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A Retrospective Analysis of STEM Career Interest among Mathematics and Science Academy Students

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Abstract. Data reflecting Science, Technology, Engineering and Mathematics (STEM) dispositions and reported reasons for interest in STEM were gathered from 342 high school students participating in a residential mathematics and science academy on a university campus in April 2013. Student participants were enrolled in a program in which they complete their last two years of high school in conjunction with their first two years of college. Analysis of these data indicated that factors influencing student interest in STEM and STEM careers include the student's own self-motivation, support from a parent or family member, science and mathematics coursework offered in school, and exposure to a high quality, motivating teacher. STEM career interest can be reasonably well predicted from a linear combination of four measures of STEM dispositions, but weightings of predictors and total variance accounted for differ for females when compared to males.

Keywords: STEM career interest; math and science; high school students; gender distinctions; retrospective study

Introduction

Although it is often difficult for youth to predict what field they will study in the future, students who are already on a Science, Technology, Engineering and Mathematics (STEM) path may be able to reflect back on what influenced their interest in following a STEM path intended to culminate in a STEM career. For this study, attitudinal data were gathered from U.S. high school students participating in a residential mathematics and science academy on a university campus in which they finish their last two years of high school in conjunction with their first two years of college. The students also were asked to indicate what influenced their interest in STEM. Researchers sought to find possible causes of students' decisions to pursue a STEM career in order to report to a broader educational audience promising ways to encourage more students to pursue a career in STEM. This unique group of high school students was provided the opportunity to retrospectively look back on indicators that may have influenced their interest in STEM. The research questions that guided this study were:

(1) STEM Interest Attribution: What do high school science and mathematics academy students report as their primary reasons for interest in STEM?
(2) Retrospective Versus Current Interest Alignment: How well do retrospective STEM interest influences align with current interest in STEM as a career?
(3) Determinants of Current STEM Interest: How well can STEM career interest be predicted from STEM dispositions for disaggregated groups?

Literature Review

Like many nations in the world, the United States is increasingly reliant on the STEM workforce to maintain leadership in the world economy (Banning & Folkestad, 2012). "As the world becomes increasingly technological, the value of these national assets will be determined in no small measure by the effectiveness of science, technology, engineering, and mathematics (STEM) education (p. v.)" (Holdren, Lander, & Varmus, 2010). International studies such as the 2012 Program for International Student Assessment (PISA) have ranked the U.S. 21st in science and 26th in mathematics for high school students (Organisation for Economic Co-operation and Development (OECD), 2013). These lower performing academic areas impact the number of students completing higher education degrees in STEM areas. Fewer than half (40%) of students entering college intending to earn a STEM degree complete it – accounting for only 300,000 STEM graduates per year when the projection of those needed for the U.S. workforce is closer to one million (Holdren & Lander, 2012). Not only are fewer students choosing to pursue a degree in a STEM area, but a large proportion of the nation's science talent leaves that area of interest while in college, often switching to a major in which they find more success and reward in the courses. Often students find the first two years of college coursework mostly theoretical and fairly abstract in the engineering and pre-med major courses. Students often change to majors where they encounter more relevance and less theory (Drew, 2011).

Along with the educational environment, teachers (Sjaastad, 2012), peers (Olitsky, Loman, Gardner, & Billup, 2010) and parents (Breakwell & Robertson, 2001) play important roles in students' motivation for learning science. One longitudinal study that followed participants' career choices in addition to their career aspirations found that learning characteristics, such as perceived ability in mathematics and science, as well as friends' interest in science had the greatest impact on student's motivation for learning science (Lee & Shute, 2010) and on student's actual career choice (Garg, Kauppi, Urajnik, & Lewko, 2007). Research on factors affecting the decision to choose a STEM career is still emerging (Banning & Folkestad, 2012).

STEM courses are often viewed as difficult and sometimes unrelated to reality. Students need to be involved in hands-on STEM activities to make the connection between education and future careers (McCrea, 2010). This attitude appears prevalent and seems to permeate science achievement for many students in the U.S. Some researchers have found that students often begin school with a strong interest in science yet decline in interest due to the way science is taught (Krajcik, Czerniak, & Berger, 2003). An examination of contributing factors is needed to understand why students choose STEM majors and continue to pursue a career in STEM (Heilbronner, 2011). Researchers are beginning to more closely study this science identity gap (Tan, Barton, Kang, & O'Neill, 2013).

