The Paradox of Middle and High School Students' Attitudes Towards Science Versus Their Attitudes About Science as a Career

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ABSTRACT

From 2005-2007, 86 pre-service science teachers surveyed 2,535 middle and high school students in 27 rural, suburban and urban school districts in Northern Illinois on their attitudes about science. The survey consisted of ten questions on a ten-point Likert scale covering interest in science, attitudes about scientists and student confidence in, and desire to do science. These students no longer hold most stereotypes cited in the literature. For example, all students feel that girls are capable of science, that science is interesting and that their parents would be proud of them if they were to become scientists. However, very few students felt they might want to become scientists. Previous attempts to increase the numbers of students participating in science by targeting these stereotypes have been effective in changing student attitudes about science but have failed to increase the desire among students to become scientists. These students feel they *can* do science; they simply do not *want* to do science. This paradox is a different kind of problem than has been previously identified in the geoscience community and will require a retooling of approaches and programs wishing to increase student participation.

INTRODUCTION

Huntoon and Lane (2007) reviewed data from the National Science Foundation (NSF) and found that since 1966, fewer degrees from the BA/BS to the Ph.D. have been awarded in the geosciences than in any other Science, Technology, Engineering or Mathematics (STEM) field. Additionally, from 1995-2001, degrees awarded to underrepresented groups were lower in the geosciences than all other STEM fields. This is particularly troubling as the U. S. Census projects that of the additional 5.6 million school age children living in the US in 2025, 93% will be Hispanic (Schmidt, 2003). Unfortunately, this group has traditionally been the most underrepresented population in science and math (National Center for Educational Statistics, 1999; Huntoon and Lane, 2007). Therefore, unless more Hispanics choose science careers, there will be a severe shortage of scientists to tackle the technical and environmental problems of the next generation.

Starting in the 1960's, science education literature has examined and attempted to explain why first girls, then ethnic minorities, and now increasingly all Americans, have eschewed the STEM disciplines. In a review of this literature, Scantlebury and Dale (2008) point out that the major research themes have shifted over time. In the 60's and 70's, it was suggested that the achievement gap might be due to girls and ethnic minorities being less cognitively capable in science. In the 80's, feminist and multicultural studies promoted "different ways of knowing" which unintentionally implied that the deficit model was correct and that although girls and minorities were not as good at science they should be allowed to participate regardless. Subsequent studies in the late 80's and the early 90's disproved this deficit model and the paradigm switched to examining possible environmental reasons why success or failure in science correlated with gender and ethnicity. Since the mid 90's, most of the studies have focused on societal/cultural biases and expectations. Today, the paradigm assumes that it is the system that needs remediation and not the students.

In examining the science education literature of the last twenty years, several socio-cultural, familial, and educational variables have been identified that may account for the gender and ethnic differences in science achievement and participation. These include: ***(1) cultural stereotypes and expectations*** (Kahle and Meece, 1994; Farenga and Joyce, 1999; Aikenhead, 2008; Hanson, 2008), ***(2) teacher bias*** (Jones and Wheatley, 1990; Potter and Rosser, 1992; Guzzetti and Williams, 1996; Greenfield, 1997; Bianchini et al., 2000; Zacharia and Barton, 2004; Hanson, 2008), ***(3) a dearth of opportunities to do science*** (Kahle and Lakes, 1983; Jones and Wheatley, 1990; Kahle and Meece, 1994; Catsambis, 1995; Greenfield, 1996; Jones et al., 2000; Hanson, 2008), (*4) diminished desire among non-traditional science students to do science* (Baker and Leary, 1995, Catsambis, 1995; Weinburgh, 1995; Greenfield, 1996; Jones et al., 2000; Zacharia and Barton, 2004), ***(5) poor science pedagogy*** (i.e. science is boring and irrelevant) (Ellis, 1993; Siegel and Ranney, 2003; Zacharia and Barton, 2004; Aikenhead, 2008; Anderson, 2008; Hanson, 2008), ***(6) low levels of student self-efficacy or confidence in science*** (Markus and Nurius, 1986; Kahle and Meece, 1994; Furner and Duffy, 2002; Sadowski, 2003; Beghetto, 2007; Britner, 2008; Brotman and Moore, 2008; Zeldin et al., 2008), ***(7) lack of role models*** (Eccles and Harold, 1993; Seymour and Hewitt, 2000; Wallace and Haines, 2004; Gilmartin et al., 2007; Hanson, 2008) and ***(8) weak parental support*** (Smith and Hausafus, 1998; Simpson and Parsons, 2008; Fouad, 2008).

