Why Students Choose a College Major in the STEM Fields

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Introduction

The National Research Council has just released its much-anticipated recommendations for K-12 science and engineering education (National Research Council 2011). Implicit in the arguments for a stronger and more focused approach to teaching and learning in these fields is the realization that fewer students are choosing to pursue degrees in science, technology, engineering, and mathematics (STEM) than will be needed to fill workforce positions in our ever advancing technology-driven society. In light of this situation, research on why students choose a college major in the STEM fields and how students are influenced toward a career in one of these disciplines is vital. We need to look at data for the country as a whole, but also at data from the state of Texas to help inform educators and other community members as they make decisions that we hope will steer students toward STEM careers.

Current research literature identifies several factors that correlate with student choice of STEM major. These include influence of teachers and parents, gender, race, socioeconomic status, and science self-efficacy (Forrester 2010; Maltese 2008; Lau & Roeser, 2002; Crisp, Nora & Taggart, 2009; Tai, Sadler & Loehr 2005). Many studies report that the influence of primary and secondary teachers is the most prominent factor in directing students toward a college major or a specific career path (Hattie 2003; MacIntyre et al.; Dick & Rallis 1991; Forrester 2010; Tai, Sadler & Loehr 2005; Tytler 2010; Lau & Roeser 2002; Maltese 2008). Parental encouragement is also a prominent factor through modeling of educational goals, support through direct involvement with a school or learning activities, and verbal, emotional and financial support before and during college enrollment (Lau & Roeser 2002; Rowan-Kenyon 2007; Smith & Hausafus 1997; Herdon & Hirt 2004). Studies have focused on the student voice, methods of teaching science, the teacher voice and influences of popular science. Research from all of these areas must be integrated to make informed decisions about science education policies (Christidou 2011). Elucidating the student reflection of characteristics of teacher interactions and teaching styles as well as parental interactions is an important step to understanding what determines the success of a student within the STEM disciplines and what piques student interest in pursuing advanced studies in these fields. (MacIntryre et al. 2010, Hattie 2003).

To give a richer, more detailed description of the pre-college factors that influence a student's choice of STEM major among students in Texas, we undertook a case study comparing and contrasting populations of college-enrolled students who chose a STEM major with those who did not choose a STEM major. The case study approach allowed for a qualitative examination of a smaller sample size so that we could concentrate on specific context-dependent scenarios that might enrich an understanding of the influences affecting students (Gerring 2004, Flyvbjerg 2006). An article published by J. Koch in Science and Children (1990) describes the use of a science autobiography to stimulate discussion among pre-service elementary school teachers enrolled in a science methods course. Ellsworth & Buss (2000) reported interesting research focused on pre-service teachers that used student autobiographies to track how educational experiences affected feelings and perceptions of math and science. We decided to include similar student-generated science autobiographies in our research design that would allow the students in our STEM/non-STEM samples to describe specific experiences, attitudes, and changes in opinions over time. Each of our study participants wrote a unique narrative in response to an assigned prompt that described experiences from their pre-college science education. We read and coded these autobiographies searching for emerging themes that might point toward common experiences (Maltese and Tai 2010). The results of this study are a descriptive analysis of factors contributing toward choice of STEM major and attitudes toward science and technology among students enrolled at a Texas university. Additional demographic data, a logic reasoning measure and a questionnaire on experiences in science teaching and learning enrich the comparison of the two student groups.

Research Questions

This study addressed four research questions:

1. Is there a correlation between student logic reasoning ability as measured by the Group Assessment of Logical Thinking (GALT) test and experiences in teaching and learning science as measured by the Experiencing in Teaching and Learning (ETL) questionnaire for students in our sample?

2. What are the differences in learning orientations between STEM students enrolled in an entry-level science major's chemistry course and non-STEM students enrolled in an entry-level education major's physical science course as determined by the Experiencing in Teaching and Learning (ETL) questionnaire?

3. What are the major educational influences on students' attitudes toward science as described in science autobiographies?

4. What are the differences between the science education experiences and attitudes toward science of STEM students enrolled in an entry level science major's chemistry course and non-STEM students enrolled in an entry level education major's physical science course based on information gleaned from science autobiographies?

Methodology

The samples chosen for this study were students enrolled at a mid-size private university located in West Texas. The sample population was all students enrolled in two entry-level science courses during the fall 2010 semester. The students self-selected course schedules and all students in each of the chosen science courses were invited and consented to participate in the IRB-approved study.

The first sample was comprised of the 22 students enrolled in Honor's General Chemistry (CHEM H133), a chemistry course covering the fundamental principles of chemistry at an accelerated pace for honors students with a math or science major or a pre-health professions emphasis. Only one section of CHEM H133 is offered per semester. This course has the reputation for being a very difficult course. Science majors and pre-health professions students

are not required to enroll in the honor's section and most choose to enroll in one of the non-honors sections. The university honor's program has a strong humanities component. Students who choose to pursue an honor's degree and are therefore eligible to enroll in CHEM H133 must also be articulate writers. As a result of these factors, the students who elect to take CHEM H133 are usually highly motivated students who are confident in their science ability, very interested in the subject matter and write well. This STEM major sample was specifically chosen because of these expected characteristics.

The second sample chosen for this study was the group of 22 students enrolled in General Science for Pre-service Elementary School Teachers (CHEM 203). This course is an entry-level physical sciences course that presents the fundamental principles of chemistry, physics, geology, astronomy and meteorology for students preparing to teach in elementary schools. Only one section of CHEM 203 is offered per semester. None of these students have chosen to major in STEM disciplines and CHEM 203 is usually the first science course they have taken at the college level. It is not unusual for these students to postpone taking CHEM 203 until their junior or senior year because they are concerned about the science content of the course. Though some of the CHEM 203 students are intimidated by science content, they are usually creative and enthusiastic learners who have spent time in education courses reflecting on effective teaching. As a result of their previous education training, their written analysis of teaching and learning situations might be expected to be much richer than one written by a student who is not an education major. Once again the non-STEM major sample was specifically chosen because of the expected characteristics of this population.

