Middle School Students' Attitudes toward Pursuing Careers in Science, Technology, Engineering, and Math

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Abstract

The purpose of this study was to describe middle school students' attitudinal changes towards careers in science, technology, engineering, and mathematics (STEM) after year-long classroom interaction with a National Science Foundation (NSF) Graduate Fellow. The study utilized a mixed methods design of content analysis and constant comparative analysis for matched pre/post student responses (N = 1066) to the open-ended question: Do you think you could become a scientist (or technologist, engineer, or mathematician) like your [NSF] Fellow? Why? Initial content analysis placed student responses into one of seven response categories: remained negative; remained positive; remained uncertain; positive to negative; positive to uncertain; negative/uncertain to positive; and negative to uncertain. Five major themes emerged from constant comparative analysis of response categories explaining why students envisioned themselves becoming STEM professionals: subject area; interests and goal; self-efficacy; work ethic and learning ability; and NSF Fellow. These five themes were consistent across all response categories. The major theme throughout student responses to becoming STEM professionals was students' self-efficacy for a particular subject. From interaction with the NSF Fellow, the students developed a positive belief in their abilities and indicated increased willingness to persevere and work toward educational goals in that subject.

Introduction

Students' classroom experiences are important factors for continued study in specific subjects. Research has shown that subject matter and poor teaching negatively affect the persistence of students in science and engineering (Colbeck et al., 2000). As students progress through school, their interests and attitudes toward science, technology, engineering, and mathematics (STEM) subjects become more negative, especially during the middle school years (Morell and Ledermann, 1998). STEM subjects play an integral role in the agricultural sciences classroom. Negative attitudes may adversely affect students' interests in the agricultural sciences.

Current job market trends indicate heavy future demand for STEM trained professionals as many STEM professionals are nearing retirement, and demand in STEM fields continues to steadily increase (National Science and Technology Council, 2000). The steady decline in interest and increased negativity toward STEM subjects by students results in decreasing numbers of young people entering post-secondary training and professional careers in STEM areas (National Science and Technology Council). Decreasing enrollment in agronomy and crop science programs has caused much concern in the agricultural science community (McCallister et al., 2005), and the steadily decreasing number of new STEM professionals entering the job market creates much concern about the future economic stability and national security of the United States (US). The US will either have to outsource jobs or import STEM professionals from other countries to fill these positions (National Science and Technology Council). In order to prevent a possible outsourcing threat, a need to understand why students change their attitudes toward STEM careers should be studied. If the underlying causes for negative attitudes toward STEM subjects can be understood, then effective intervention strategies could be designed and implemented to reverse current trends.

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Theoretical Framework

Bandura (1986) linked students' motivation and achievement for a subject to their personal beliefs of how "good" they were in a particular subject. Bandura termed this personal belief as "self-efficacy." Pajares and Miller (1994) defined self-efficacy as "a context-specific assessment of competence to perform a specific task, a judgment of one's capabilities to execute specific behaviors in specific situations" (p. 194). Pajares and Miller stated that self-efficacy is a strong indicator of students' self-concept. Self-concept, according to Bandura, is a global concept of oneself that individuals form through "direct experiences and evaluations adopted from significant others" (p. 409). Bandura believed that students were more motivated and enthusiastic toward subjects in which they held a positive belief of their self-efficacy.

Colbeck et al. (2000) stated that "students are more likely to experience their own accomplishments…when engaging in active, hands-on learning experiences rather than when passively listening to lectures" (p. 176). This sense of accomplishment is one of Bandura's (1986) four sources of self-efficacy cited by Colbeck et al. of "experiencing one's own accomplishments, learning by vicarious experience as one observes behaviors modeled by others, verbal persuasion, and emotional arousal" (p. 176). Research by Lindner et al. (2004) indicated students' positive experiences (emotional arousal) in science increased their enthusiasm for science and their belief in their ability to pursue science careers.

Pajares (1996) in a meta-analysis of self-efficacy research found that people will participate in those activities they feel they will be successful in and avoid those activities in which they do not feel successful. Pajares also found that the greater a person's sense of self-efficacy, the more effort, persistence, and resilience a person will demonstrate in an activity. He found those people with low self-efficacy generally believed that things were harder than they actually were and that "self-efficacy beliefs are strong determinants and predictors of the level of accomplishment that individuals finally attain" (p. 545). Johnson and Wardlow (2004) indicated that students with higher computer self-efficacy scored significantly higher on computer exams than did students with lower self-efficacy, further supporting Pajares' findings.