In order to address these issues, NSF, NASA and other governmental agencies have made funding available to support programs designed to increase the participation of all students but especially minorities and women in the geosciences (Riggs and Alexander, 2007). Such programs include but are not limited to NSF's Geoscience Education (GeoEd), Geoscience Teacher Training (GEO-Teach), Opportunities for Enhancing Diversity in the Geosciences (OEDG) and NASA's

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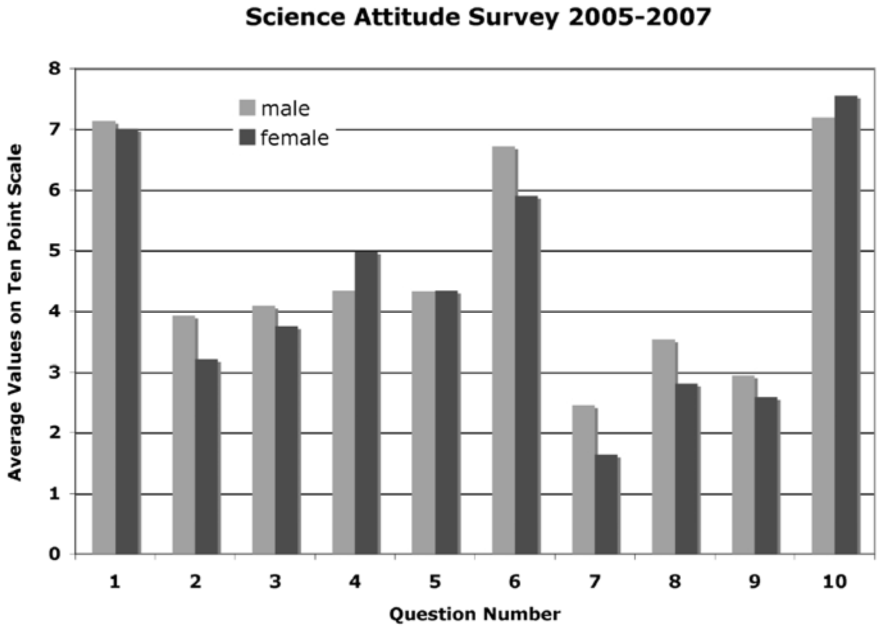

FIGURE 1. Male and female responses to the 10 survey questions listed in Table 1. The respondents replied using a 10-point Likert scale with 10 being "absolutely agree" and 1 being "absolutely disagree". Note there is no statistical difference in the means of the male and female responses.

Education and Public Outreach (EP/O) grants. In reviewing the abstracts of the projects funded (available online via FASTLANE and NSPIRES), four main themes can be identified: (1) content (direct delivery to students or via teacher professional development); (2) assuring equal access for all students (including active recruitment of women and minorities); (3) elimination of stereotypes; and (4) mentoring.

Huntoon and Lane (2007) reviewed the more successful programs funded by OEDG and identified key strategies for increasing diversity in the geosciences. These include: (1) demonstrating relevance of the field and dispelling myths (i.e. the socially inept male scientist wandering the deserts in search of dinosaur bones); (2) the critical importance of mentoring; (3) financial concerns (i.e. need for scholarships above and beyond tuition); and (4) development of partnerships encompassing K-20 to identify and prevent "leaks in the pipeline." However, despite some successes, Riggs and Alexander (2007) point out, "[I]n forty years of data collected by the National Science Foundation and the American Institute of Physics, the low numbers of minorities graduating in the geosciences has not changed in any significant way, despite decades of programs put in place to address the problem."

TABLE 1. SCIENCE ATTITUDES SURVEY QUESTIONS

1. I think science is really interesting.
2. Scientists are mostly men who wear white lab coats.
3. I might want to be a scientist.
4. Science is too hard for me.
5. I know a scientist personally.
6. You can't do science without knowing lots of math.
7. Girls aren't good at science.
8. Scientists can't be trusted.
9. Scientists can't be religious.
10. My family would be proud of me if I became a scientist.

