Effective Strategies to Change Attitudes toward Female Participation in Science and Technology

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Abstract

The pay and position gap between college-educated men and women can be attributed, in part, to their majors. Science, technology, and engineering majors typically command higher salaries than those with education or humanities degrees. Women's limited access to science, technology, engineering and mathematics (STEM) education continues to be a problem in the US where the STEM fields have an 85-15 undergraduate ratio of men to women, while overall college enrollments reflect a 45-55 ratio. The NSF funded project pursued by the authors, is designed to employ STS (Science/Technology/Society) or "context-based" approach to change attitudes toward women in science and technology, and in effect increase female participation in these disciplines.

An instrument was designed to measure attitudinal changes. Upon analyzing the pre-posttest data using factor analysis, five major factors emerged. When compared to the control group, the interventions had a positive effect on attitudes toward science and technology (S & T), with respect to the five factors.

The revised innovative practices are being weaved into existing university general education courses for long-term impact. The authors hope to create improved recruitment and retention of females in STEM disciplines by increasing awareness of career options, demonstrating that STEM can be fun and challenging without being intimidating, and most importantly, increasing social acceptance of STEM females through enhanced gender-sensitivity awareness among males and the adult population involved in this project.

The model exemplified in this project has the potential for replication at comparable institutions, and the results from the control group emphasize the need for curricular interventions.

Introduction

The investigation of students' attitudes toward science and technology has been a substantive feature of the work of the education research community for several decades. Its current importance is emphasized by the mounting evidence of a declining interest in key fields ? science, technology, engineering, and mathematics (hereafter, referred to as "STEM") ? which are the foundation of future technological progress (National Science Foundation, 2002). Today, the United States is the world leader in the scientific and technological enterprise, but other

countries stand ready to challenge this strength. This challenge is exacerbated by a projected shortfall of scientists and engineers in the workforce. In the next decade, demand for these professions in the United States is predicted to increase by 47%, whereas the labor force will increase by only 15% (Bureau of Labor Statistics, 2002). Osborne, Simon, and Collins (2003) argue that the continuing decline in numbers choosing to study science at the point of choice requires a research focus on students' attitudes toward science if the nature of the problem is to be understood and remediated.

Background

Attitude is defined as a positive or negative sentiment, or mental state, that is learned and organized through experience and that exercises a discrete influence on the affective and conative responses of an individual toward some other individual, object or event (Reid, 2006). The theory of reasoned action (Ajzen & Fishbein, 1980) supports the view that beliefs about an object imply the creation of an attitude toward the object. This attitude leads to behavioral intentions, which in turn affect actual behavior, and finally, actual behavior causes the revision of the initial attitudes (Fraser, 1982). People's attitudes toward science and technology evolve continuously as they increase their knowledge and understanding of these disciplines, develop their skills, and become more familiar with scientific and technological breakthroughs.

Purpose of the Study

The project targets female and male students and their parents during the students' transition from high school to college, and demonstrates the effectiveness of several intervention strategies. The primary research question is: Will there be a detectable change in attitudes of students toward female participation in STEM as a result of the project interventions?

Methodology

The study explored the effects of STS (Science/Technology/Society) teaching strategies on certain attitudes of 375 first-year college students (primarily of age 18) in a large state-operated university located in the central United States. The key to the STS or "context-based" approach is to start with a "real-world" issue or question that students can readily connect with, and to develop an understanding of theory and principles as a way of dealing with that issue or question.

Research Design

The study employed a pretest posttest control group design. Participants were enrolled in 16 different sections of the Foundations of Inquiry freshman seminar. This 3-credit-hour course focused on the development of critical thinking skills and dispositions, on information-gathering strategies, and on what it is to be a college student. The course was required of all incoming first-year students in their first semester on campus, and was taught in sections of 30 students each by faculty drawn from all academic disciplines.

The 16 sections involved in this study were taught by 13 different faculty members from a wide range of disciplines, and were divided into three categories—Group A, Group B, and Group C. Varying STS curricular interventions occurred in Group A and Group B, while Group C (control group) sections were taught in a standard way with no STS interventions.