Several educational reform methods such as integrated curriculum, inquiry learning, and teacher/scientist collaborations have long been in use in the agricultural classroom, and are being implemented in core curriculum classrooms with varying levels of success (Balschweid, 2002; Caton et al., 2000; Davis et al., 2003; Evans et al., 2001; Finson, 2002; Harris et al., 2001; Munn et al., 1999; Parr and Edwards, 2004; Sawada, et al., 2002; Tanner et al., 2003; Thompson, 1998; Tretter and Jones, 2003; Trexler and Suvedi, 1998; Weinburgh, 2003). Caton et al. (2000) found that after collaboration with research scientists, classroom science teachers reported deeper content knowledge, increased use of inquiry teaching methods, and increased levels of student learning, participation, and interest. In a study by Balschweid (2002) it was found an agricultural industry expert teaching science within the context of agriculture had a positive effect on student attitudes toward agriculture and agricultural careers. These studies indicate an exciting avenue for further research as to why a subject matter expert positively impacts students and just how long-lasting and far-reaching those impacts are.

Objectives

The purpose of this study was to describe middle school students' attitudinal changes toward future STEM careers. To achieve this purpose the following objectives were developed.

1. Identify pre/post survey attitudinal response categories.
2. Quantify pre/post survey attitudinal response categories.
3. Identify thematic areas within attitudinal response categories indicating change.
4. Explore reasons for attitudinal change toward future STEM careers.

Method

A mixed methods design (quantitative content analysis and qualitative constant comparative analysis) was used to achieve methodological triangulation, defined as "the use of multiple methods to study a single problem or program" (Patton, 2002, p. 247). Content analysis, "a research technique for the objective, systematic, and quantitative description of the manifest content of communication…usually written materials" (Borg and Gall, 1989, p. 519), was deemed appropriate for identifying pre- to post-survey response categories and frequency counts of those categories. The population for this study was large and student responses were in written form. Glaser's (1965) constant comparative method was utilized to identify major themes within each response category. Frequency counts were completed for each theme identified in each response category.

School districts in a 40-mile radius of the university were invited to participate in the program. Ten schools agreed to participate, resulting in a voluntary population of 2,184 middle school students from classrooms of 12 lead teachers and 12 other teachers, in a 40-mile radius of the university. STEM graduate students were selected through an application and review process, The STEM graduate students, termed NSF Fellows, were each assigned to a lead teacher. Due to teacher and school turn-around, student absenteeism, attrition, errors in survey administration, and incomplete surveys, matched pre- and post-Fellow data were analyzed for 1,145 students. Students responded to open-ended questions on the pre-Fellow survey: Do you think you could become a scientist (or technologist, engineer, or mathematician) like your [NSF] Fellow? At the end of the school-year, students responded to the matched open-ended post-Fellow question: Do you think you could become a scientist (or technologist, engineer, or mathematician) like your [NSF] Fellow? Of the 1,145 students, 79 students failed to answer this question on both the pre and post-Fellow survey. Therefore the sample for this study was 1,066 students. There were no engineering classes or engineering NSF Fellows in this population; therefore all results may be generalized only to students studying science, mathematics, and technology.

Pre-Fellow surveys were administered at the beginning of the school-year by the classroom teacher prior to the NSF Fellow's entry into the classroom in order to determine students pre-existing beliefs. Each NSF Fellow was then introduced to the teacher's classroom. Fellows spent approximately 10 hours/week interacting with middle school students, four hours/week preparing materials and developing inquiry-based activities, and one hour/week attending weekly meetings. NSF Fellows were responsible for creating, conducting, and co-teaching inquiry-based classroom lessons, as well as serving as a resource, content specialist, and student role model in middle school STEM classrooms. NSF Fellows helped correct student stereotypes, increased student awareness of the importance of STEM in everyday life, fostered positive student attitudes toward STEM, and increased teacher appreciation and comfort with inquiry teaching methods. Each NSF

