Chapter 5

A Longitudinal Study of Mathematics and Science Motivation Patterns for STEM-Intending High Schoolers in the US

James A. Middleton, Daniel Mangu and Andrew Lee

Abstract This research explored various motivational factors that influence US high school students' intentions regarding careers in STEM. Data from the High School Longitudinal Study of 2009 surveyed 24,000 students in 9th and 11th grades. Respondents showed four categories of intentions: (1) Not STEM Intending, those who did not select a STEM field as an intended occupation in either the 2009 or 2011 administrations; (2) Leavers, students who selected a STEM occupation in 2009 but not in 2011, (3) Newcomers, those who did not originally specify a STEM career in 2009, but who did in 2011; and (4) Stayers, those who chose STEM careers in both 2009 and 2011. Results show that occupational intentions change dramatically between 9th and 11th grades, and that the relationship between STEM intention and motivation is highly time-sensitive: Of the STEM intending students in 2009 (29% of the total sample), only 48% remained STEM intending in 2011.

Keywords Motivation · Career intentions · Secondary data analysis · Longitudinal · STEM

5.1 Introduction

For many years, the relationship between students' attitudes and their college and career intentions has been an important area of inquiry in Science, Technology, Engineering and Mathematics (STEM) education. In general, research has found that, since students perceive their earlier STEM experiences as indicative of future

J. A. Middleton (✉)

Arizona State University, Box 896101, Tempe 85287-6101, AZ, USA
e-mail: jimbo@asu.edu

D. Mangu

Arizona State University, PO Box 82431, Phoenix 85071, AZ, USA
e-mail: dmangu@asu.edu

A. Lee

Arizona State University, PO Box 6572, Mesa 85216, AZ, USA
e-mail: andrew.ryan.lee@gmail.com

© The Author(s) 2019

M. S. Hannula et al. (eds.), *Affect and Mathematics Education*,
ICME-13 Monographs, https://doi.org/10.1007/978-3-030-13761-8_5

experiences, particularly potential successes and failures in a potential occupational field, these perceptions also color their career intentions and occupational choices (Suárez-Álvarez, Fernández-Alonso, & Muñiz, 2014).

Students' perceptions of their mathematics experiences in high school and early college, have been shown to be a strong predictor of their occupational intentions; perceptions of bad experiences tend to filter out future mathematically-intensive courses and academic majors that could lead to participation in STEM occupations (VanLeuvan, 2004). In seminal work in this area, Betz and Hackett (1983), for example, examined the impact that mathematics self-efficacy beliefs had on high schoolers' intention to select science majors in college. They surveyed upwards of 250 students and found that, not only are students' expectations for future success in mathematics significantly related to their choice of college major, but that young women and young men differed significantly in their mathematical self-efficacy. Partial causative factors for this disparity include young women's beliefs in the utility of STEM for their future career goals, lack of role models, and young women having more developed communal goals, as opposed to individualistic goals, than young men (Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011). Following up on this line of reasoning Hackett and Betz (1989) found that college students' mathematics achievement was significantly predicted by mathematics self-efficacy, perceptions of the utility of mathematics, and lower mathematics anxiety. These perceptions significantly predicted their choice of a science-related major versus non-science, accounting for more variation than even mathematics performance measures.

Similarly, Priess-Groben and Hyde (2017) studied US adolescents as they transitioned through high school and then into college. Using surveys, high school records, and interviews during college, they found four variables that significantly impact mathematics course taking in college: Expectancies of success in high school, mathematics self-concept, utility value of mathematics, and high school mathematics achievement. Their Structural Equations Model supports the integration of these variables in predicting intent to study further mathematics. Specifically, they found that mathematics self-concept influenced their expectancies of success, and this in turn influenced the utility value that future mathematics courses had in their collegiate plans.

However, lack of participation, and intent to pursue, STEM careers is not solely a function of poor experiences in mathematics. The STEM fields in general, are perceived by both men and women, but particularly women as not fostering communal goals and interests, instead promoting agentic goals (individualistic, self-promoting) (Diekman, Brown, Johnston, & Clark, 2010), potentially leading many to pursue careers they feel better match their desire to help and care for others.

