections, we included all surrounding text relevant to the current analysis as "Early interest in science". Once all of the transcripts were reviewed and coded for early interest, we used *NVivo* to coalesce all of the references. During the first pass through these coded sections, additional contextual data were included (or deleted) to make the reduced set of data more complete. With each pass through the coded sections, additional data were deleted (or rarely included), as necessary. To complete the search for appropriate excerpts, we used the *NVivo* Query function to search the transcripts for words commonly used in the relevant questions or responses including: early and earliest, interest, kid, child, family, parents, teacher, grade school, middle school, and high school. The word search turned up a few previously un-coded excerpts that were pertinent, and therefore included in the data.

Once satisfied that no major sections of text related to early science interest were missing from the reduced "corpus" of data, we began axial coding at a more micro-level. Although we entered into coding with vague conceptions of what we thought the data contained—as a result of conducting the interviews and reading of relevant literature—we sought to follow a grounded approach and allow the codes to develop from the data (Lonkila, 1995). However, unlike strict grounded theory, we did not code the text in a word-by-word fashion. Instead, we coded sentences or paragraphs with multiple *NVivo* nodes. We sought to include enough surrounding text to provide context for the codes, but also worked to separate chunks of text concerning distinct issues.

Because the codes in grounded theory are developed from constant comparisons throughout the data, there is continuous evolution of the coding structure. After the first coding pass through the text, it was necessary to read through the text again with the updated set of codes and work toward consistent coding of the data. After the third pass through the data, we were confident that there was a high level of consistency with the coding.

After completing the exploratory batch, we sought to code the remaining transcripts using the same coding structure. Before coding the second batch of transcripts, we reduced the data in an identical fashion as described previously. Once the data were reduced, we proceeded to read through the excerpts and code the text based on the scheme established during the exploratory phase. Because the overall analysis focused on "concrete" coding categories (e.g., timing, content), it was not necessary to add many additional categories to the established scheme while coding the confirmatory batch of transcripts. The only significant change was to include an "Always" category to the timing of initial interest. As a result of this addition, we read through the exploratory batch of transcripts and recoded excerpts, as necessary.

When we believed the exploratory and confirmatory stages of coding to be complete, we began to search through the coded text using the Matrix Query function in *NVivo*. The Matrix function allows the researcher to search for co-occurrences of multiple codes. We used the function to search out instances of a code marking statements of initial interest with coding that indicated the timing of that event (i.e., college, high school (Grades 9–12), middle school (Grades 6–8), early (K–5), always, or unclear). We ran additional queries searching for the source (i.e., self, family, or school) responsible for sparking the initial interest and also the nature of the experience. For the nature of the experience, we included codes concerning activities such as: tinkering, reading science fiction, participating in science fairs, and other similar experiences. All of these queries were saved in *NVivo* to make it easier to review and update the queries as necessary.

Although our coding strategy was based on the grounded theory approach, we feel that the analysis of the data followed the data reduction ↔; data display ↔ drawing/verifying conclusions model proposed by Huberman and Miles (1994). Huberman and Miles argued that this is a circular process that should take place before, during, and after data collection. In this analysis, it was primarily used post data collection. Separating out and reassembling the data in different ways allowed us to create and refine a theory regarding early student interest in science.

Sample

From the interviews of the 116 participants, 85 of the transcripts (or available autobiographies) contained data regarding early interest in science. Of the 85 transcripts used in this analysis, 30 were from females (F), and 55 from males (M). Forty-nine of the participants were working as PhD-level scientists or engineers (14 F, 35 M), 4 were involved in post-docs (1 F, 3 M), 27 were active graduate students in science (13 F, 14 M), and the remaining 5 participants were employed in other areas. Although there were a variety of specialties among the participants, generally the sample separated into 46 chemists (22 F, 24 M) and 39 physicists (8 F, 31 M).

Results

In the following section we will discuss the results of coding the interviews. The presentation of the results is separated into sections based on when the interest was initiated, who was responsible for the initial interest, and the nature of the initial experience (e.g., subject matter, activity).