This survey may provide at least one answer to this unfortunate lack of progress. Data presented here suggest that despite the dispelling of many myths and increased access (i.e. middle and high school students no longer feel that science is beyond their reach), these students are simply not interested in pursuing science as a career.

METHODOLOGY AND RESULTS

The original goal of the survey was to provide pre-service science teachers taking a Nature of Science course in the department of Geology at Northern Illinois University (NIU) a way of evaluating the attitudes of their students so they might adjust their teaching methodologies. However, it soon became apparent that the results being produced were significant enough to be of interest to the greater community and the survey was expanded. Over the course of three years from 2005 to 2007, 86 pre-service science teachers surveyed 2,535 middle and high school students in 27 rural, suburban and urban school districts in and around NIU. Northern Illinois University is located 65 miles west of Chicago.

In Illinois, the secondary teaching certificate covers grades 6-12 and NIU certifies in Biology, Chemistry, Geology and Physics. The eighty-six pre-service teachers collecting the surveys were composed of 50% Biology certification seekers, 25% Geology certification seekers, 15% Chemistry and 10% Physics. The NIU science teacher certification program requires that all pre-service teachers participate in two clinicals at both the middle and high school levels before selecting a level for student teaching. This afforded the pre-service teachers ample and equal access to both middle and high school students and assured that all surveys were conducted with appropriate permissions and in a professional manner (i.e. all data were aggregated and encoded assuring anonymity of student responses). The courses surveyed in the 27 school districts covered the gamut of general science in 6th grade middle school to

TABLE 2. SURVEY QUESTIONS MEANS AND STANDARD DEVIATIONS

Question	Average All	S.D.[1]	Average Female	S.D.[1]	Average Male	S.D.[1]
1	7.1	1.0	7.0	1.0	7.1	1.0
2	3.6	1.0	3.2	1.0	3.9	0.9
3	3.9	1.2	3.7	1.2	4.1	1.2
4	4.7	2.7	5.0	3.7	4.3	0.9
5	4.3	1.8	4.3	1.7	4.3	1.8
6	6.3	1.1	5.9	0.8	6.7	1.2
7	2.0	0.9	1.6	0.4	2.5	1.0
8	3.2	0.9	2.8	1.0	3.5	0.6
9	2.8	0.9	2.6	0.8	2.9	1.0
10	7.4	0.9	7.6	0.8	7.2	1.0

[1] standard deviation

advanced 12th grade physics. Approximately 50% of the student respondents were from middle school (6-8) and 50% from high school (9-12).

The survey examined students' attitudes about science. The survey consisted of ten questions on a ten-point Likert scale covering interest in science, attitudes about scientists and student confidence in and desire to do science. See Table 1 and the legend in Figure 1 for the complete list of questions. These questions were taken from a quantitative affective domain instrument developed in partnership with the University of Nebraska-Lincoln and NIU and funded in part by an NSF GeoEd collaborative grant (#0507341) awarded to the author. These specific questions were selected in order to examine whether the socio-cultural, familial, and educational variables identified in the science education literature and described in the introduction were still viable given all the recent interventions in the region mostly supported by NSF and NASA.

The questions in Table 1 can be mapped to the major variable groupings in the following way: cultural stereotypes (Q#2, Q#4, Q#7, Q#8, Q#9) teacher bias (Q#4, Q#7) opportunities (Q# 2, Q#4, Q#6) general interest in science (Q#1, Q#3), desire to enter science (Q#3), science pedagogy (Q#1, Q#6) perceived competency in science (Q#4, Q#6, Q#7), mentors/role models (Q#5), and familial support (Q#10).

Other information gathered in this study was age, grade level, sex and an optional blank for identification of race. Approximately sixty percent of the respondents self-identified race. The pre-service teachers identified the class, school and district and this information was encoded with the student responses.

Once aggregated and encoded, the data were analyzed via various statistical methods including the Student's t test. The goal of the analysis was to determine whether any statistical differences existed in averaged responses among the following categories: (1) male and female respondents, (2) school districts (rural vs. suburban vs. urban), (3) middle school (6-8) and high school students and (4) race. The results were surprising. No statistically significant differences as determined by Student's t test ($p \leq 0.05$ confidence level) were identified among the groups. The only possible exception could be that of Latinas who may feel less confident in their ability to do science (Q. #4) and that girls aren't as good as boy in science (Q. #7). This can be seen in the large standard deviation for question four with female responses ranging from a vehemently disagree (1) to a slightly agree (6). However, as the identification of race was optional and only about 60% of the students self-identified their race, this observation may or may not be real and is not considered robust with p values greater than 0.05.