Group A sections

These 5 sections included at least four weeks of guided-inquiry investigation of the role of women in science or of the relevance of science and technology to life issues. Additionally, students were expected to attend biweekly meetings outside of class in which professionals from scientific and technological fields interacted with the students by demonstrating or explaining their work. Most of these meetings included a gender-related subtext—female work in Science & Technology (S & T) was highlighted. Students were recruited from all majors to enroll in these sections, in order to set a time in their class schedules for the meetings.

Group B sections

These 4 sections were like Group A sections in terms of course content, but without meetings outside of class. The students in these sections were unaware that they were in a section that had specially designed content built in for the purposes of the project.

Group C sections

These 7 sections lacked any emphasis on scientific or technological content, and had no outside of class meetings. Students enrolled in these control sections were taught in the normal way, without knowledge that these sections were part of a study.

Development of an Attitude Measurement Scale

In spite of an extensive literature review, the authors did not find a scale designed to measure attitudes of college freshman toward science and technology in general, and more specifically, their attitude toward female participation in those fields. In order to study the effects of college curriculum on those attitudes, the authors developed a valid and reliable scale—the Attitudes toward Science and Technology (A-ST) Scale.

The subjects for the 2004 validation study consisted of first-year students enrolled in 19 selected sections of the required gateway course at the same four-year institution described earlier. Since the 15 instructors of these sections had agreed to participate in the project, and they administered the revised A-ST in class, the response rate was 100% except for the rare student who was absent, or who did not sign the 'Informed Consent' form. The resulting sample consisted of 535 students of which 195 were males and 253 were females (87 students failed to indicate a gender). This sample had a demographic make-up similar to that of the pilot sample. It took an average of 14 minutes to complete administration of the questionnaire.

The factor analysis revealed four factors similar to those found in the pilot study, and one additional factor; all five orthogonal factors had eigenvalues greater than unity. These analyses are a major justification for the validity of this Scale. Cronbach's coefficient alphas were calculated for the 30 item instrument as a whole, for all factors together, and for each of the five factors. The overall coefficient alpha for the 30-item instrument was .806. For the 5 factors composed of 25 items, the coefficient alpha was .721. The internal consistencies provide evidence for the reliability of the instrument and the internal semantic consistency of the items identified in the factor analysis is evidence for factorial validity in this instrument.

Table 1 provides information about the five similar factors that emerged in the Scale. The coefficient alpha for each factor is given in square brackets [ ], and indexed by its item numbers and factor loading (in parentheses).

Factors A-ST Scale Questions (2004)	
Factor 1: Interest in Gaining Science and Technology Knowledge [.714]	4. It is important for me in my daily life to know about science (.68) 10. Science and technology courses make significant contributions to one's education (.48) 23. I enjoy learning about new scientific discoveries and their effects on technology (.76) 24. I am well informed about new inventions and technologies (.55) 25. I am interested in the application of science and technology on space exploration (.76) 26. I like to read about science, mathematics, engineering and technology (.80) 27. I like to watch science and nature shows on television (.75) 28. I have looked for information on science, technology, engineering or mathematics topics on the Internet (.71)
Factor 2: Science and Technology are Beneficial to Humankind [.749]	1. Science and technology are making our lives healthier, easier, and more comfortable (.52) 7. Because of science and technology, work will become more appealing (.56) 12. Because of science and technology, there will be more opportunities for the next generation (.48) 13. Benefits from science research have outweighed the harmful results (.50) 21. New inventions will always be found to counteract any harmful consequence of technological development (.54)
Factor 3: Appropriateness of Science and Technology for Females [.749]	2. Males tend to have more natural talent for science and technology than females have (.47) 14. It is all right for women to have careers in science and technology (.72) 19. Women should be encouraged to pursue careers in science and technology (.72) 20. Males rather than females should play leadership roles in science and technology (.68) 30. Women would be more successful in science and technology if they had a strong peer support system (.45)

Factor 4: Males and Females have Equal Opportunity in Science and Technology [.673]	5. The same opportunities to succeed in technical field are available to men and women (.79) 11. The same opportunities to develop technical abilities are available to men and women (.77) 17. The work environment faced by females in science and technology is the same as that faced by males (.75)
Factor 5: Concern that Science and Technology is Dangerous to Humankind [.627]	6. Science makes our way of life change too fast (.71) 9. Technological discoveries will eventually destroy the earth (.68) 15. People would do better by living a simpler life without so much technology (.71) 16. Technological development creates an artificial and inhuman way of living (.77)

Table 1. A comparison chart of the five similar factors establishing the reliability and validity of the A-ST Scale

Within each factor, the corrected item-to-total correlation for each question had values greater than 0.45, demonstrating the homogeneity of each subscale, and the between-factor correlations had values less than 0.80, which is evidence that each factor contributed in a unique way in the total score (Anastasi, 1990).