Table 1. Student Response Categories and Reasons

Response Categories	*n*/%	Reasons	*n*
Remained Negative	654 (61.4%)	Do not like the subject	179
		Not good/smart enough in subject	189
		Not interested/other goals	197
		Too much work/stereotypical perceptions	63
		NSF Fellow	26
Remained Positive	130 (12.9%)	Like the subject	39
		Smart/good in subject	36
		Positive self-perception of learning ability and work ethic	22
		Useful in future career/teach others subject	16
		NSF Fellow	17
Remained Uncertain	12 (1.1%)	No reason stated	3
		Depend on type of career and length to complete	3
		Undecided about subject	3
		Liked subject and hands-on aspect	1
		NSF Fellow	2
Positive to negative	109 (10.2%)	Do not like the subject	12
		Not good/smart enough in subject	33
		Not interested/other goals	31
		Too hard/too much time	12
		Peer pressure/personal problems	15
		NSF Fellow	6
Positive to uncertain	26 (2.4%)	The subject	9
		Uncertain about future goals	3
		Amount of work involved	4
		Unsure why, more realistic perception of career	9
		NSF Fellow	3
Negative/uncertain to positive	99 (9.3%)	Like the subject	30
		Good/smart enough in subject	25
		Positive self-perception of learning ability and work ethic	19
		Wish to go to college/help others	14
		NSF Fellow	11
Negative to uncertain	32 (3.0%)	No reason stated	7
		Subject	7
		Developed positive self-perception of ability in the subject	3
		Other goals/too early to decide	9
		Uncertain about ability in subject/wish to help others	5
		NSF Fellow	1
Total	1,066 (100%)		

Fellow was expected to reach out to other teachers in the school and by the last 12 weeks of the school-year, spend approximately 40% of their time interacting with students in classrooms other than their lead teacher's.

At the end of the school-year, post-Fellow surveys were administered to the students. Pre- and post-Fellow surveys were matched and each student survey was assigned a number. Researchers used content analysis to sort pre- and post-Fellow matched surveys according to student response patterns. The primary analysis allowed researchers to sort surveys into seven broad groups: 1) negative no change; 2) positive no change; 3) uncertain no change; 4) positive to negative response; 5) positive to uncertain response; 6) negative to positive response; and 7) negative/uncertain to positive response. Frequency counts were conducted on the seven categories. Uncertain pre-Fellow responses were placed in the negative response category as there were too few to justify a single category. Upon further examination of the uncertain student responses, students' reasons indicated negativity, more than neutrality, toward the STEM subject.

Each of the seven categories found in the initial analysis were further analyzed using the constant comparative method to identify themes in each category; again frequency counts were conducted on each theme. The researcher used post-Fellow surveys in the constant comparative analysis because of the principal interest in students' attitudes toward STEM careers after interaction with NSF Fellows.

Table 2. Typical Middle School Student Pre and Post-survey Responses

Category	Subcategory	Student code	Pre-survey response	Post- survey response
Positive to Negative	Do not like the subject	10	*"Yes, because I listen in science class and I'm very smart"*	*"No, because it seems kind of boring"*
	Not good/smart enough in subject	131	*"Yes. Because I am smart and I love science and I won't give up"*	*"No, because I don't like science and it is very hard for me and it is a lot of responsibility"*
	Not interested/other goals	338	*"Yes, because I love math and I would like to do something with my life"*	*"No, because when I go to college I don't want to study math. I want to study being a lawyer"*
	Too hard/too much time	115	*"Yes, because i'm [sic] good at memorizing, doing eriments,[sic] and sort of smart"*	*"No. Because once I go through school once I don't want to go through it again,"*
	Peer pressure/personal problems	1135	*"Yes, cause I am a smart child"*	*"No to cool."*
	NSF Fellow	510	*"Yes, because I know a lot about mathematics"*	*"No, because I don't think I could ever be as smart as her."*
Positive to uncertain	The subject	491	*"Yes, because I am good at experiments and good at measuring"*	*"I don't know because this isn't my best subject, but I can if I tried harder."*
	Uncertain about future goals	681	*"Yes. I am very interested in science, I'm <u>very</u> inquisitive and I'm determined"*	*"I might be able to, if I decided that's what I want to do with my life. I like science, especially biology and microbiology."*
	Amount of work involved	237	*"Yes, I have loved science all my life"*	*"Yes-No It would take a lot of studying and practicing, but it would make me feel smart."*
	Unsure why, more realistic perception of career	314	*"Yes! Because I like science and I learn"*	*"Maybe! Well I might not make it."*
	NSF Fellow	210	*"Yes it's my favorite subject"*	*"Yes and no I will be a scientist but probably never be as good [NSF Fellow's name]."*

Results and Discussion

Objectives 1 and 2

Of the 1,066 student responses analyzed, 61.4% (n = 654) remained negative, 12.9% (n = 130) remained positive, 1.1% (n = 12), remained uncertain, 10.2% (n = 109) changed from positive to a negative, 2.4% (n = 26) changed from positive to uncertain, 9.3% (n = 99) changed from negative/uncertain to positive, and 3% (n = 32) changed from negative to uncertain post-Fellow responses (Table 1).