Gender differences in the selection of STEM careers have been the focus of research for many years (Archer, DeWitt, & Willis, 2014; Beghetto 2007; Tan et al., 2013; Zeldin, Britner, & Pajares, 2008). While girls are reportedly performing equal to or higher than males on math and science assessments in both middle school and high school (National Center for Educational Statistics, 2010) there is a disconnect in how many females compared to males pursue a STEM-related career (National Center for Educational Statistics, 2007; Smith, 2011). Despite girls having a positive disposition toward science (if not higher than boys), girls aged 10-13 are much less likely to aspire to careers in science (Archer et al., 2012). A study of 6,000 students completed in 2012 indicated that by the end of high school, the odds of being interested in a STEM career are 2.9 times higher for males than for females (Sadler, Sonnert, Hazari & Tai, 2012). Young women believe that science and technology are not relevant to their future career goals (Lent et al., 2005). Girls tend to prefer to learn in a more social context and need to see connections between school assignments and the real world. Formal role models are also an important factor that is often missing for girls in STEM areas (McCrea, 2010).

While there are many reasons students choose not to enter STEM careers, this paper identifies some of the attributes of secondary students who have chosen a path toward a STEM career. Students in this study responded retrospectively, selecting the one factor that most influenced their interest in pursuing study in a STEM field.

Research Methods

Subjects

Attitudinal data were gathered from 342 high school students participating in a residential mathematics and science academy on a university campus in which students complete their last two years of high school in conjunction with their first two years of college. Surveys were completed by 186 first-year students (11th grade) and 156 second-year students (12th grade). Surveys were completed via paper and pencil forms during a seminar at the end of the 2012-2013 academic school year. The gender distribution of the students was approximately 54% male and 46% female. While there was some ethnic diversity, the majority of students (68%) were of Asian descent. Approximately 21% of the students were Caucasian, 4% African American, 4% Hispanic, 1% American Indian and 1% reported “other.” These students were selected for the retrospective study because they were high school students who had already chosen a STEM-related path.

Instrumentation

The two attitude/disposition instruments utilized in this research were the STEM Semantics Survey and the Career Interest Questionnaire. These instruments had been used to obtain meaningful data on several recent studies on STEM dispositions where the ages of subjects ranged from middle school level students to STEM career professionals (Knezek, Christensen & Tyler-Wood, 2011; Ducamp & DeJaegher, 2013). The STEM Semantics Survey was adapted from Knezek and Christensen's (1998) Teacher's Attitudes Toward Information Technology Questionnaire (TAT) derived from earlier Semantic Differential research by Zaichkowsky (1985). The five most consistent adjective pairs of the ten used on the TAT were incorporated as descriptors for target statements reflecting perceptions of Science, Math, Engineering and Technology. A fifth scale representing interest in a career in STEM was also created.

Internal consistency reliabilities for the five scales of the STEM Semantics Survey for this group of students ranged from Alpha = .89 to Alpha = .93, consistent with other studies using these instruments (Tyler-Wood, Knezek, & Christensen, 2010). These reliability estimates fall in the range of “very good” to “excellent” according to guidelines provided by DeVellis (1991).

The Career Interest Questionnaire (CIQ) is a Likert-type (1 = strongly disagree to 5 = strongly agree) instrument composed of 12 items on three scales. This instrument was adapted from a longer instrument developed for a Native Hawaiian Studies project promoting STEM interest in Hawaii. Adaptations of the instrument were based on a comprehensive analysis completed by Bowdich (2009). Cronbach’s Alpha for the three subscales of the CIQ ranged from .70 to .93 among the group of students in the current study. These values fall in the range of “respectable” to “excellent” according to guidelines by DeVellis (1991).