Results

Pretest results for Group A indicated that on average these students were somewhat more interested in S & T than the students in Group B or C, but the differences between the Groups was not large. On a five-point scale with 5 being the high end, the average Group A student's interest level in science and technology was close to 3.5, while the average for Group B and Group C students was about 3.2. This showed that all these groups of students could demonstrate attitude shifts without running into a ceiling or floor effect. Since we are looking only at attitude changes within each Group, each Group's pretest scores are used as a baseline for that Group.

Pre- and Post-test Comparisons for Group A Students

The typical section mean-score for Factor 1 (interest in gaining S & T knowledge) on the pretest was 3.5, and for Factor 4 (appropriateness of S & T for females) it was 4.0, where '5' represents the maximum positive attitude. Since Factor 2 items represented a negative attitude, we reverse the coding for those items, so that '5' represents the maximum possible lack of concern about the dangers of S & T, and '1' represents the maximum level of concern. The typical Group A section had a Factor 2 mean of 3.4, indicating a moderate lack of concern.

Pre- and Post-test Comparisons for Group B Students

These students were on average initially somewhat less interested in science and technology with a Factor 1 pretest section mean score of 3.2, and slightly less approving of female participation in

science and technology, with a section mean of 3.8. Their concern level about the danger of science and technology was identical to that of Group A.

However, comparison of pre- and post-tests revealed a startling result: female students in Group B became less accepting of science and technology as appropriate for female participation. The measured negative change in female student attitudes was significant at the 99.9% confidence level. No other attitude changes in male or female students in Group B were significant at the 95% confidence level with respect to any of the other Factors.

Pre- and Post-test Comparisons for Group C Students

Pretest scores indicated that these students, whose sections served as a control for the study, were nearly identical to the Group B students in terms of initial attitudes toward S & T. This is not surprising, since Group B and Group C sections would have looked the same to the students as they registered: in both cases the fact that they were signing up for a section that was to be studied by us was not something known to the students.

But Group C attitude changes were dramatically different from the one Group B change and the absence of change found in Group A. Group C male students did not change during the course of the semester in any way measured by the scale; that is, they maintained modestly positive attitudes. But the Group C female students became significantly ($p < .05$) more negative with respect to all the Factors (with coding reversed on negative items so that becoming more negative means adopting more negative attitudes). That is, these females became less interested in S & T, more concerned that S & T is dangerous, less convinced that S & T is helpful, less approving of female participation in S & T, and less convinced that females have equal opportunity in S & T.

Table 2 summarizes all the significant results in terms of gains in factor scores, for each factor on the attitude scale. All the significant gain scores were negative, that is, all significant attitude changes were in the negative direction.

	Mean Pretest Factor Score	Mean Post-test Factor Score	Gain, Pre- to Post-	Significance level
Group A males				
Factors 1 - 5			Insignificant	
Group A females				
Factors 1 - 5			Insignificant	
Group B males				
Factors 1 - 5			Insignificant	
Group B females				
Factors 1, 2, 3, 5			Insignificant	
Factor 4	16.92	15.35	– 1.57	p <.0001
Group C males				
Factors 1 - 5			Insignificant	
Group C females				
Factor 1	22.27	20.94	– 1.33	p < .015
Factor 2	17.39	16.37	– 1.02	p < .002
Factor 3	17.08	16.43	– 0.65	p < .045
Factor 4	17.27	16.77	– 0.50	p < .041
Factor 5	12.92	11.82	– 1.10	p < .001

Table 2. Significant changes in factor scores by group and by gender

Discussion

The literature on young adult attitudes toward S & T provides some support for the notion that the results obtained in this study may well point to typical young adult attitude patterns, not only in the US.