The majority of the students who participated in this study are Texas residents who attended public schools in Texas. Four out of the 22 students in the STEM sample received their high school diplomas outside of Texas, while 2 out of the 22 students in the non-STEM sample graduated from high school in another state. The pre-service teachers enrolled in CHEM 203 are in training to be certified and teach in the Texas school systems.

Demographic information was retrieved from university databases. Two assessments were administered to all students in both samples during the first days of course enrollment to ensure that the results indicated a reflection on previous experiences: the Group Assessment of Logical Thinking (GALT) test and the Experiencing in Teaching and Learning (ETL) questionnaire (Roadrangka 1986, Roadrangka, Yeany & Padilla 1986, Enhancing Teaching-Learning Environments). The GALT test measures logic reasoning ability and has been shown to have a correlation with success in science coursework (Bird 2010; Bunce & Hutchinson 1993; Jiang et al. 2010). The ETL questionnaire was used to assess previous teaching and learning environments and student approaches to studying, ways of thinking and practicing a subject. Both assessments have been used previously to study a variety of student populations and have been shown to have high reliability and strong validity (Parpala 2010; Xu 2004; Bird 2010). Data collected using these two tools were compared and statistical analyses were performed using R and SPSS.

The first assignment in each course was to write the science autobiography. Instructors provided a written description of the assignment with the prompt and students were given one week to complete the work (Figure 1). Essays were submitted electronically. All students were assured that their essays would be confidential and that the goal of the assignment was to learn about their previous experiences in studying and learning science that had influenced their attitudes toward the discipline. Students were also informed that grades would be assigned based on thorough completion of the task and not on positive, negative or indifferent content.

Figure 1: Science autobiography prompt

Assignment #1: Science Autobiography

Respond to the following prompt in essay form. Your response should be at least 500 words long, but no longer than 1000 words. Completed autobiographies should be submitted electronically to your course drop box.

When you think about your science education beginning in elementary school, through middle school and high school what are your dominant memories and impressions from each stage?

Think about these questions as you answer: (1) Did you like science, hate science, or just feel a bit neutral about it? (2) Who or what influenced your attitudes toward science and how did they influence you? (3) When did you feel like you learned science most effectively? (4) What topics do you remember studying? (5) Do you remember times when your experiences with science affected life choices? (6) Are there differences between in-school and out-of-school memories?

Please be as specific as possible in describing experiences and include examples to support your answers.

Respond to this prompt at the conclusion of your autobiography: ***Thinking about what you've just written about your science education, describe an ideal science teacher's role in a classroom and an ideal science student's role in a classroom.***

In this study, the science autobiographies were read by each author/researcher who independently coded and categorized the content of the writing samples by general attitude. Five attitude categories were used: overall positive, overall neutral, overall negative, positive to negative, and negative to positive. If a student autobiography included only positive statements regarding their science experiences, they were placed in the "overall positive" category. If they wrote exclusively about negative experiences, they were placed in the "overall negative" category. Students who were placed in the "positive to negative" or "negative to positive" groupings typically wrote about a transition period when their opinion toward science changed. Students whose autobiographies expressed indifference toward science were place in the "overall neutral" category. These classifications were similar to those used in the Ellsworth & Buss (2000) autobiography analysis. We independently analyzed each autobiography and then compared ratings to reach and record a consensus categorization.

We also analyzed the science autobiographies for evidence of expected themes by looking for evidence of several non-demographic factors that previous research has shown to correlate with student success in and pursuit of STEM education. These categories were mention of teacher impact, mention of parental impact, and allusions to student science self-efficacy. We recorded the number of times teachers or parents were mentioned as positive and negative influences and the number of sentences dedicated to these topics. We looked for evidence of science self-efficacy by looking for descriptions of student confidence or lack of confidence in preparation for a university level science course or in academic performance in science courses taken during secondary education. Finally, we looked for any additional emergent themes in the student science autobiographies that might elucidate possible connections between early experiences with science and choice of a STEM major.

Quantitative Data
Comparison of demographics of STEM and non-STEM samples

Table 1 lists the gender, major, and classification distributions of the STEM and non-STEM student samples. The student participants enrolled in CHEM 203 were all female and a majority of the students were classified as juniors and education majors. Three CHEM 203 students had a declared major in a field closely aligned with education that also falls in the non-STEM category. Students in CHEM 203 comprise the non-STEM sample. There were 13 men and 9 women enrolled in CHEM H133 and most had declared a biology or biochemistry major. The four students who were not science majors had declared a pre-health professions concentration that includes significant undergraduate level science coursework and their career goal requires enrollment in a graduate level health science program. All CHEM H133 students were classified as STEM students for the purposes of this study. Though many of the students in CHEM H133 were technically classified as sophomores, all but one were first-year university students; honor's students often begin their college careers with over 30 hours of AP or duel-credit coursework and therefore may be classified as sophomores before high school graduation. The one senior enrolled in CHEM H133 had chosen to take the course due to a late-in-degree program decision to take pre-requisites courses for medical school and declare a pre-health professions concentration.