The averaged results and standard deviations of all 2,535 respondents with the male and female responses broken out appear in Table 2. Figure 1 shows only the male and female responses. Again, it is emphasized that there is no statistical difference in the means of the male and female populations. One purpose of the graphic is to underline this fact. Despite pre-service teachers making multiple observations of male students taunting female students about their lack of ability during the taking of the survey (Q. #7), the written results show that male and female students do not differ statistically in their opinions. Despite the lack of differences among identified groupings, there are some significant observations to be made from the data represented by Figure 1 as a whole.

DISCUSSION

As outlined in the introduction, much effort and many resources have been allocated to STEM and Geosciences education in the hope of encouraging students to enter science-related careers. As these data show, progress is being made in the areas of increasing interest, assuring access and elimination of stereotypes. Specifically, students feel that science is interesting (average of 7.1 ± 1.0 on Q. #1) and that their parents would be proud of them should they choose to become a scientist (average of 7.4 ± 0.9 on Q. #10). Additionally, the students no longer believe the stereotypes that scientists are mostly men in white lab coats, who are untrustworthy and irreligious (averages of 3.6 ± 1.0, 3.2 ± 0.9 and 2.8 ± 0.9 on Qs. #2, #8 and #9 respectively). Most encouragingly of all, the students in this study no longer believe that girls are not good at science (average of 2.0 ± 0.9 on Q. #7).

However, the students are neutral on whether science is too hard (average of 4.7 ± 2.7 on Q. #4) and they disagree somewhat with the statement that they know a scientist personally (average 4.3 ± 1.8 on Q. #5). This insinuates that students do not consider their teachers to be scientists and hints at some other misconceptions that are not explicitly investigated by this survey such as the specifics of the students' definition of a scientist.

This apparent lack of role models is significant. The adolescent identity development literature (e.g. Sadowski, 2003) clearly shows that mentoring is a vital component in expanding the concept of self (Markus and Nurius, 1986). For example, members of U.S. ethnic minority groups are particularly challenged in their identity formation because of cultural stereotypes about their competence (Board on

Children, Youth & Families, 2002 and Hanson, 2008). At minimum, in order for minority youth to explore and consider science as a career, they need to identify with scientists and envision the possibility of themselves as scientists. Despite many mentoring opportunities (e.g. Pyrtle and Williamson-Whitney, 2007 and other programs as described in the same JGE special issue), the number and coverage of such programs are still insufficient in Northern Illinois at the 6-12 grade level.

This apparent lack of mentorship may have two additional effects. First, Frome et al. (2006) found the most significant predictor for a young woman to change her career plans was a desire for a job that would allow the flexibility to have a family. In addition, they found that encouraging women to take classes in math and science was not sufficient. Role models who could demonstrate a successful balance between career and family were a requirement. This possibility of perceived conflict with having a family was not directly assessed by this survey.

Second, in an NSF study from 2003 with a follow-up in 2007, the mentality of needing to "weed out" weaker students in quantitative STEM disciplines was found to disproportionately screen out women. This was not because women were failing but rather that women often perceived "Bs" as inadequate grades and dropped out, while men with "Cs" effectively stayed. It was also found that mentoring and "bridge programs" that prepared students for challenging coursework could counter this effect. Changing the curriculum often led to better recruitment and retention of both women and men in STEM. However, as discussed above, no gender difference was observed on question #4 (science is too hard) and the averaged response was neutral.

Continuing in the vein of challenges to be met, the students somewhat agreed that science cannot be done without knowing a great deal of mathematics (average 6.3 ± 1.1 on Q. #6). No one would dispute the contention that math skills are an important tool required to do the business of science. However, this and other studies (e.g. Furner and Duffy, 2002) suggest that students have an exaggerated view of how much higher math is required to do science, which results in high levels of anxiety. This belief is widely held even by college professors teaching in the STEM disciplines.