It is encouraging to note 11.3% of students in classrooms with NSF Fellows indicated a positive attitude change, as attitude changes during middle school have the most long-lasting effect on attitudes than at any other time of life (Anderman and Maehr, 1994). This positive attitude change is counter the progressively negative STEM attitudes reported by Morell and Ledermann (1998) in GK-12 classrooms, indicating that NSF Fellows have the potential to reverse this negative trend.

Objective 3

Five major themes explaining why students envisioned themselves as STEM professionals emerged from the constant comparative analysis. Those themes were subject area; interests and goals; self efficacy; work ethic and learning ability; and the

Table 2 Cont.

Negative/uncertain to positive	Like the subject	685	*"I would not become a scientist because I'm not very good at science"*	*"Yes, I like working with experiments and learning or creating new things"*
	Good/smart enough in subject	1041	*"No, because I am not exactly great at science"*	*"I think I could because I am fairly good at science"*
	Positive self-perception of learning ability and work ethic	323	*"No, because I'm not good at it."*	*"Yes, I'm willing to put [in] the effort to go far in life"*
	Wish to go to college/help others	31	*"No, b/c I don't think I'd be able to come up with a lot of ideas like most scientists"*	*"Yes, because I plan on getting an education and going to college, plus I would like to be a scientist,"*
	NSF Fellow	853	*"Maybe and maybe not. My dad is a great mathematician. My dad say I have some of my mom in me in math (She not so good)"*	*"Yes, after being with her [NSF Fellow]. I look at math a hole[sic] new way. A way that is fun and exciting. I'd love to be that kind of person who has that influence on people."*
Negative to uncertain	Subject	102	*"No because I would get frustrated, but it is fun"*	*"I'm not sure because I kinda like science and I kinda don't"*
	Developed positive self-perception of ability in the subject	922	*"No, because I'm not very good at it"*	*"Maybe, I'm pretty good at science"*
	Other goals/too early to decide	1063	*"No, because I really don't have an interest in science. Sometimes I like to do experiments but sometimes the[sic] boring"*	*"Maybe it depends on if I like it later on, but I want to be a volleyball coach."*
		463	*"No, because I am going to be something else"*	*"I really don't know b/c I will let whatever I become happen in the future."*
	Uncertain about ability in subject/wish to help others	256	*"No, because I sometimes think science is boring, but I try to do hard work"*	*"Maybe, because I am not that good at scientist."*
		401	*"No, because math is boring to me"*	*"Maybe, I would liked to help students enjoy math."*
	NSF Fellow	617	*"No it would take to much of my time."*	*"maybe because she made it look so easy."*

NSF Fellow. These five themes were consistent across response categories. Listed below are the four change categories identified and exemplified as typical student responses for each of the themes identified in each response category (Table 2).

Objective 4

The major theme derived from student responses to becoming STEM specialists was students' self-efficacy for a particular subject. Generally, students' beliefs of becoming scientists, mathematicians, engineers, or technologists were based on their beliefs of how well they performed in those subjects. Students who believed themselves smart or good in the subject responded positively to future STEM careers regardless of whether they had positive or negative attitudes on the pre-survey.

Students who indicated subject area as a determinant of future STEM career pursuit, indicated that changes in their own perceived ability in that subject influenced their like or dislike of the subject. Students who viewed themselves as smart or good in a subject were more inclined to express positive attitudes toward their ability to pursue STEM careers. These students tended to enjoy the subject, identify positively with the NSF Fellow, and exhibit positive attitudes toward learning and working hard in the subject. Students who viewed themselves as not smart or good enough in the subject tended to express negative attitudes toward their ability to pursue STEM careers. These students were more inclined to dislike the subject, identify negatively with the NSF Fellow, exhibit a negative attitude toward learning and working hard in the subject area, and find the subject boring, confusing, or too difficult. With regard to the Fellows' influence, those students who responded negatively on the post-survey cited their own feelings of inadequacy in the subject and magnified those feelings in relation to the Fellows' competency. Those students who responded positively to the Fellows' influence did so because of their self-perceived competence in the subject matter.