Table 1: Sample demographics

	STEM	Non-STEM
Gender	13 Males	0 Males
	9 Females	22 Females
Majors	9 Biochemistry	17 Education
	9 Biology	2 Applied Studies
	2 Bible	1 Speech Pathology
	1 History	1 Family Studies
	1 Psychology	1 Psychology
Classification	1 Senior	4 Seniors
	0 Juniors	12 Juniors
	11 Sophomores	4 Sophomores
	10 Freshmen	2 Freshmen

Comparison of GALT data for STEM and non-STEM samples

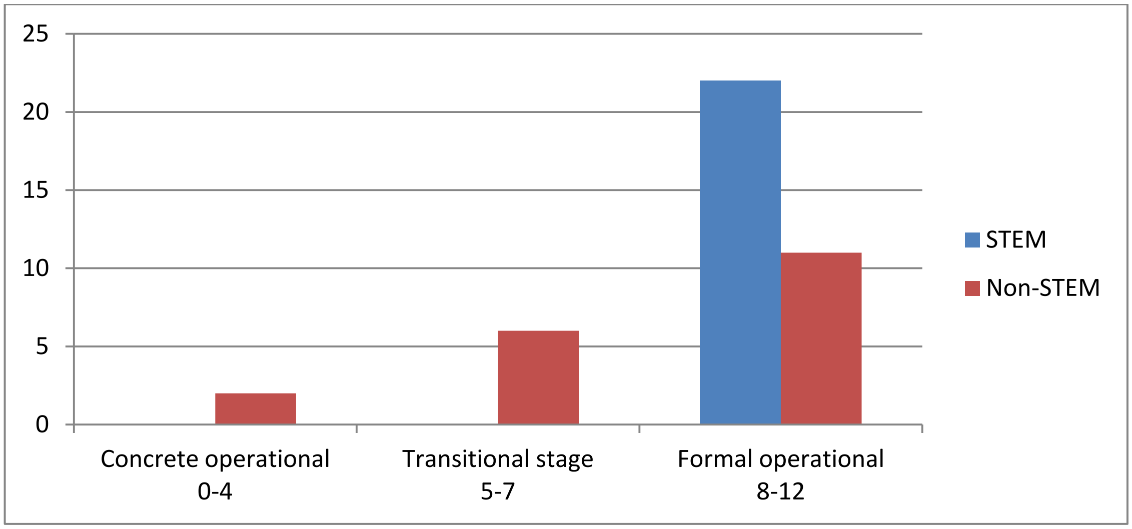
The GALT test can be used to assess logic reasoning ability and separates students into three operational stages that correspond to Piaget's developmental model: the concrete stage, a transitional stage and the formal stage (Roadrangka 1986, Roadrangka, Yeany & Padilla 1986). This test has particular relevance when examining data for STEM and non-STEM university students as numerous research studies report a correlation between science ability and development of logic reasoning ability (for example: Bird 2010; Bunce & Hutchinson 1993; Jiang et al. 2010). We planned to use this data to investigate connections between logic reasoning ability and experiences in learning and teaching of science among our sample populations. We might expect higher GALT scores for students who have a track record of success in STEM disciplines at the high school level and in turn expect a greater proportion of students who choose a STEM major to exhibit high GALT scores. During this administration of the GALT test, reliability is indicated by a Cronbach's alpha of 0.71. Table 2 summarizes the mean performance of each sample population on each GALT item. One point is assigned for correct completion of an item, and perfect performance on the GALT test corresponds to a score of 12. Figure 2 is a representation of the stage distribution of students in each sample as determined by GALT performance. Most students in both sections can be categorized in the formal operations stage based on GALT score; however, 7 non-STEM students fell in the concrete and transitional stages.

There is a statistically significant difference between the mean GALT score of the STEM sample (10.3 $\pm$ 1.35) and the mean GALT score of the non-STEM sample (7.8 $\pm$ 2.21). Analysis of the sub-categories measured by the GALT test show that the cause of the overall statistical difference is a statistical difference in performance on questions testing proportional reasoning, probabilistic reasoning, correlational reasoning and combinatorial reasoning ($p < .05$). The median overall GALT score for the STEM sample was 11, 0.7 higher than the mean, and the median overall GALT score for the non-STEM sample was 8, 0.2 higher than the mean. Four students in the STEM sample scored a perfect 12. No GALT data was collected for three of the students in the non-STEM sample.

Table 2: Results of Group Assessment of Logical Thinking Cronbach's alpha = 0.71

Logical reasoning mode	Question	Mean score		*p*- value
		STEM	Non-STEM	
Mass/Volume conservation	One	1.000	0.895	0.1628
	Two	0.905	0.789	0.3292
Proportional reasoning	Three	0.809	0.632	0.2238
	Four	0.905	0.474	0.003373
Experimental variable control	Five	0.952	0.842	0.2711
	Six	0.667	0.789	0.3947
Probabilistic reasoning	Seven	0.952	0.947	0.944
	Eight	1.000	0.737	0.02072
Correlational reasoning	Nine	0.857	0.211	0.00000789
	Ten	0.476	0.053	0.001867
Combinatorial reasoning	Eleven	1.000	0.8947	0.1628
	Twelve	0.952	0.579	0.006678
Total GALT score	All	10.2650	7.7909	0.00004659

Figure 2: Operational stages determined using GALT



GALT data can be further analyzed through examining any interaction effects by gender within the STEM sample. (The non-STEM sample does not include male students, limiting our analysis of this sample by gender.) Table 3 shows the mean GALT scores on each item by gender and the results of t-tests comparing these. At the $p < .05$ level only item ten (one of two questions testing correlational reasoning) is statistically significantly different for the male and female STEM students. Extending the limit to $p < .10$ the female STEM students performed at a statistically higher level on both correlational reasoning GALT items. All other mean GALT item scores for the STEM sample by gender show no statistically significant differences.

Table 3: Comparison of STEM sample GALT data by gender

Logical Reasoning Mode	Question	Mean Score		*p*-value
		MALE-STEM	FEMALE-STEM	
Mass/Volume Conservation	One	1.000000	1.000000	1.000000
	Two	0.9230769	0.8750000	0.7488
Proportional reasoning	Three	0.8461538	0.7500000	0.6287
	Four	1.00	0.75	0.1705
Experimental variable control	Five	1.000	0.875	0.3506
	Six	0.6153846	0.7500000	0.5413
Probabilistic reasoning	Seven	1.000	0.875	0.3506
	Eight	1.000000	1.000000	1.000000
Correlational reasoning	Nine	0.7692308	1.0000	0.0821
	Ten	0.2307692	0.8750000	0.00174
Combinatorial reasoning	Eleven	1.000000	1.000000	1.000000
	Twelve	0.9230769	1.00000	0.337
Total GALT Score	All	9.9000	10.66667	0.2319

Comparison of ETL data for STEM and non-STEM samples

The data collected using the ETL questionnaire and displayed in Table 4 shows statistically significant differences in the STEM and non-STEM student intrinsic reasons for taking the science course and extrinsic reasons for taking the science course. The STEM student sample on mean reported having stronger intrinsic reasons for enrolling in the science course ($p < .10$) than non-STEM student sample. Likewise, the non-STEM student sample on mean reported stronger extrinsic reasons for taking the science course ($p < .05$). It is not surprising that students choosing a STEM major would express greater personal motivation for enrolling in a science course than students who have not chosen a STEM major and are required to take a science course for completion of their non-STEM degree. The reliability data as expressed by Cronbach's alpha for the measures of intrinsic and extrinsic motivation are low perhaps indicating some conflict of thought among the students about their reasons for enrolling in the courses or their level of interest in the science content.