Timing of Interest

From the many interviews we conducted, we remembered a number of the participants making comments such as "Well, I don't know how prominent this is but I've always been interested in science" (Male, Scientist, Chemistry). These comments made us want to look into this phenomenon more deeply and see how unique, or ubiquitous, it was in the data. Coding the transcripts for mention of the earliest memories of interest in science and the timing of that interest revealed intriguing results. For this sample, it seems that the view of the chemist stated above was, in fact, very prevalent among those interviewed (see Figure 1). It was unclear about the timing of initial interest from six of the interviews—all males in Physics—and they were therefore excluded from further analysis. Sixty-five percent of those in the remaining sample mentioned that the root of their interest in science took place before their middle school years.[2] Approximately 30% of the interviewees indicated that interest began in middle school or high school, with an additional 5% of the interviewees claiming that they didn't find science engaging

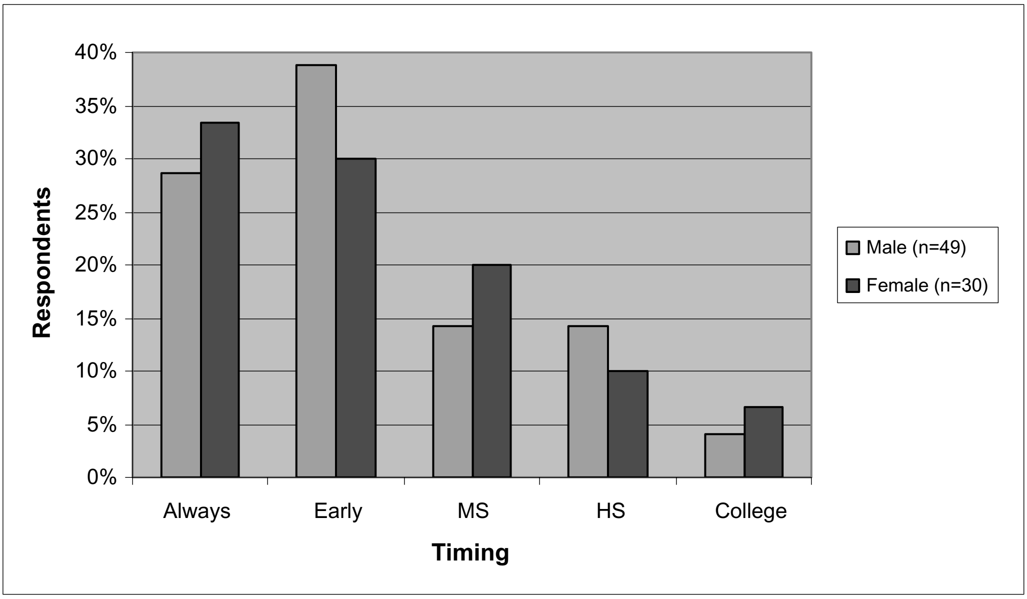

Figure 1. Timing of initial interest in science, by gender
Note: The categories are based on the following: Always (non-specific, but from earliest memories); Early (K–5); Middle School (MS, Grades 6–8); High School (HS, Grades 9–12); College

until their college years. See Table 1 for examples of quotes from each time category.

Contrary to the findings from the Royal Society, equal proportions of women (66%) and men (68%) in this sample reported gaining an interest in science before reaching middle school. If the Early and Always groups are combined, there is no meaningful difference in the percentage of men and women reporting initial interest for any of the time categories. Looking at the sample across fields, there are significant differences in the respondents reporting earliest interest. Although the large majority of participants in both fields reported interest before middle school, a greater portion of the physics sample (81% vs. 54% in chemistry) made that claim.

Source of Interest

The next relevant question that we sought to answer was: Who do these people attribute with initiating their early interest? Relevant responses were coded as either self, family, or school-based (i.e., teacher, faculty, or class). At this stage an additional interview (F) was excluded because the source of interest could not be determined.