Additionally, students were asked to choose from a list, the one factor that had most influenced their interest in science, mathematics, engineering and technology (STEM). The list from which students selected was compiled from analysis of previously obtained open-responses regarding the same question. More details about the analysis of the open-ended responses can be found in another publication (Christensen & Knezek, 2013).

Data Analysis and Results

Research Question 1: What do high school science and mathematics academy students report as their primary reasons for interest in STEM?

This section addresses research question one, regarding the reported reasons students who chose to attend an academy of mathematics and science developed an interest in STEM prior to their academy attendance. Respondents were asked to select the most important factor that has influenced their interest in STEM, from a list of seven common reasons previously compiled through analysis of open-ended responses obtained from the same group of students at the beginning of the school year. The list was created based on prior data collection using an open-ended response to the question of factors influencing the students’ interest in STEM (Christensen & Knezek, 2013). The four most frequently reported reasons for interest in STEM were: 1) self-motivation/naturally inclined (reported by 48%), 2) parent/family member (reported by 30%), 3) science and mathematics classes offered in school (reported by 9%) and 4) a high quality/motivating teacher (reported by 8%). These and other reasons are listed in Table 1.

Table 1
STEM Interest Primary Factor

Primary Influential Factor	Frequency	Percent
Parent/family member	101	29.6
High quality/motivating teacher	26	7.6
Friend/peer	3	.9
Self-motivated/naturally inclined	165	48.4
Science and mathematics classes offered in	30	8.8

school		
Science and mathematics clubs	4	1.2
Science fair/competitions	6	1.8
Other	6	1.8
Total	341	100.0

Analyses were completed to compare the differences in the responses for males and females. Fifty-five percent (55%) of the males attributed their interest to being self-motivated and naturally inclined toward STEM, while only 41% of the females attributed interest in STEM to their self-motivation. Conversely, females (34%) were more likely than males (26%) to attribute their interest in STEM to a parent or family member.

Research Question 2: How well do retrospective STEM interest influences align with current interest in STEM as a career?

One-way analysis of variance was conducted to examine differences in the STEM Career Interest as measured by the STEM Semantics Survey, based on the primary (retrospective) reason reported by students for interest in STEM. The analysis revealed significant ($p < .0005$) differences existed in level of STEM Career Interest based on reported reasons. As shown in Table 2, *science and mathematics classes offered in school* and *self-motivated* were aligned with the highest STEM Career Interest means. A post hoc analysis (Scheffe) revealed the significant pair-wise differences were between *self-motivated* and *science fair/competitions* (p = .027) as well as between *science and mathematics classes offered in school* and *science fair/competitions* (p = .046). As shown in Figure 1, whenever *science fair/competitions* was the category selected by a student as his or her primary reason for an interest in STEM, the actual level of STEM Career Interest was noticeably lower. Conversely, there were at least four reported reasons for interest in STEM that resulted in group mean averages that were notably high.

Table 2
One-Way ANOVA for Career Average by Reason for Interest in STEM

	N	Mean	Std. Dev.
Parent/family member	101	5.84	1.14
High quality/motivating teacher	26	5.94	1.22
Friend/peer	3	5.67	1.27
Self-motivated/naturally inclined	165	6.12	1.10
Science and mathematics classes offered in school	30	6.17	1.17
Science and mathematics clubs	4	5.85	.82
Science fair/competitions	6	4.17	2.46
Other	6	4.53	1.92
Total	341	5.96	1.21

Note: Sig. $p < .0005$.