A statistically significant difference is also evident in the reported measure of taking a surface approach to learning. Non-STEM students reported that they are more likely to take a surface approach to learning ($p < .05$, Cronbach's alpha =.863). The surface approach subscales that contributed to the statistical difference were the memorizing without understanding subscale and fragmented knowledge and unthinking acceptance subscales. Non-STEM students more frequently agreed that in previous science courses they had often attempted to learn information that did not make sense to them and struggled to remember this information. The strong reliability of this data gives us confidence in the accuracy of these self-reported learning tendencies.

When comparing data for organized study habits, on mean the non-STEM students reported a more systematic approach to studying and learning than the STEM students. The difference is statistically significant at the at the $p < .10$ level (Cronbach's α =.869). Again, the strong reliability of this measure indicates consistent student reporting of study habits.

Table 4: Results of the Enhancing Teaching-Learning Environment Questionnaire (ETL)

ETL sub-scales	Cronbach's alpha	*t*-test results		
		STEM	Non-STEM	*p*-value
Intrinsic learning orientation	.588	4.712	4.807	0.436
Intrinsic reason	.305	4.450	4.197	0.0894
Extrinsic reason	.452	2.640	3.136	0.009602
Deep approach	.813	4.200	3.955	0.2183
Surface approach	.863	2.281	3.074	0.002043
Monitoring studying	.795	3.956	4.193	0.2164
Organized studying	.869	3.842	4.253	0.07474
Effort management	.717	4.050	4.318	0.1480

In looking at evidence for gender differences that might be displayed among the STEM student sample we see a statistically significant difference in the mean value of the measure of intrinsic reasons for enrolling in the course and in the deep approach to learning at the $p < .10$ level. The female STEM students reported a lower intrinsic motivation ($p = .08206$, Cronbach's alpha = .305) and a lower tendency toward a deep approach to learning ($p = .0744$, Cronbach's alpha = .869) than the male STEM students.

Table 5: Comparison of STEM sample ETL data by gender

ETL sub-scales	*t*-test results		
	MALE-STEM	FEMALE-STEM	p-value
Intrinsic Learning Orientation	4.625000	4.777778	0.486
Intrinsic Reason	4.633333	4.222222	0.08206
Extrinsic Reason	2.660000	2.666667	0.9816
Deep Approach	4.400000	3.902778	0.07447
Surface Approach	2.075000	2.638889	0.1325
Monitoring Studying	4.000	3.875	0.6335
Organized Studying	3.983333	3.851852	0.651
Effort Management	4.200000	3.962963	0.3936