Although it's logical that all instances of interest required some form of motivation and persistence on the part of the student, we wanted to look at who was attributed

Table 1. Samples of interview excerpts regarding earliest interest in science

Timing	Responses
Always	"I think I've always been interested in science, as long as I can remember."
	"My father was an eighth grade science teacher. And so, basically everything we did on a daily basis involved something scientific ...."
	"I don't know, my father's a biologist so I was kind of raised in a house with I guess scientific influence."
Early (K–5)	"I always loved science. I remember in third grade ... we did some experiment where you would like filter dirty water through sand, and I totally loved it."
	"My earliest memories. They go back really about as far as I can remember being in school. I always thought that the science class was always the coolest class. It was the most interesting to me. I don't know if I can go beyond that because it goes that far back I mean into like first grade."
Middle school (6–8)	"Well, you have to run it back further than that because even in high school, in junior high, I knew I was going to be a scientist."
High school (9–12)	"I'd say it dates as far back as high school even. I remember having a biology class and just learning about hormones and I was just really fascinated by the idea that there are really molecules in the body that cause physiological changes in me as an adolescent at the time."
College	"I'd actually planned on kinda following a more humanities type language tract ... I just really fell in love with [Organic Chemistry] for some reason and I don't know if it was just the challenge of it or I had a really very exceptional teacher, so that was kind of what changed my whole mind set with regard to science."

with providing the initial spark. Forty-five percent of the sample indicated that the source of their interest was intrinsic self-interest in the subject. Responses included:

> I liked toys like tinker toys and building blocks and taking things apart and seeing how they worked from early on. Science play was kind of more my inclination rather than physical play. (Female, Professor, Chemistry)

> I recognized it back then ... I had a lot of curiosity about the world and about how things worked. And I noticed that, like, I had a lot more curiosity than a lot of the kids around me did. (Male, Professor, Physics)

Coding indicated that an additional 40% of the respondents' initial experiences were related to a school or education-based experience (i.e., science competition, science camp), and the remaining 15% indicated that it was likely based on a family member. School-based experiences were often related to demonstrations by the teacher or project work. Typical responses included:

> I made that decision about science in fifth grade. I had this extraordinary teacher who put us in a room with a whole bunch of stuff and let us play and I clearly left grammar school thinking science and nothing just ever disabused me of that. (Male, Professor, Chemistry)

> My third grade teacher, really sort of—she did a lot of science and … we got to do a lot of projects and part of it was astronomy and I thought that was the coolest thing. (Female, PhD Student, Physics)

Those indicating that a family member played a role in their initial interest commented on science being a common topic of discussion. One respondent indicated that science discussions were not common, but remembered the instance that first got him hooked:

> The first time I thought about science or how it really interested me was, I was probably six or seven years old, and I remember one time after dinner, my dad had a bunch of balls in his hand, and he showed me the solar system, how things moved around the Sun. And from there, I was fascinated with space. And that led to my interest in space and astrophysics and led to me going for a degree in astrophysics at [College]. So it began with basically, as a young kid, with my dad showing me what the solar system was with just a bunch of balls. (Male, Professor, Physics)

Although not evident in the previous quote, some participants mentioned being pushed or prodded into science by family members who thought science was a good career choice. One respondent stated:

> I was encouraged strongly by my father, who was paying the bills for college, to start in engineering. I mean I was basically told, you have to start in engineering and then if you really don't like it, you can maybe think about something else. (Female, Professor, Chemistry)

Even though the quote above was at the "extreme" end of family pressure, others related similar experiences.

Occurrences of self-interest were not equally distributed across timing levels and were much more prevalent for those indicating their interest started at an early age (21% Early, 18% Always), with no instances mentioned after middle school. Those excerpts coded as school-based initial interest were spread somewhat equally across the timing partitions: 13% Early, 10% Middle school, 13% High school. Nearly all of those participants indicating that their family was the initial source of their interest cited early timing (13% Always, 1% Early) of their initial interest.