More recently, Sadler, Sonnert, Hazari, and Tai (2012), administered a retrospective survey of a representative sample of 6000 students enrolled in 34 two- and four-year colleges in the US. They asked the students questions such as "Which of the following BEST describes what you want(ed) to be" at various stages in their lives (e.g., start of high school, end of high school, start of college). They provided the students a set of 19 career fields and asked them to choose one from the list with which to answer the question. They found that students who desired to go into

STEM fields at the beginning of high school were 9 times more likely to continue in STEM in college, than students who were not interested at the beginning of high school. They also found large gender differences with only about half of the females surveyed interested at the end of high school, who were interested in STEM careers at the beginning of high school. This and other studies show the importance of the development of STEM interest early on, and the relationship of long-term interest and career aspiration. We interpret such results to mean that the “catch-and-hold” process that is used to describe the transition from situational interest to personal interest (Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000) also is a useful model for describing the transition from personal interest to *career* interest.

But interest is only one of several factors interacting in the long-term development of career intentions. As mentioned above, Self-Efficacy beliefs constrain young people’s intentions when there is a perceived mismatch between the rigors of higher level mathematics and science, and the learner’s own perception of their capabilities. Lent, Lopez, and Bieschke (1991) show us that mathematical Self Efficacy influences students’ *science* career intentions. Additionally, mathematical Self-Efficacy and Interest were found to be highly related. Presumably, we become more interested in subject matter in which we perceive ourselves to be efficacious. Other research has shown that situational interest in subject-matter increases task persistence, and personal, long-term interests is associated with career choice. Thus, a cycle of situational interest increasing task-level persistence, thus improving performance is begun. (Un)Improved performance, then alters self-efficacy beliefs, and these beliefs impact long-term interest in the subject matter and associated career pathways.

Two other factors have been found in the literature to interact significantly with interest and self-efficacy: Utility and Identity. When subject matter is found to be instrumental for the student’s personal goals, i.e., is considered *useful*, the subject matter, or task within which the subject matter has been situated, is perceived as more interesting than tasks that have no instrumental value. This instrumental value can be short term, wherein the knowledge learned in the task helps to solve an immediate problem, or it can be long term, wherein performance on the task may be necessary to obtain a grade or continue in a mathematically intensive course (Husman & Hilpert, 2007). So, this utility factor can also be seen as interacting with a student’s nascent, task-based interest and efficacy beliefs, but also contributing to longer-term goals and aspirations stemming from their growing academic and career identities (Boaler & Greeno, 2000). This plays into the student’s Identity, which interacts strongly with a student’s educational and career intentions. Factors relating to *identity* within at least one domain (mathematics) are highly predictive of pursuit of STEM in general, and engineering in particular (Cass et al., 2011).

Identity is developed over time in a field, but there is evidence that consistency across the high school years is paramount for keeping students engineering intending. Adelman (1998) analyzed the transcripts of persons enrolled in the High School and Beyond longitudinal study (1982–1993) and their subsequent choices of major and occupation. He found that at age 28/29, the people who persisted in engineering displayed a consistent occupational goal, beginning in high school. Forty-one percent of engineers displayed a consistent goal through high school and through

college, as compared to only 10% of engineers who changed their career goals often. Because many students move from discipline to discipline in college, the likelihood of a student with engineering intent going into university actually graduating with a degree in engineering is below 50%. This is especially true for women. Marra et al. (2009) studied nearly 200 undergraduate women to ascertain their efficacy-related beliefs and career intentions. They found that self-efficacy mediated students' career intentions, and that, at least for women, it should be a factor in deciding when to switch majors.