Approximately 40 years ago, one famous early study of the "Swing from Science" tied the drop in Scottish college female participation in science to a drop in female interest in science during the first years of college—between the first and third years—while student interest in humanities and social studies continued to increase among females (Butcher, 1969).

Other published studies of college student attitudes indicate that growing negativity toward science during standard introductory science courses is common, while STS approaches show promise in alleviating this negativity.

For example, in a study comparing two introductory biology course offerings at Ferris State University, it was found that the general education biology course designed for non-science majors and designed to be personally relevant produced statistically significant improvements in student attitudes over the course of one term, while the more traditionally designed course for biology majors resulted in growth of some negative attitudes toward science even while the students continued to hold the value of science in high esteem and had a favorable impression of the instructor (Gogolin & Swartz, 1992).

Another comparative study involving introductory biology courses at Louisiana State University found that a rigorous introductory biology course appeared to be creating negative attitudes toward science in freshmen majors enrolled in it, with respect to almost all the attitudes measured, while the non-majors course, described as being less rigorous, produced some improved attitudes toward science and greater comprehension gains (Sundberg et al., 1994). The authors suggest that the key relevant difference between the courses was "rigor". However, the "less rigorous" course is also described as relying more on discussion and STS approaches in some sections (p. 691). Some of the "attitude" components measured in this study were nonstandard, making it difficult to generalize.

Many studies of high school adoption of the STS approach report that the approach is successful in improving student attitudes, although the instruments used are often not sufficiently analyzed (Bennett et al., 2007; Lee & Erdogan, 2007). There are many more studies of the STS approach at the high school level than at the undergraduate level.

Educational Uses of the A-ST Scale

The population used for norming the Scale consisted of traditional first-year college students (primarily of age 18) drawn from across all disciplines and colleges in the university. This Scale can be used to evaluate, in young adults, affective influences of different socialization situations in which these individuals are situated. In the educational arena, the Scale could be used to evaluate the affective impacts of alternative teaching/learning methodologies in science and technology, or it could be used as a pre- and post-test to assess the impact of changes in curricular structures or requirements. It could be used to compare attitudes of one population to another—for example, attitudes of one cohort of entering students with the attitudes of the following year's cohort, or the attitudes of a control group with the attitudes of a study group being exposed to a new educational approach.

The Scale is versatile. Because the Scale does not presuppose detailed knowledge of any scientific or technological content, it may be used effectively in college general education courses and with populations of young adults whose knowledge of science and interest in science is limited. The Scale does not ask for responses to any items regarding any specific course or any specific educational technique or strategy, so it may be used in any educational setting as a pre- and post-test to measure attitude change occurring over time—perhaps even over the course of a fairly extended period of time.

The Scale should be seen as a tool for the use of educators who need a general-purpose, reliable, and valid measure for an important range of student attitudes toward science and technology. The sample involved students from one university in Illinois; this limits generalizability, as well as desirability of replication with other samples in future research.

(Potential users are cautioned, though, not to remove items from the Scale, even if those items do not load on any factor, or even if those items are all loading in a factor that the user finds irrelevant to their own research interests. Changes of that sort have unpredictable effects on reliability and validity.)

Conclusion

The university, where the study was conducted, has a progressive general education program, and a faculty that is generally committed to good teaching of undergraduates, even in general education courses. It actively participates in national initiatives to improve undergraduate education, and in particular, freshman education. Yet, the female students in the control group—Group C—displayed significant declines in all their measured attitudes toward S & T during their first semester on campus.

Despite the fact that there was significant decline in the attitudes of female students in the control group, such decline is not the inevitable result of forces at work in first-year female college students enrolled in introductory science courses. This is demonstrated by the fact that female attitudes in experimental Groups A and B did not decline (with one exception in Group B). Because of the way in which the Groups were formed, the students in all the Groups were enrolled in the same general education curriculum, living in the same dormitories, presumably with the same kinds of friends, and homes in the same geographical areas.

We conclude that curricular change can make a significant positive difference, even when it does not occur in the context of a science course. It appears that the activities in Group B and in Group A sections *prevented* a *decline* in those attitudes among female students. Moreover, they did so without negatively affecting male student attitudes. This result appears to have important implications for science education in the US.

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