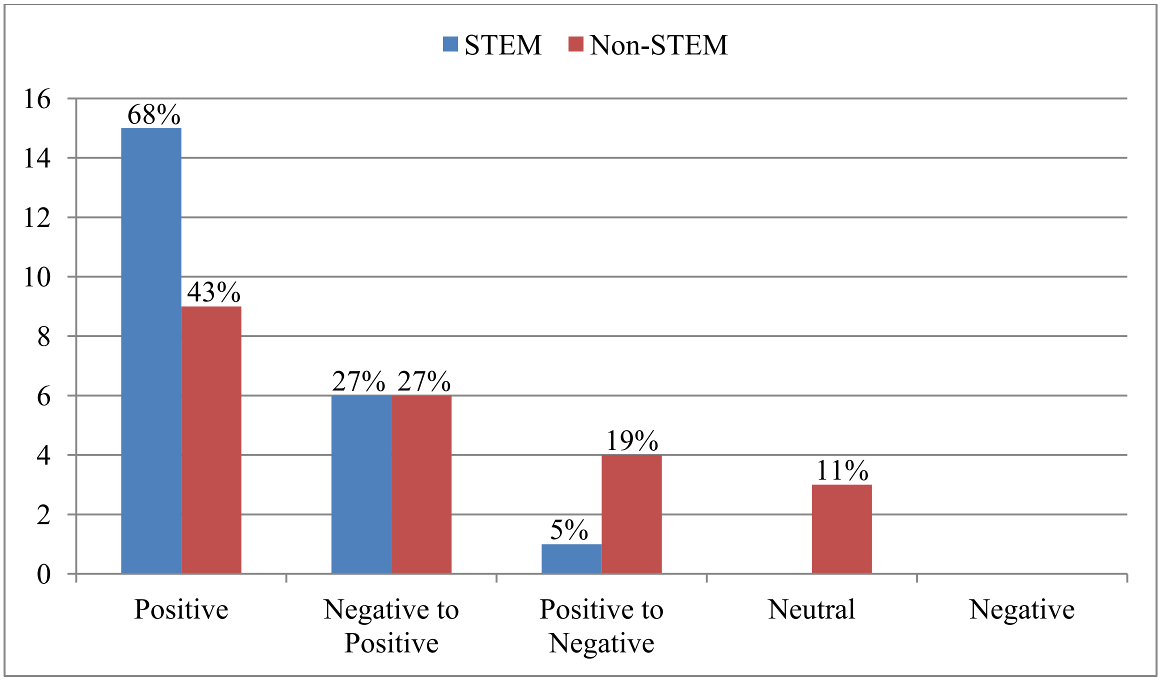
Qualitative Data

General attitudes toward science

General attitudes toward science as expressed in the science autobiographies of students in both the STEM and non-STEM samples were analyzed and categorized. Five categories were used to group the student attitudes that resulted from pre-college experiences: overall positive, overall neutral, overall negative, positive to negative, and negative to positive. None of the students in either group had an overall negative attitude toward science during their early education years. In the STEM sample, 15 students had an overall positive attitude toward science, 6 students reported transitioning from a negative to a positive attitude through their primary and secondary education years, and one student reported a transition from a positive to a negative attitude toward science during pre-college education (Figure 3). By contrast, the non-STEM sample included 9 students with an overall positive attitude toward science, 3 students were classified as overall neutral, 6 students reported transitioning from negative to positive attitudes and 4 students included information in their autobiographies suggesting a shift from positive to negative attitudes toward science (Figure 3).

Examination of Figure 3 shows that the greatest proportion of students in both samples can be classified as having a positive attitude toward science before beginning their college educations (combining the positive and negative to positive categories). However, it is not surprising that slightly more than 25% of the non-STEM students expressed a neutral or positive to negative transition of attitude toward science that resulted in either a neutral or a negative attitude before beginning their college career. It is surprising that one STEM student expressed a negative attitude toward science and still chose a career path that included heavy science coursework.

Figure 3: General attitudes toward science



Themes in the science autobiographies

Previous research suggests several common influences on student pursuit of and success in a STEM major in college. We began our analysis of the autobiographies by looking for evidence of these influences during the pre-college years to see if we could gather more detail about how students in our samples were affected in either positive or negative ways. Students discussed the influence of teachers, family, school and out-of-school experiences. We saw evidence of student self-efficacy in both sample groups. One emergent theme that we did not initially target was prominent in writings collected from both sample groups: the importance of hands-on or laboratory learning in the classroom. A discussion of the data gathered under each of these themes follows.

Theme I: The positive influence of teachers

Among all of the anticipated and emergent themes, students in both samples dedicated the greatest number of sentences to discussing the influences of primary and secondary teachers on their attitudes toward science. All 44 students mentioned pre-college level teachers in their science autobiographies. Nine out of the 22 students in the STEM sample specifically mentioned high school science teachers who fostered a personal relationship with their students and served as mentors. This is seen in the following statements from STEM sample autobiographies:

- "It was a strange relationship at first; almost with a love for teacher more than a love for subject, but with a great teacher comes an appreciation for what he or she is passionate about."
- "She had a way of knowing us so personally, that she could discover each individual's learning style and accommodate it."
- "His classes were structured as 30 minutes of lecture, 45 min of lab and 15 min to solve problems. During the entire time however, he would be talking to us, giving us life lessons, and being more of a mentor/ fatherly figure than a teacher. That really inspired me to pursue my goals, and just fortified my love of science."
- "Physics was a hard subject for me because it is unlike any other science that I had grown accustomed to, but (my teacher) helped me to be able to get through the class, and still enjoy science. I am very grateful for his faith in actions, and his caring personality."
- "Something that is similar in every stage of my life is the fact that my attitude towards science usually reflected that of my current science teacher. The ideal science teacher would be one that is interested in their students as well as the subject they are teaching."

Students in the non-STEM sample discussed the importance of a teacher's ability to actively engage their students in learning and did not stress the importance of personal relationships or mentoring relationships. They equally sited primary and secondary teachers who were positive influences. The following excerpts from autobiographies written by non-STEM students are examples of student belief in the importance of creative and interesting teachers:

- "She always had a new and creative way to help us learn hard concepts, and that quality made her one of the most effective teachers in my life."

- "At the elementary age I enjoyed all my subjects because I had great teachers who made it fun and exciting no matter what we were doing. My teachers definitely influenced my attitude about science at the elementary age, and they influenced me by doing a lot of fun and hands on activities."

- "My freshman year I had a physical science teacher (whose) passion for the subject was obvious from the first class. He was extremely upbeat and excited about science, and he made sure everything that he taught us was engaging and fun. He would go very in depth in the subjects he was teaching and not just teach the words of the textbook. He incorporated creative hands-on learning experiences, and science felt like less work."

- "In middle school I had a fantastic teacher that had a way of making science interesting and understandable to everyone She was a great teacher because she never made me feel like I was learning useless information just for the sake of learning science. She applied every detail to my life."

While both groups clearly site teachers as an inspiration, it is notable that the students in the STEM group frequently mentioned being mentored by science teachers and the non-STEM group did not. The non-STEM students seemed more interested in the mechanics of how a course was taught, than in who was teaching it. Both appreciated creative teachers who were interested in the subject matter they taught and who were enthusiastic about drawing students into the learning experience.

Theme II: The negative influence of teachers

Our sample autobiographies cited teachers as a strong influence, both positive and negative, in the development of students' view of the discipline of science. The following statements exemplify how the students believed teachers served as negative influences in shaping their attitudes. There were no lengthy descriptions of specific negative teacher influences among the STEM autobiographies, but general statements written by STEM students about negative teacher attitudes consistently reflects their interest in a mentoring relationship with teachers.

- "Students can usually tell when teachers could care less about them, and I know for me personally, it lessens my motivation greatly."
- "I most effectively learned science at this level despite the teacher's unpleasant attitude towards the students in my class."

All students in the non-STEM sample who described a positive to negative shift in their attitude toward science pinpointed teachers as the primary reason for this shift. When describing negative influence of teachers, the non-STEM students continued to focus on whether the teacher worked to make the material engaging rather than on the personality or function of the teacher as a mentor.

- "The teachers were not engaging and did not make it fun for any of the students."
- "During my aquatic science class, the information we were learning was not what the teacher enjoyed teaching, so unfortunately I was not able to learn and retain very much information from that class."
- "My teachers in middle school also had an enormous impact on my feelings toward science. All of them were boring and monotonous, and not one of them incorporated hands-on learning or experiments. The love that I had previously felt for science disintegrated, and I began to think of it as a chore."
- "I remember in 8th grade sitting in the classroom, we were learning about organisms and life stages and I just could not understand why we need this information, why I was being told to memorize any of the things, I just did not like it…After having that one bad experience (with the teacher) in science I decided it was something I didn't need any more so I just stopped learning."