It has been consistently shown that these key variables: Interest, Identity, Self-Efficacy, and Utility each impact the effort adolescents are willing to expend in academic subject matter, and that they interact to significantly predict academic performance in STEM subject matter (Middleton, 2013). In general, a voluminous body of research suggests that interest and perceived utility of the subject matter is a key driver of effort students are willing to expend, and that self-efficacy and identity mediate students' goals for engaging and persisting in STEM (See Middleton, Jansen, & Goldin, 2017). The purpose of the present study builds on this body of research to ascertain the longitudinal impact of these variables on the career intentions of high schoolers, with particular attention to STEM aspirations. Mathematics and science beliefs are analyzed separately since, though they are related, they also show quite different patterns in students' identity and the role they play in students' career aspirations (Christensen, Knezek, & Tyler-Wood, 2015).

5.2 Method

5.2.1 *HSLS: 09*

The High School Longitudinal Study of 2009 (HSLS:09, NCES, 2011) is a long-term study of 21,000 US 9th graders in 944 schools administered by the United States National Center for Education Statistics. The intent of the study was to paint a picture of students' experiences in high school, focusing specifically on mathematics and science courses. Students' projected career aspirations including whether they planned to take future mathematics and science courses, and their desired majors were a special focus of the study.

The initial administration of the HSLS: 09 began in Fall, 2009, surveying 9th graders on their past experiences in middle school, and on their current attitudes, motivation, and achievement. Students were surveyed again in the Spring of 2011, and a follow up survey was administered again in 2013 following expected graduation. Future data collections are planned to learn about students' experiences and success post-graduation.

5.2.2 Study Population

HSLs: 09 generated a sample of 944 high schools, including public and private schools, that are representative of communities in the US. Following sampling schools, approximately 25 ninth-graders were randomly selected from each school. The resulting sample totaled approximately 24,000 students. The students are representative of all ethnic categories and socioeconomic strata in the US. We only analyzed data at the national level in this report.

5.2.3 Motivation Scales

Sixteen items common to the 2009 and 2011 administrations were utilized in the construction of motivation and achievement indices in the present study. Table 5.1 provides the list of items in each scale. HSLs has aggregated some items to create scales for of the variables hypothesized in this report (e.g., Identity). Some variables such as Effort, however, were not constructed by the HSLs authors. For that reason, we developed scales by examining the wording of each of the mathematics related attitude items, and constructing scales whose wording addressed the hypothesized variables best theoretically, eliminating items with low reliability. We used listwise elimination of cases with missing values. This reduced the response rate to 17,602 out of the original 24,000 (around 73%). The items for each scale are presented in Table 5.1. All items were measured on a (4 point) Likert scale. Unfortunately, the authors of the study did not use parallel items to measure effort in 2009 and 2011. In 2009, effort was operationally defined as a general construct: *academic effort*, and was not focused on mathematics and/or science coursework. In contrast, the 2011 scale specifically asked students to rate their frequency of effortful behaviors specifically related to mathematics and science classwork (see Table 5.1).

5.2.4 STEM Intention

STEM career intentions were measured using standard categories from the US Bureau of Labor Statistics (2010): Computers/Mathematics, Architecture/Engineering, Life and Physical Sciences, and Healthcare Professionals. Participating students were asked to choose from 23 standard occupational categories. Students who chose one of these four categories of occupations as “where they see themselves at age 30” was classified as STEM intending. With measures administered longitudinally at two points in time (2009 and 2011), we classified students into four categories of intentions: (1) **Not STEM Intending**—those who did not select a STEM occupation in either administration; (2) **Leavers**, students who selected a STEM occupation in 2009 but not in 2011, (3) **Newcomers**, those who did not spec-