Interestingly, there were large differences between the source of initial interest as reported by male and female participants (see Figure 2). Most of the discussion of interest by the male participants indicated an intrinsic source of initial interest (57%), followed by school and family. The sources of initial interest for females were largely different, with 52% of the occurrences associated with school. Only a quarter

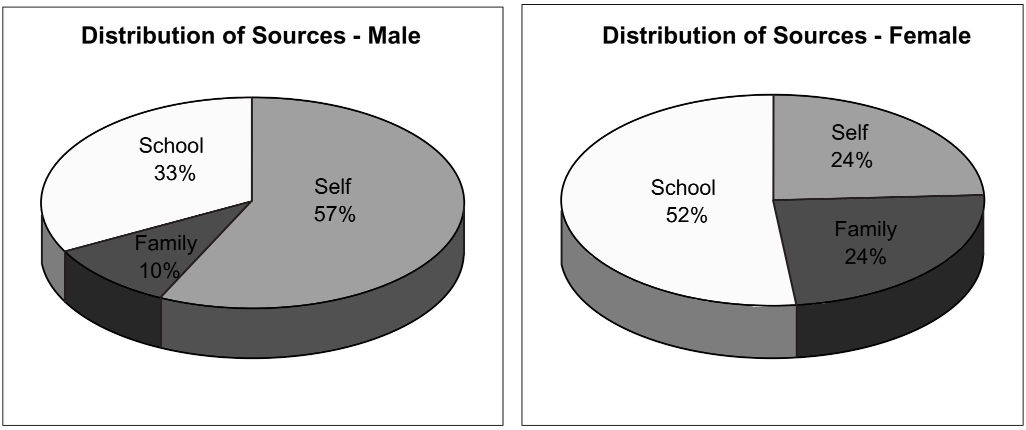

Figure 2. Distribution of sources of initial interest for males (left) and females (right)

of the female excerpts indicated an intrinsic self-interest, and an equal share was related to family members.

Nature of Initial Experience

Finally, we wanted to assess the nature of the experience—the subject matter or type of experience—that participants associated with their initial interest. For a number of the participants, it was impossible to identify a single experience. As a result, we decided to allow multiple sources for a single individual. In total, there were 120 coding occurrences for 23 different experiences. Using the source of the interest (i.e., self, family, or school) provided a general framework for categorizing the nature of respondent experiences.

As discussed in the previous section, intrinsic interest was the most common source of interest, and that is evident here as well, with just under 50% of the instances related to activities carried out at home or individually. These activities included tinkering with electronics, conducting home experiments, and reading science or science fiction. In terms of subject matter, the one topic most commonly referenced was "space".

Education-based themes followed as the second most common topic, with 38% of the codes. Participants commonly mentioned interest in the class content (24%); demonstrations, lab experiments, and science projects (18%); or other enrichment experiences (22%). A few of the instances were based on teacher characteristics and related to teacher personality, encouragement, or teaching style (24%). Some respondents noted that they performed well in their science courses (10%), and figured that they should naturally continue in an area where they showed proficiency. Interestingly, a few interviewees commented on the role that teacher comments—not specifically based on encouragement—played in their early science experiences.

> The teacher was obsessive about penmanship and called me down and gave me a ferocious tongue-lashing and said that my penmanship was the worst that she had ever seen in her life and that the only people that wrote that poorly were doctors and scientists and all the rest of us, young man, have to have immaculate penmanship. And I vividly remember thinking (1) My penmanship is never going to improve, and (2) If she's right I have two choices, either being a doctor or a scientist. Being a doctor sounds yucky and this little light bulb went off in my head and I was like oh, maybe I can be a scientist. (Male, Professor, Physics)

The above excerpt demonstrates that teacher comments can have a profound effect on the path students follow and may influence whether some continue or leave pursuing science.

For the students and scientists who indicated family as the source of their interest, most of these instances were from participants who discussed growing up in a household where science permeated many of the common activities (See Table 1). For a few other participants a different type of family influence included feelings of pressure to pursue careers in scientific or medical fields, as demonstrated in the following exchange (Female, PhD Student, Physics):

> Student: I guess ah maybe it's more cultural or related to my family like science has always been very important and so just coming from [the Middle East], science, like people who had degrees in science always kind of had stability in you know jobs …. So um culturally that's kind of the direction everyone has led and you would have to be a huge rebel to kind of move on to a different field or area. So it wasn't so much that—like it was kind of always ingrained in me and then when I went to high school you know I was in that direction anyways. So I guess I was getting encouragement in that direction that I was already in.
>
> Interviewer: This encouragement was coming from your family?
>
> Student: Ah yes. Like it was kind of just assumed that we were going to go into science.