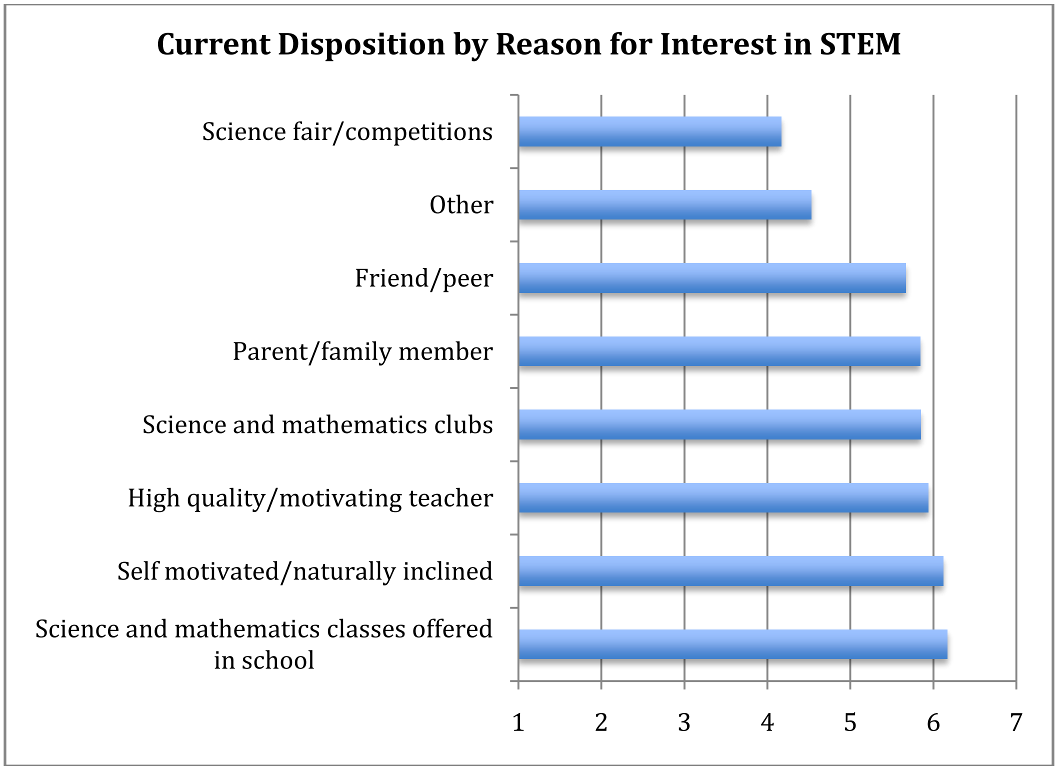

Figure 1. Group mean averages for STEM Career Interest based on retrospectively reported primary reason for interest in STEM.

Regression analysis was used to determine whether selection of one of the four top reasons students attributed their interest in STEM could be used to predict STEM Career Interest. The four reasons used for the regression analysis were *parent/family member*, *quality teacher*, *self-motivated* and *science/mathematics classes offered in school*. The measure used for the dependent variable was the STEM Semantics Career Interest mean for the group. While only 6% of the career interest measure could be predicted (RSQ = .06, p <.0005) from a combination of having reported one of the four reasons as primary, the beta coefficients were significant and especially strong for the *self-motivated* reason (β = .517, see Table 3). Beta coefficients, as standardized regression coefficients, represent the strength of the contribution of an individual predictor, given that the other predictors are held constant.

This analysis indicates that reporting *self-motivated* as the primary reason (in retrospect) for establishing an interest in STEM was most strongly aligned with having a measurably high degree of STEM Career Interest at the time of the survey. *An influential parent or family member* as the primary reason for an interest in STEM (in retrospect) was also strongly aligned with positive STEM Career Interest as measured on the survey. In fact, each of the four reasons listed in Table 3, if viewed as a kind of discrimination index for primary reason (coded as 1) versus not primary reason (coded as zero), are shown to serve well in the sense that students who reported any of these four reasons as their primary reason for interest in STEM (coded = 1) have more positive dispositions toward STEM as a career *(p < .003)* than students who did not report the four top variables as his or her top choice (coded zero).

Table 3
Regression Analysis of STEM Career Interest as Function of Primary Reported Reason for Interest in STEM

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.874	.271		18.006	.000
	Parent	.964	.295	.364	3.267	.001
	Self	1.250	.286	.517	4.373	.000
	Teacher	1.065	.356	.234	2.990	.003
	SciClass	1.293	.346	.303	3.738	.000

Note: Dependent Variable: CARAVG (STEM Career Interest)

(3) How well can STEM career interest be predicted from STEM dispositions for these disaggregated groups?