For example, in an unpublished study comparing the math course requirements for geology majors at several large state universities including NIU, it was discovered that Geoscience professors tended to greatly exaggerate the level of mathematics required to be successful in their classes. Two groups Vacher (2000) and MacDonald and Bailey (2000) identified the actual mathematical skills required for the majority of geoscience specialties. These lists included mostly arithmetic, algebra, geometry and trigonometry but limited higher math such as differential equations and integration. Naturally, some sub-disciplines in geoscience require extensive higher math skills, but if a phobia about higher mathematics is turning off science students at the 6-12 level, the geoscience community may need to address this fear directly. Ironically, Hyde et al. (2008) have shown that scores on standardized math tests in the U.S. for boys and girls are now indistinguishable and that the achievement gap has disappeared. This is a positive development for girls but may not help the geosciences if math anxiety is turning off both sexes equally.

Indeed much has been done to improve math education and decrease anxiety at the undergraduate level in geoscience courses (Bailey 2000; Keller et al. 2000; Lutz and Srogi 2000). Additionally, there have even been sporadic efforts at the high school level that integrate both science and math. These efforts have been shown to be effective especially with minority students (Ellis, 1993). However, with the introduction of No Child Left Behind testing requirements, many of these efforts have been abandoned by public schools in order to increase reading and math practice time in an abortive effort to raise standardized scores (Nichols and Berliner, 2007). To exacerbate matters, the Center on Education Policy (2008) surveyed 349 school districts and found that 28% of them reduced science time for an average of 75 minutes per week in order to allow for more reading instruction.

Paradoxically, and most significantly, students feel that science is interesting and that their parents would be proud if they were to become scientists (average 7.1 ± 1.0 and 7.4 ± 0.9 on Qs. #1 and #10) but few want to become scientists (average 3.9 ± 1.2 on Q. #3). It appears that students now feel that they have the access, the parental support and the confidence to pursue science.

Two other recent studies support this contention. Specifically, an NSF study (2007) has shown that (1) girls are as interested in science as boys in direct contrast to older studies (e.g. Catsambis, 1995; or Weinburgh, 1995), (2) classroom interventions that work to increase girls' interest in STEM also increases that of boys in contrast to e.g. Sommers (2001), and (3) parental motivation is very effective and prevalent among parents of girls and ethnic minorities in contrast to e.g. Eccles and Harold (1993).

In the second study, Baram-Tsabari et al. (2008) analyzed the nearly 79,000 questions posed at the Ask-A-Scientist site during the last decade and found that female contributions dominated in direct opposition to the idea that males have a greater interest in science. They also noted that this carried across countries without correlation to the level of gender equity in those countries. To quote Baram-Tsabari, "This suggests that the Internet as a free-choice science-learning environment plays a potentially empowering and democratic role that is especially relevant to populations that are traditionally deprived of equal opportunities in learning formal science."

Therefore, assuming that American students have the access, the parental support and the confidence to pursue science and are now simply not choosing to do so, the question facing the Geoscience community becomes, "Why not?" The data in this survey do not provide the answer but instead suggest that if our efforts remain focused solely on content, equal access and avoidance of stereotypes that in fact we may not obtain our goal of increasing student participation in science.

This finding is not unprecedented. Weisgram and Bigler (2006) examined the role of attitudes and intervention in high school girls' interest in entering the computer science field. They found that increasing the self-efficacy, valuing and egalitarian attitudes towards computer science in these girls resulted in no change in their desire to enter the computer sciences. These authors also recommended further investigation and, despite listing several possibilities, could not offer a specific explanation as to why an increase in positive attitude towards computer science did not translate to an increase in participation in the field.

CONCLUSION

The take-home message is clear. Most students no longer labor under the false impressions that scientists are all lab-coat wearing males who lack ethics and religious beliefs or that girls are not capable of doing science. However, the students still have a skewed view on the level of mathematics required to do science. Additionally, the students feel they do not know any scientists personally. Consequently, the students have difficulty identifying with scientists. The key finding of this study is the paradox that students find science interesting, feel their parents would be proud of them if they were to become scientists yet very few students feel they want to enter the field.

Previous attempts to increase the numbers of students participating in the geosciences have strived to combat these stereotypes. The data presented here indicate that these programs are effective in changing student attitudes about science. However, these efforts have failed to increase the desire among students to become scientists. Students feel they *can* do science; they simply do not *want* to do science. This paradox is a different kind of problem than has been previously identified and will require a retooling of approaches and programs wishing to increase student participation in the STEM disciplines. Thus, the geoscience community must identify the reasons why students lack a desire to enter into a science career and address those issues directly.

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