Overall, the focus on teacher influence is a dominant theme among the 44 written autobiographies. Teachers impacted students in both positive and negative ways and the students in our sample who chose a STEM major as they began their university career reported a deeper connection with science teachers as mentors than the students in our non-STEM sample. The students in the non-STEM sample described teacher interest in the subject matter and effort to engage the students through active learning strategies as key components for positive teaching and pointed to absence of these attributes as contributors to negative teaching.

Theme III: The positive influence of family members

Undoubtedly family members have an enormous impact on student performance in school and attitudes toward education including attitudes toward specific disciplines (Lau & Roeser 2002; Smith & Hausafus 1997; Herdon & Hirt 2004; Hurtado & Carter 1997; Desmond & Turley 2009; Rowan-Kenyon 2007; Buchmann & DiPrete 2006). This theme was evident in autobiographies written by students in both the STEM and non-STEM samples. Twice as many students in the STEM sample (8) than in the non-STEM sample (4) described their parents or other family members as strong influences on their attitude toward science. Family members impacted students through discussion about their own careers that included a science component or through taking an active role in their student's science education. Though the STEM students were more vocal about family influences, there were not notable differences in the types of family influences described by students in the two samples. The following excerpts drawn from a mixture of STEM and non-STEM autobiographies exemplify student views of the importance of family influence on their attitudes toward science:

- "In an academic sense I learned way more in the classroom, but in a far more significant way my Dad has taught me what science really means in the real world."
- "My teachers were central to developing my love for science, but my Dad is responsible for my fascination with it…even from before I could write we were doing experiments. When I was little we used the scientific method to test which cereals stayed crunchy the longest, and when I got older he taught me why the barbecue turns things to charcoal."
- "As a young child, our families shape many of our preferences and beliefs. In this way, my interest in science in elementary school was greatly influenced by my father, a physician, who has a great interest and understanding for sciences, and also by my older sister, who also loved science."
- "My mom started working as a nurse in the cardiac cath lab at (a hospital) and her stories reminded me of my interest and love of the heart."
- "I feel like my family had the biggest influence on my opinion on science…many of my family members have worked for NASA as long as I could remember. When I was a young child, I always wanted to follow in my grandfather's footsteps and become an aerospace engineer."
- "My mother was a teacher and

taught biology for several years at our local high school…She did a lot of fun experiments and made her students write a daily notebook… When I think about my earliest memories of science I think about my mother and the effort she put into planning and assessing her lessons at home."

Students who expressed a negative attitude toward science did not include any mention of family influence in their autobiographies. Of the students who were classified as having an overall positive attitude toward science from both samples 25% (6 out of 24) mentioned a positive family influence.

Theme IV: Science experiences outside of school

The science autobiography prompt asked students to consider whether there were "differences between in-school and out-of-school memories" with respect to science. Family impact could fall under the category of an "out-of-school" memory so we anticipated some overlap in student responses. Despite the fact that they dedicated more sentences to their discussion of the influence of teachers than out-of-school influences, 11 out of the 22 STEM students (50%) described experiences outside of the school setting as the primary reason for their interest in pursuing a career in science. These experiences included internships, science projects, interaction with doctors, and visits to museums in addition to family interactions. The following quotes are illustrative of the breadth of out-of-school experiences STEM students described as being highly influential:

- "I was able to experience science on a deeper level than most while working at an oral surgeon's office last summer. It was there that I was able to observe and participate in surgeries at a minor level and realize that this field of study is fascinating to me."
- "I volunteered at the…zoo as a junior mammal keeper during the summers of my sophomore and junior year."
- "For me, the in-class experiences and memories helped to cultivate my interest and love in science, but it was the out of class experiences that really led to my passion for biology that I have today."
- "I was a part of an internship that enable me to learn hands on medicine. This is when I truly fell in love with science and what it has already accomplished with endless possibilities for the future."
- "…I began to get really bad migraines…we discovered that (it) was a benign cyst that only one surgeon…would even consider surgically removing. It was at that moment that I knew (I wanted) to be a neuro researcher."
- "My earliest recollection of exploring the creation…was at a the Science Place. There they had all sorts of exhibits to show how things worked in the universe, how things were in the past, pools of water showing how waves worked…and giant animatronics of everything from dinosaurs to human thumbs…I was probably 6 or 7 when this happened, but it left a lasting impression on me about how much life there is all around us."

By contrast, only one student in the non-STEM sample described an outside of school experience as the *primary* influence on her attitude toward science and one additional student listed out of school experiences as being important. In both of these cases, the out-of-school experience they discussed was family influence.

Theme V: The science self-efficacy

Low self-efficacy is frequently suggested as a limiting factor in student success (Forrester 2010; Lau & Roeser 2002; Schoon & Boone 1998). We examined the student autobiographies for evidence of attitude toward the ability to succeed in learning science content materials. Interestingly, the STEM students dedicated fewer sentences to any discussion of their science ability than the non-STEM students. This may be due to a tacit assumption among students enrolled in an honors chemistry course that they are capable science scholars. Many of their statements about future careers in science or medicine included statements that implied confidence in their ability to achieve their post-graduate goals. They also made statements about their roles in learning or in coursework that indicated they considered themselves successful science students. The following excerpts are indicative of the STEM students' confidence.