Retrospective Reasons in Context of Current Interests
A hierarchical cluster analysis (interval scale, average linkage between groups) was run using the five scales from the STEM Semantic Survey, three scales from the CIQ, the top four categories for reasons for interest in STEM, and the demographic variables of gender and school size (UIL) classification. This cluster analysis was used as a form of data mining (Berkhin, 2006) in order to focus on relationships for further examination. As shown in Figure 2, three clusters emerged illustrating: a) gender is related to the reasons for reported interest in STEM, b) school size is related to the three career interest questionnaire scales, and c) career interest is related to the four measures of STEM dispositions on the STEM Semantics Survey. The relationships within each of these three clusters will be explored further.

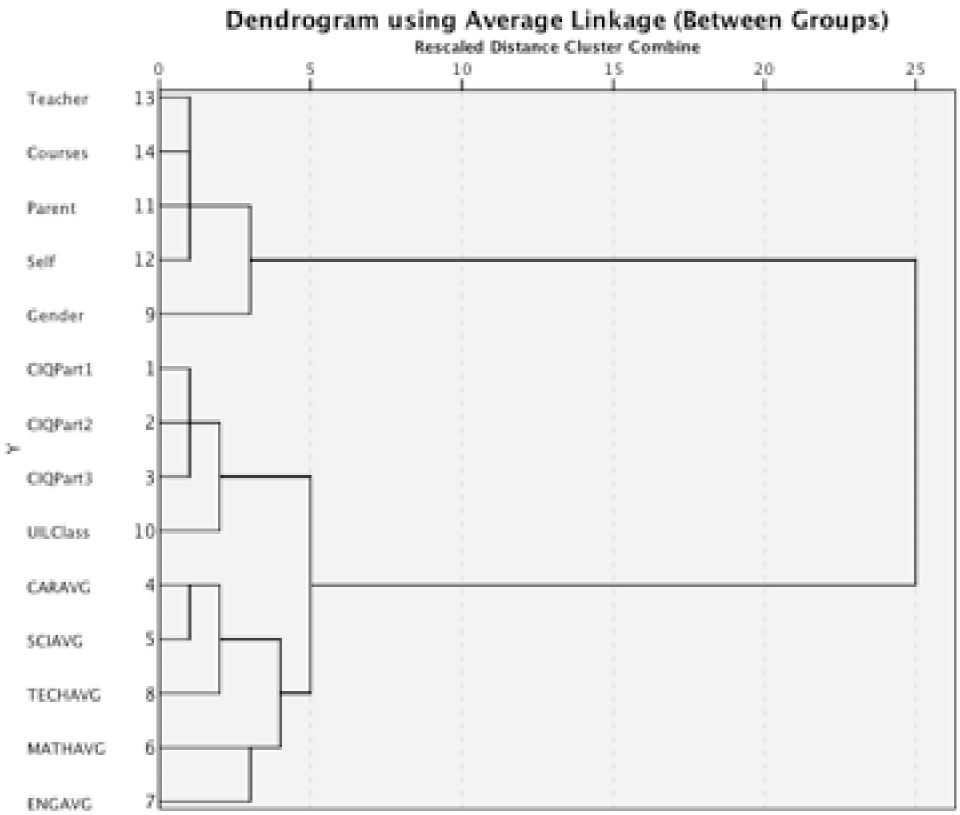

Figure 2: Dendogram showing clusters of relationships.

Gender Differences in Interest in STEM

Four chi-squared tests were conducted to determine whether the proportion of males versus females reporting each of the four primary reasons for interest in STEM differed by gender. A two-tailed significance criterion ($p < .05$) was used. As shown in Table 4, 100 out of 183 (60%) of the male respondents listed *self-motivation* as their primary reason, while only 64 of 157 (41%) of the female respondents listed *self-motivation* as their primary reason. This difference in frequency count by gender would rarely occur by chance (Fisher's Exact Test, $p = .012$). Males more frequently chose *self-motivation* as their main reason for an interest in STEM.

Table 4
Chi-Squared Test for Self-Motivation

		Gender		Total
		Male	Female	
Self	No	83	93	176
	Yes	100	64	164
Total		183	157	340

As shown in Table 5, 53 of 157 (34%) females selected *parent or family member* as their primary reason for their interest in STEM, while only 48 of 183 (26%) *males selected a parent or family* *member* as their main reason for interest in STEM. Although females reported this reason more frequently, the difference was not large enough to be considered significant (Fisher's Exact Test, p = .153).