It should be noted that regardless of the source of interest, the overwhelming majority of participants commented on the unconditional support that their families provided during their formative years.

> They were always very encouraging of my academics but didn't particularly push me in one direction or another. (Female, Professor, Chemistry)
>
> I mean I think there was more, let's see—the support was more general in the sense that, I mean, they knew I was good at doing [science] but also good at a bunch of stuff and they were just sort of supportive of whatever I wanted to do. So it wasn't all that conditional on being science. (Male, PhD Student, Physics)

The above quotes are representative of those involving family support and demonstrate how the support was not specifically tied to the pursuit of science.

The small sample sizes make a discussion of minute differences in results immaterial; however, a general trend is clear in the nature of experiences respondents reported. The majority of male responses (60%) dealt with activities that they initiated. The exact opposite was seen in the female group, where the majority of responses (60%) discussed experiences initiated by an external source.

Analysis and Discussion

As stated in the beginning, the goal of this analysis is to investigate the timing and factors involved with the initiation of student interest in science within a sample of those studying and practicing chemistry and physics at an advanced level. Examination of the results yielded some intriguing patterns. Although we presented the timing, source, and nature of the experience that initiated respondents' interest in science, any analysis must assess the interaction of these three factors. The first characteristic of note is the equivalent frequencies of women and men in mentioning an early (pre-middle school) interest in science. This contradicts many anecdotal stories and even findings by recent studies (Royal Society, 2004).

This finding is important for two reasons. First, it substantiates the notion that women and men become interested in science at early periods in their educational careers (Johnson, 1987; Weinburgh, 1995). Second, it runs counter to many initiatives (e.g., President Bush's *American Competitiveness Initiative*) where the focus is on improving science education at the secondary level by simply improving student achievement or increasing enrolments in advanced science courses (Domestic Policy Council, 2006). With a high percentage of both genders reporting interest in science prior to entering high school or even middle school, it may be important to instead center efforts on engaging young children in science. Focusing all efforts on improving performance in high school may miss a good number of students who have already lost interest in the subject (Kahle & Lakes, 1983).

Another important finding is that nearly 40% of the responses from the participants indicated that school-based factors played a key role in sparking their initial interest in science, with the women in this study more likely than men to mention teachers as the source of their initial interest. One participant relayed a comical story about her initial experience:

> When I was in third grade, my teacher did something you couldn't do in class anymore—we dissected cow eyes. And I thought it was so cool and so much fun that he sent a bunch of extras home in a paper bag, and reminded me to put them in the fridge when I got home. And so I did. [When my mom came home she] said, "Hey, how was your day?" I said, "Great!" and I just went about my business and forgot the eyeballs in the fridge. She thought it was leftover lunch and went to open it up, and there were, like, four or five eyes looking back at her. And so all of a sudden I heard this screaming, and I realized what I had done … then from that point I started to really love science. (Female, PhD student, Chemistry)

Early experiences similar to this may engage many young boys and girls in science class. Additionally, teachers must work to foster this interest so that it is not lost as students mature. Although Harvard's former-President might think there is an innate difference between the scientific capabilities of women and men (Summers, 2005), the difference in numbers of practicing scientists is generally considered to be a result of women leaving science because they lose interest along the way (Kahle & Lakes, 1983). Recently Lindahl (2007) reported that as girls matured from age 12 to age 16, female students reported a greater *decrease* of interest in science than their male classmates. It may be that women are not supported in maintaining their interests. One of the participants in the study indicated her teacher pulled her into science simply through his encouragement:

> Then this teacher happened to—yeah, he saw something in me. He asked me to be on some chemistry Olympiad team, and I think at that point, I had been pretty unsupported academically in my family, and so this person just showing a little bit of interest and saying, "Hey, you seem to be good at this." That was enough to convince me that maybe I would be good enough at it. And I just never really deterred from that track, actually. (Female, Professor, Chemistry)

Encouragement is often seen as a means of fostering interest in a topic, but in this case it played a major role in sparking someone's initial interest in the topic. A common theme in science education is concerned with how to improve the training of science students; however, if one of the goals of science education is student persistence in STEM, it seems that teachers should focus on initiating interest and fostering engagement rather than on preparing for standardized examinations. This suggestion is not directed only to the grammar or middle school level educators—this should be the focus at all levels.