- "After serious considerations I made one of the greatest decisions in my life, I decided to follow my heart and take the harder route."
- "I am very confident that with the science background that I have, this major is not far off and well within my grasp."
- "The ideal science student's role in a classroom (is) to be able to learn some of it on your own. It really is the best way to retain information. To realize that the goal is not for teachers to teach everything they can, but for students to learn everything they can."
- "I remembered how much I had loved biology and so I chose to take AP biology last year. Not only is it the most challenging class I have ever taken, but it is also the class I have gotten the most out of…I have never learned so much in one course before. I was not the best in the class by any means, but I sure gave it my all."
- "In order to truly learn, students must find the answers themselves."
- "Junior high was when my love for science truly took flight. By then I had mastered the scientific method, and thought I can do anything."

The non-STEM students more frequently directly described their science confidence levels as younger students. Like students in the STEM sample, students from the non-STEM sample referred to the confidence gained from learning challenging materials.

- "When I think back to my elementary classrooms, however, I can remember becoming excited about the science experiments we conducted, and I remember going to great lengths to ask questions about what we were studying."
- "I knew that I liked the ocean and sea creatures, but until I took this class I did not realize how much I enjoyed learning about marine biology. I started to go further in depth with what we studied in class on my own time, and I started to seriously

consider becoming a marine biologist."

- "I always liked science. In elementary school, as much as I can remember, I always had fun, enthusiastic teachers. It was something that I was good at so I did not mind doing it."
- "I think the time in which one of my science classes most affected a life choice was simply that I knew I could learn and handle anything, and therefore could do anything."
- "I did struggle with some of the topics discussed between chemistry, biology, and physics but I seemed to work through it and understand the materials to the best of my ability."

Completely absent from any of the autobiographies is any discussion of student lack of ability to understand or "do" science. Students with positive to negative overall attitudes did express lack of interest, but attributed this to poor science teaching, not to the subject matter.

- "I had a very different experience in high school…the teachers I had were a different breed than the ones I had formerly. My tenth grade biology teacher was less than satisfactory. She failed to challenge the minds of her students…My interest in science grew weaker and weaker because I lacked good direction in my classes."
- "But after some of my experiences with science (teachers) the idea (of studying science) became less appealing…I feel a bit intimidated by science, and I do not feel confident with my science foundation."
- "My physics class was by far the worst class I have ever experienced…(my teacher's) lessons plans never differed much; we either did activities on a computer program of he put in a DVD of a college professor teaching a lesson…It was a struggle to do work in that class, and care about my grades."

<u>Theme VI: The effect of teaching using activities and experiments</u>

Discussion centering on activities and experiments that were part of school science curriculum is an emergent theme in autobiographies written by students in both sample groups. Students state that such "active", "hands-on" approaches greatly influenced their interest in and understanding of science and made science a lot more "fun." STEM students (13 out of 22) and non-STEM students (16 out of 22) discussed this topic. Non-STEM students dedicated 140 sentences to describing specific science activities in contrast to 79 sentences written by students in the STEM sample. This is not a surprising theme for a science autobiography, but its prominence emphasizes that experiential classroom curriculum is very memorable and influential! Students from both samples articulated this idea:

- "The science classes that I loved and remember the most are the classes that I had incredible learning experiences because of fun activities or experiments."
- "I feel like overall I learned science most effectively when we preformed activities to go along with the lesson, instead of just doing worksheets and listening to lectures."

- "What made my 6th grade science class so exciting was that the whole class seemed to be participating in experiments or other hands-on work. I don't think we even had a text book."
- "In one of my chemistry classes, the teacher allowed us to perform a burn test lab where we burned certain chemicals and saw what color their flames were. It is during this period that my neutrality toward science turned into more of a fondness for the subject."
- "My most memorable thoughts about science in elementary school was when we learned about the digestive system in the sixth grade. We did an activity where we pretended to be our favorite type of food and we had to draw what the food was like as it went through the digestive system."
- "It was hands-on, self-paced and discovery based. We learned about astronomy, electricity, and simple machines that year. I had a better understanding of electrical current than most of my friends for years because of that science class."
- "We made our own periodic table. We made shirts and posters of endangered animals. We made videos of different groups of elements. Everything really made me love science."

Conclusions

Previous research into the motivations for pursuing a STEM discipline in undergraduate and even graduate education identify several demographic and environmental factors that are correlated with pursuit of and success in advanced STEM education. In this case study we have attempted to investigate some Texas students' perceptions of the influences in their pre-college education that have affected their attitudes toward science to provide a richer description of how students might be supported toward higher education goals in the STEM disciplines. We chose a sample of students who are enrolled as STEM and non-STEM majors at a Texas university and investigated their pre-college experiences in the sciences. Most students completed their high school educations at a Texas high school. We planned to try to answer four research questions that we hope will help Texas educators identify methods of continuing to improve our encouragement of students in science, technology, engineering and mathematics.

The first question we wished to address was whether we saw a correlation between student logic reasoning ability as measured by the GALT test and experiences in teaching and learning science as measured by the ETL survey. Comparison of the GALT data for the STEM and non-STEM samples indicates that the STEM sample had a significantly higher mean GALT score. This is not a surprising result since many previous studies have shown a correlation between logic reasoning ability and performance in STEM discipline coursework. Grouping of the GALT scores by Piaget's stages of development for each sample show that all students in the STEM sample would be placed in the formal reasoning category while 61% of the non-STEM sample would be categorized in the formal reasoning stage. The remaining 39% of the non-STEM students would be placed in the transitional or concrete stages.

Comparison of the ETL data for the

students from both samples who would be categorized as formal reasoners to the ETL data for the students from both samples who would be categorized as concrete or transitional reasoners shows two statistically significant differences: the intrinsic ($p < .05$) or extrinsic ($p < .05$) motivation for enrollment in the university level science course. Students with the higher GALT scores were more likely to report a personal interest in science that motivated their course enrollment than students with a lower GALT score. It might be suggested that this motivation is linked to a "natural ability" that is reflected in the GALT performance, but it may also be linked to previous experiences with STEM learning that led to a motivation for developing skills in STEM areas. It is interesting that comparison of the ETL data for formal reasoning students with the concrete and transitional stage students does not result in any significant differences in surface learning or deep learning, or in an organized approach to studying. These are qualities we might expect to be linked with logical approaches to learning and thus logic reasoning.