Table 5
Chi-squared Test for Parent/Family

		Gender		Total
		Male	Female	
Parent	No	135	104	239
	Yes	48	53	101
Total		183	157	340

As shown in Table 6, 20 of 157 (13%) females selected *science and mathematics classes in school* as their primary influence for their interest in STEM, while only 10 of 183 (5%) males selected this reason. Although the total numbers were small, twice as many females as males selected this reason and the difference was significant (Fisher's Exact Test, p = .021). Females were more likely to attribute science and mathematics classes as their primary influence on their interest in STEM.

Table 6
Chi-squared Test for Science and Mathematics Courses

		Gender		Total
		Male	Female	
Courses	No	173	137	310
	Yes	10	20	30
Total		183	157	340

As shown in Table 7, 13 females and 13 males selected a *high quality/motivating teacher* as their primary influence on their interest in STEM. Although females had a slightly higher percentage, these small differences in proportion were likely due to chance (Fisher's Exact Test, p = .689).

Table 7
Chi-squared Test for Motivating Teacher as Reason for STEM Interest

		Gender		Total
		Male	Female	
Teacher	No	170	144	314
	Yes	13	13	26
Total		183	157	340

School Size and Career Interest in STEM

Partial correlation analysis was used to examine in detail the relationships between the Career Interest Questionnaire (CIQ) Part 1, Part 2, Part 3 scores and school size as indicated by University Interscholastic League (UIL) school size classification. UIL rating was used as a school size indicator because it was well known to the students in this study, whereas more precise enrollment figures might not be known. UIL classifications form a monotonically increasing variable of the form: 1 = 199 or fewer students school enrollment, 2 = 200 to 429, 3 = 430 to 989, 4 = 990 to 2064, and 5 = more than 2065 students while CIQ scale scores ranged from 1 = Strongly Disagree to 5 = Strongly Agree. Overall, CIQ scale scores were not found to be strongly related to UIL school size, but for males there was a significant ($p < .05$, r = .197) relationship of larger schools being associated with stronger agreement on Part 2 of the CIQ. Since CIQ Part 2 focuses on the desire to enter into a STEM major and career, the authors conjecture that larger schools may have greater resources to support counseling in many career options, and therefore may tend to offer greater opportunity awareness regarding STEM careers. For females, the relationship between school size and CIQ measures was not evident (p = .408, NS) in the data. None of the individual predictors approached the $p < .05$ level of significance for females. Further research is needed in this area.

Career Interest and STEM Dispositions

Regression analysis was conducted with four STEM disposition measures predicting STEM career interest. A previous study using the same instruments with middle school students showed females had greater predictability for STEM career interest (RSQ = .46) than for males (RSQ = .40) (Mills, 2013). Findings were consistent with previous research in the current study of academy high school students which found that for females, 47% of STEM career interest could be predicted from the four STEM disposition measures (RSQ = .47, p <.0005), while for males 42% of STEM career interest could be predicted from the four measures (RSQ = .42, p <.0005). As shown in Table 8, for females the significant individual predictors were semantic perception of science (β = .594, p <.0005) and semantic perception of technology (β = .146, p =.036). As shown in Table 9, for males the significant individual predictors were semantic perception of science (β = .448, p <.0005) and semantic perception of math (β = .261, p <.0005). The general conclusion from this analysis is that academy students' interest in STEM career can be predicted in the same manner as for middle school students who were participating in a National Science Foundation funded project to foster middle school students' interest in STEM careers. However, the strength of the relationships for the academy students is stronger. This may be due to a higher level of maturity closer to entry into a STEM career.