Many students did not wish to be scientists or mathematicians because they already had other areas they wished to pursue, other subjects they liked better, or did not think they could work with students like the NSF Fellow did. These students perceived themselves to be more competent in subjects or areas other than particular STEM subjects. Students who indicated other goals as reasons to not pursue STEM careers indicated positive self-efficacy for those areas, and rarely changed their goals. These findings support Bandura's (1986) argument that people place more importance on those things they believe they are able to accomplish, than on those things in which they have little confidence. So, in order to increase students' pursuit of STEM careers, STEM instructors should frequently implement authentic instructional activities structured to maximize student success, reinforcing positive student self-efficacy.

Students who wished to help others indicated more positive self-efficacy on the post-survey. These students had desires to help others become better in the subject area. Students with a positive work ethic and beliefs in their abilities and perseverance, held positive attitudes about STEM careers, supporting Pajares' (1996) findings that the greater a person's self-efficacy, the more willing that person is to work, persist, and persevere in their chosen career. Frequent classroom use of authentic instruction promoting cooperative learning may increase the self-efficacy of both positive and negative students. The cooperative element will provide positive students opportunities to help others and provide a scaffold for negative students, allowing them the opportunity to be successful, improving self-efficacy and subject-matter attitudes.

Students who indicated changes due to the NSF Fellow did so in direct relation to their own positive or negative self-comparison to the NSF Fellow. Students with negative self-efficacy usually magnified their own self-perceived inadequacy in relation to the NSF Fellow as why they could not pursue a STEM career. These students felt they would not be as good as the NSF Fellow, so they should not pursue a career in that subject, supporting Pajares' (1996) findings that people will pursue activities where they feel successful and avoid those in which they do not. Introducing a variety of subject matter specialists into GK-12 settings may counter this reaction as students would have increased opportunities to interact with someone with whom they may more closely identify. Other factors that negatively affected students' attitudes toward pursuing STEM careers were peer pressure, personal problems, and the development of a more realistic understanding of the STEM area.

Students who changed from negative to positive attitudes because they wanted to be like the NSF Fellow believed the subject was fun and wished to help other students learn and enjoy the subject. From interaction with the NSF Fellow, the students developed a positive belief in their abilities and indicated excitement and interest in the particular subject. Student 448's statement "Yes the things she taught us maybe I could be able to do things like that" exemplifies the positive impact the NSF Fellow had on the students' self-efficacy beliefs, supporting Balschweid's (2002) findings that a subject matter specialist in the classroom increases student interest in the subject and careers in that subject area, and Lindner et al. (2004) that students' positive experiences increase their enthusiasm for the subject and related careers. Therefore, more opportunities are needed to involve subject matter specialists, and university students (especially from the agricultural sciences) in GK-12 classroom instruction. Increased interaction of agricultural scientists in GK-12 STEM classrooms has great potential to positively affect students' attitudes toward pursuit of agriculturally-related STEM careers.

Summary

Increased involvement of STEM specialists in GK-12 classrooms has the potential to positively impact students' pursuit of STEM-related careers. Students gain subject-matter confidence through practical learning experiences provided by the STEM specialist and gain an appreciation for the STEM specialist as a role model. Middle school students' self-efficacy affects their attitudes toward pursuing STEM-related careers. Many of the agricultural sciences are related to STEM disciplines; agricultural scientists should actively seek opportunities to interact with middle school classrooms to provide students and teachers with authentic learning opportunities. Active participation of agricultural STEM scientists in GK-12 classrooms has the potential to significantly impact the number of students choosing careers in the agricultural sciences.

The results of this study may only be applicable to the population under study. Further research is needed on the effect of STEM specialists in the classroom to determine if the results could be generalized to a broader population. Although students who indicated changed opinions represent a small proportion of the total population, those students should be studied to determine why they changed their attitudes toward pursuing STEM careers. Understanding the many factors involved in students' changing attitudes will help future researchers design programs that produce large positive changes in middle school students' attitudes toward STEM subjects, reversing the current negative trends.

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