A few of the interviewees commented that personal attributes of their science teachers were involved with their initial interest. A female PhD student in Physics commented that her high school science teacher "was never dismissive in any way like if I asked him about something he'd give me like this great answer," which was echoed by a few other participants in the study. Another interviewee commented:

> I guess the point where I got interested in what I wanted to do … would be in high school. And it was just the professor … he's just a nutcase. You know kind of the mad scientist, and he was great. He related to people, even the kids that hated chemistry liked going to his class. (Male, PhD student, Chemistry)

The nature of the comments regarding teacher personality was interesting to us for three reasons. First, these comments came from both male and female respondents. A lot has been written about the negative impact that teachers can have on female interest in science, but it was interesting to find that male participants were commenting on the "likeability" and engaging mannerisms of teachers as well. Second, in an age of accountability where the major focus at schools is on student performance, it is interesting to note that the way teachers interacted with students, rather than their content knowledge, was an important factor in getting students interested in science. We are quite certain this dynamic is universal across disciplines (e.g., English, art, etc.) in students choosing fields to study; however, this is a point that speaks to other factors that can help to retain students in science. Third, with regard to timing, the comments concerning the influences of teacher personality were more prominent in students who indicated their interest began after middle school. The comments citing activities (e.g., labs, projects, demonstrations) or content covered in class as the source of initial interest were more common for students whose interest in science started in the middle and elementary grades. This may indicate that as students age, not only the science content and pedagogy but also the personality of the teacher plays a role in students developing an interest in science. As mentioned by Osborne et al. (2003) in their review of research on student attitudes, it is findings like the ones presented here, which are based on retrospective reports of former students, that give a better picture of the teacher-based factors that can engage students in science learning.

In summary, most of the scientists and graduate students interviewed for this study indicated that their initial interest in science occurred prior to entering middle school. For those reporting this early interest, most females indicated the source of the interest as school, or family-based, while the interest of males was typically attributed to some internal source of curiosity. For the remaining interviewees reporting an initial interest occurring during middle school, high school, or college, nearly all attributed their experiences to extrinsic, school-based factors.

Implications

At the conclusion of an earlier study (Tai et al., 2006), we commented that students reporting interest in science careers in eighth grade were more likely to complete degrees in science, but we emphasized that it is likely that student interest began at an earlier age. The results of this analysis indicate this is indeed true for many pursuing advanced degrees or careers in science.

The scientists and students involved in this study persisted to advanced levels in science, despite the prevalent classroom conditions that may discourage many students from continuing (Cleaves, 2005; Lyons, 2006). Therefore, if a goal of science education is to encourage students to continue their study of science, we may be doing interested students a disservice with the way science is presented in many classrooms. This finding may be particularly important to women, who indicated in this study that school was more common in initiating their interest in science. Matching what Osborne et al. (2003) reported, it seems that teachers may be influential in turning students *onto* and also *off from* science.

Overall, there was a general sense of enjoyment in the subject from nearly all of the participant transcripts. However, a number of participants mentioned points in their scientific development where they had a negative experience that might have caused them to pursue other subjects. It is impossible to get every student interested in science to continue in the science pipeline; however, with the need for more scientists to help solve some of the issues that plague our society it is crucial to improve the nurturing of young students showing interest.

We used to believe that improving science education meant better training for teachers and increasing student understanding of scientific principles. We assumed that improving instruction and performance would lead to greater numbers of scientists in the pipeline. The results of this analysis make us believe that there are other factors that play a more significant role in getting students to consider careers in science. From the teaching perspective, it seems that including a variety of content and activities to engage students with different interests, providing an engaging classroom environment, and allowing students to feel comfortable asking questions about their understanding are all important factors that can improve student interest in science.