Table 8
Beta Coefficients for STEM Career Interest as a Function of STEM Dispositions (Female Subjects)

Model		Standardized Coefficients	Sig.
		Beta	
1	(Constant)		.048
	Science Scale	.594	.000
	Math Scale	.076	.283
	Engineering Scale	-.031	.654
	Technology Scale	.146	.036

Note: Dependent Variable: CARAVG (STEM Career Interest)

Table 9
Beta Coefficients for STEM Career Interest as a Function of STEM Dispositions (Male Subjects)

Model		Standardized Coefficients Beta	Sig.
1	(Constant)		.026
	Science Scale	.448	.000
	Math Scale	.261	.000
	Engineering Scale	.042	.551
	Technology Scale	.090	.194

Note: Dependent Variable: CARAVG (STEM Career Interest)

Discussion

Data in Table 3 indicate that retrospectively reported reasons for STEM interest are significantly (p <.01) related to current STEM career interests for academy students but the relationship is not overly strong. Only 6% of the variance (RSQ = .06) in STEM Career Interest was found to be attributable to primary reported reason for an interest in STEM. This can be contrasted with 47% of current STEM Career Interest being explained if current level of positive or negative dispositions toward the individual content areas of science, technology, engineering and mathematics are used in the predictive equation. One limitation may be that the retrospective reason reported by students is about STEM interest in general while the primary measure in this study focuses specifically on STEM as a career. An additional limitation on better predictive ability may be due in part to the dichotomous nature (0 or 1 choice) of each retrospective reason reported, versus a continuous rating scale (1 to 10) that would allow students to report level of strength of influence. It is also possible that current dispositions are better predictors than retrospective reasons because one is current while the other is past. Future research is planned to include a continuous rating scale in order to further address this issue as well as asking students additional questions regarding their interest in STEM as a career.

The current study did not directly address the area of content proficiency, which is also known to be important for sustaining interest in STEM as a career (Bouvier, 2011). From one perspective, the rigorous selection method used for academy students assures the study participants are in the top tier of high school students across the state regarding mathematics and science proficiency, upon entry. However, this does not mean all students perform well in the self-regulation environment of typical university courses. Undoubtedly content proficiency accounts for a major proportion of the 53% of unexplained variance in STEM Career Interest in this study. Future studies that include measures of STEM content proficiency as well as career interest would have a better foundation from which to address this type of question.

Conclusions and Implications of Findings

This study revealed that factors influencing student interest in STEM and STEM careers included a student's own self-motivation, a parent or family member, science and mathematics courses offered in school and a high quality, motivating teacher. Differences emerged by gender in the strength of the influential factors that were related to the STEM disposition and career interest indicators. Males more frequently attributed their own self-motivation as their primary reason for interest in STEM and STEM careers, while females were more likely to attribute science and mathematics courses in school as their reason for their interest in STEM. Findings from this study are consistent with prior research (Zeldin, Britner, & Pajares, 2008) in which self-confidence in females was found to be nurtured by family members, teachers and peers, being provided mostly in terms of encouragement or direct experiences. Females frequently attributed their beliefs and confidence to specific influential persons who helped them in specific instances. Findings for males were quite different in that men attributed their mastery experiences and personal abilities to their science and mathematic-related achievements.

In this study, school size was strongly related to the STEM and CIQ indicators. However, for males, higher dispositions on the CIQ Part 2 were aligned with coming from a larger school. Part 2 of the CIQ measures dispositions toward preparing for and succeeding in a STEM career, including college level coursework.

In general, the researchers concluded that STEM Career Interest can be predicted from the four STEM semantic scales measuring current dispositions toward science, technology, engineering, and mathematics, for both males and females. However for females the strongest predictors were related to science and technology. For the males the strongest predictors were related to science and mathematics. These findings for academy high school students are consistent with prior research on middle school students (Mills, 2013), using the same instruments.

Implications of these findings are potentially far-reaching. With approximately 25% of STEM Career Interest attributable to semantic perception of science, the importance of positive experiences with science at an early age begins to emerge. Also, as shown in Tables 8 and 9, dispositions toward technology and mathematics also contribute to STEM Career Interest, although the relative importance differs for male and female students. Because the females' dispositions that predict STEM career interest are not that different from the males in this study, although females' attribution of their interest in STEM is more strongly tied to the influence of other people such as parents and teachers, there is an implied need to have parents and teachers encourage females who exhibit an early interest in STEM to persist in their focus in a STEM-related career.

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