Using data from the ETL we can address the second research question and look at the differences in self-reported learning orientations between STEM students enrolled in an entry level science major's chemistry course and non-STEM students enrolled in an entry level education major's physical science course. As discussed in the quantitative data presentation, analysis of data for these two groups shows several significant differences in learning orientations. The STEM sample students report higher intrinsic motivation and the non-STEM sample students report greater extrinsic motivation. The STEM sample students indicate that they are less organized studiers and also less likely to take a surface approach to studying content materials. The alignment of more organized studying and surface approach to studying as reported learning habits in the non-STEM sample is an interesting juxtaposition of traits. It may be often assumed that students who are organized in their approach will exhibit the deepest learning approaches resulting in greater interest in a subject matter, but this data seems to negate that connection for our sample.

The third research question asked what students identified as the major educational influences on their attitudes toward science as described in their science autobiographies. As reported in many previous studies, our students identified primary and secondary teachers, parents and other family members and outside-of-school volunteer and educational experiences as the dominant influences on their attitudes toward science. Students attributed much of their interest or lack of interest in formal science education to the level of enthusiasm and commitment of their science teachers. The hands-on laboratory teaching that occurred in classrooms left a deep impression on students in both samples. Interestingly, none of the students described their own ability to understand science content as a limiting factor in their success in science courses or interest level in science content. The majority of students in both samples who expressed thoughts about their ability to learn about science exhibited strong self-efficacy.

Finally we wanted to identify the differences between the science education experiences and attitudes toward science of STEM students enrolled in an entry level science major's chemistry course and non-STEM students enrolled in an entry level education major's physical science course by comparing the information gleaned from science autobiographies. We saw several important trends in the information provided by students in their autobiographical narratives describing experiences in science throughout their pre-college education years. STEM sample students identified teachers as mentors and role models and were very affected by the personal interest that teachers expressed in their students. The science autobiographies of the non-STEM students focused on classroom teaching styles of their primary and secondary teachers, but did not identify these teachers as mentors or comment on whether the teachers took a personal interest in the students. Further research into mentoring influences across disciplines might help us learn about teachers of other subjects who did serve as mentors for the non-STEM students and more about how these mentoring relationships were formed.

The influence of family members on a student's positive interest in science was a topic addressed by both STEM and non-STEM students in our samples, however twice as many STEM students identified family members as a major influence. No students identified family members as a negative influence on their interest in science. Descriptions of family involvement in science education revolved around parent occupations and a few descriptions of parents who provided opportunities for their students to experiment at home. Our students seemed to be very impressed by the work their science-minded parents pursued and wanted to follow in their footsteps. Internships and volunteer opportunities were also highly influential for our STEM sample students and several described these as the defining experience that motivated their choice of major. The presence of a parent who has a career in the sciences or an internship/volunteer work with professionals in science or technology fields give students first-hand experience that widens their understanding of how workers in these disciplines contribute to society. With this window into the everyday work life of a STEM professional, students are more likely to picture themselves pursuing a similar career.

Identifying the influences on the students in our sample is both enriched by and limited by the unique pre-college experiences of every student. While we cannot directly compare the quality of their primary and secondary educations, we can compare the attitudes and impressions that the students have taken from those experiences and listen to their explanations of the genesis of their attitudes. From listening to the student voice as expressed in their autobiographies and in their analysis of their experienced teaching and learning styles, we can learn how our actions and interactions as teachers might affect student perceptions of STEM disciplines and eventually influence their decisions about pursuit of a STEM major.

What conclusions can be drawn from the data presented in this study? First, all of us are being encouraged to pursue deeper learning objectives and to teach our students in ways that will encourage them to be lifetime learners. Sometimes this means that we are tasked with teaching study skills and organized studying habits regardless of our discipline. The ETL data in this study suggest that students who have chosen to pursue STEM disciplines may not be as organized in their study approaches, but also are not as likely to take a surface approach to studying. This result is a reminder that it is vital that we impress upon our students the importance of understanding what they are studying and assess our students in ways that require understanding of material, not rote memorization. Organized studying of rote material will allow students to be successful in reproducing information, but does not provide the important foundation that will allow students to understand, retain and apply what they have learned or apparently lead to greater interest in pursuing a STEM discipline major.

Second, this study re-affirms that the active, student-centered classroom makes science memorable and a positive enthusiastic teacher who draws students into learning can have an enormous impact on students. Additionally, teachers who are willing and able to mentor students seem to be a vital link to encouraging students to pursue a career in a STEM discipline. The teacher's interactions with students is central to the learning process; a new curriculum or end-of-course exam may provide some motivation, but most essential is an instructor who is willing to show personal interest in students. Mentoring can take many forms. A recent publication in this journal implicitly highlighted the work of countless mentors in assisting students through co-curricular science projects and competitions (Hedge 2011). Students often have opportunities to learn about health science careers through programs planned by Area Health Education Centers (National Area Health Education Centers 2011). There are also statewide initiatives like the Joint Admission Medical Program that have been very successful in recruiting students into health sciences (JAMP 2011). Magnet schools in areas of denser population have gathered students to study science and technology and health sciences. These are all excellent ventures. In a time of budget shortfall, many teachers are being asked to take on heavier loads. In the decision process, the importance of student mentoring and the time and attention it requires should be taken into consideration.

Finally, increasing opportunities for students to volunteer or participate in internships in a professional setting that includes a wider variety of STEM careers could make a significant difference in student career choices; we see such exposure as a defining influence for many of the STEM students in our sample. While opportunities to shadow and learn from health professionals are more commonly available, opportunities to learn from a computer programmer at a software development firm, a chemist working in water quality control, an electrical engineer managing a project or any number of other essential STEM positions are scarce. Our data indicates that finding creative ways to expose students to careers in a STEM discipline may be one way to widen the stream of students entering our universities and technical schools to pursue careers in science, technology, engineering and mathematics. It's a goal worth pursuing that will be key to continued economic growth in our state and nation.

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