Limitations

The greatest limitation to this study is variability across the interviewers and even across interviews. Sometimes interviewees were asked about their earliest interest in science and sometimes about their earliest interest in a science career. Although it seems that many reported similar answers, there is the potential for a difference in those responses. For this analysis, unless the responses indicated otherwise, we made the assumption that the questions were equivalent. This study involved students and professors willing to talk about their experiences. As volunteers, there is a good chance that these participants had different experiences than those that chose not to be interviewed or those who were not solicited. However, we feel there is enough commonality to the responses to make the findings meaningful. Finally, since this study was based on retrospective reports from the participants, it is probable that there are limitations to the accuracy of specific details provided to us in the interviews. While this is a limitation in any self-report study, we trust that the stories recounted in the interviews were significant in the lives of the participants and therefore provide valuable insights into the development of interest in science.

Acknowledgments

This work was sponsored by a grant from the National Science Foundation (Project Crossover, REC 0440002). The views and opinions expressed here are solely those of the authors and do not represent the policies of the National Science Foundation.

Notes

1. Personal communication with D. R. Webb, Head of recruiting for scientists at Proctor & Gamble, in the fall of 2006.
2. This categorization included those responses coded as "Early" and also those as "Always". The "Always" category was used for excerpts where the respondents indicated that they had an interest "from very early on," or for "as long as I can remember," without any specific reference to grade or age. See Table 1 for examples.

References

Bush, G. W. (2006). *State of the Union address* (Copy of text from speech). Retrieved April 27, 2007, from http://www.whitehouse.gov/stateoftheunion/2006/

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education, 27*(4), 471–486.

Domestic Policy Council. (2006, February). *American competitiveness initiative*: *Leading the world in innovation.* Retrieved April 27, 2007, from http://www.whitehouse.gov/stateoftheunion/2006/aci/

European Commission. (2004). *Report by the High Level Group on increasing human resources for science and technology in Europe.* Luxembourg: Office for Official Publications of the European Communities.

Huberman, E. A., & Miles, M. B. (1994). Data management and analysis methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *The handbook of qualitative research* (pp. 428–444). Thousand Oaks, CA: Sage.

Johnson, S. (1987). Gender differences in science: Parallels in interest, experience and performance. *International Journal of Science Education, 9*(4), 467–481.

Kahle, J. B., & Lakes, M. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching, 20*(2), 131–140.

Lent, R., Brown, S., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*(1), 79–122.

Lent, R., Brown, S., & Hackett, G. (2000). Contextual supports and barriers to career choice: A social cognitive analysis. *Journal of Counseling Psychology, 47*(1), 36–49.

Lindahl, B. (2007, April). *A longitudinal study of students' attitudes towards science and choice of career.* Paper presented at annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Lonkila, M. (1995). Grounded Theory as an emerging paradigm for computer-assisted qualitative data analysis. In U. Kelle (Ed.), *Computer-aided qualitative data analysis: Theory, methods, and practice* (pp. 41–51). London: Sage.

Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591–613.

Mau, W.-C. (2003). Factors that influence persistence in science and engineering career aspirations. *Career Development Quarterly, 51*(3), 234–243.

National Academies. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington, DC: National Academies Press.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Rodrigues, S., Tytler, R., Darby, L., Hubber, P., Symington, D., & Edwards, J. (2007). The usefulness of a science degree: The "lost voices" of science trained professionals. *International Journal of Science Education, 29*(11), 1411–1433.

Royal Society. (2004). *Taking a leading role: A good practice guide* (Scientist survey). Retrieved on April 20, 2007, from http://www.royalsoc.ac.uk/page.asp?id=2903

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview.

Summers, L. (2005). *Remarks made at NBER conference on diversifying the science & engineering workforce.* Retrieved April 26, 2007, from http://www.president.harvard.edu/speeches/2005/nber.html

Tai, R. T., Liu, C. Q., Maltese, A. V., & Fan, X. T. (2006). Planning early for careers in science. *Science, 312*(5777), 1143–1144.

Wang, J., & Staver, J. R. (2001). Examining relationships between factors of science education and student career aspirations. *Journal of Educational Research, 94*(5), 312–319.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*(4), 387–398.