Table 5.1 HSLS:09 items chosen to comprise motivational scales

Motivation scale
<i>Prompt</i>
Item
Identity
<i>How much do you agree or disagree with the following statements?</i>
1. You see yourself as a math person
2. Others see you as a math person
Interest
<i>How much do you agree or disagree with the following statements about your Fall 2009 math course?</i>
1. You are enjoying this class very much
2. You think this class is a waste of your time (R)
3. You think this class is boring (R)
Utility
<i>How much do you agree or disagree with the following statements about the usefulness of your Fall 2009 math course? What students learn in this course...</i>
1. is useful for everyday life
2. will be useful for college
3. will be useful for a future career
Self-Efficacy
<i>How much do you agree or disagree with the following statements about your Fall 2009 math course?</i>
You are confident that you can do an excellent job on tests in this course
You are certain that you can understand the most difficult material presented in the textbook used in this course
You are certain that you can master the skills being taught in this course
You are confident that you can do an excellent job on assignments in this course
Effort (2009)
<i>How often do you...</i>
1. go to class without your homework done? (R)
2. go to class without pencil or paper? (R)
3. go to class without books? (R)
4. go to class late? (R)
Effort (2011)
<i>How often [do/did] you do these things in [math/science course title]?</i>
1. You [pay/paid] attention to the teacher
2. You [turn/turned] in your assignments and projects on time
3. When an assignment [is/was] very difficult, you [stop/stopped] trying
4. You [do/did] as little work as possible; you just [want/wanted] to get by

(R) indicates reverse scored items

ify a STEM career in 2009, but who did in 2011; and (4) **Stayers**, those who chose STEM careers in both 2009 and 2011.

5.3 Results

Results show that STEM intentions changed *dramatically* between 9th and 11th grades. Of the nearly 6800 STEM intending students in 2009 (29% of the total sample), only roughly 3500 remained STEM intending in 2011. This is an overall attrition rate of 48% for the 2009 cohort. The attrition away from STEM occupations was heavy across all occupational categories. Computer/Mathematics professions saw a drop from 350 original students to only 94 (a drop of 73%). Architecture/Engineering dropped from 1035 to 363, an attrition of 65%. Physical and Biological Sciences saw the largest attrition, dropping from 1055 to 208, an 80% rate. Health Professions, the category representing the largest group of STEM intending students in 2009, dropped from 4348 to 2193 (50%).

While attrition away from STEM occupations was heavy across all occupational categories, there is hope! Overall, students selecting STEM careers as their intended occupation at age 30 increased only by 5% over the two-year study. Table 5.2 details the behavior of students regarding their career intentions for 2009 and 2011. A significant number of students intending towards a given STEM field in 2009 selected away from a STEM field in 2011. Of those intending to major in computers and mathematics in 2009, only 94 (26.9%) students were consistent with that choice in 2011. However, some of those who had previously shown no interest in STEM (244 students) selected into computers/mathematics in 2011. There is an increase in students interested in computers/mathematics, architecture/engineering, and health, which bodes well for STEM major selection. Table 5.3 summarizes the transitory behavior of students between years.

5.3.1 *Relationship Between Motivation Variables and STEM Career Intention*

When investigating the relationship between the motivational factors and career intentions, it is important to consider the reverse-coding of some factors as is evident in the mean values of some, as they appear in Table 5.3 with negative signs. Not surprisingly, Stayers tended to maintain a positive view of mathematics (and science) over the two years studied. Leavers initially showed positive ratings in 2009, but then dropped significantly by 2011, while Newcomers initially had negative ratings in 2009, but then increased significantly by 2011 (see Table 5.4). Specifically, non-STEM intending students dropped in their ratings of Identity and Interest over the two years, while increasing in ratings of Utility and Self-Efficacy. Leavers, as expected, dropped across all motivation variables between 2009 and 2011. Newcomers, as

Table 5.2 Percentages of students selecting STEM fields as potential occupation at age 30 in 2009 versus in 2011

	2011						Row total 2009
	No preference listed	Comp/Math	Arch/Eng	Phys/Bio	Health		
2009	No Pref (~ STEM)	13,056 (79.0%)	244 (1.5%)	662 (4.0%)	527 (3.2%)	2138 (12.9%)	16,627
	Computer/Math	210 (60.0%)	94 (26.9%)	19 (5.4%)	6 (1.7%)	21 (6.0%)	350
	Architect/Engineer	523 (50.5%)	33 (3.2%)	363 (35.1%)	25 (2.4%)	91 (8.8%)	1035
	Physics/Bio Sci	618 (58.6%)	17 (1.6%)	43 (4.1%)	208 (19.7%)	169 (16.0%)	1055
	Health profession	1877 (43.2%)	24 (0.6%)	82 (1.9%)	172 (4.0%)	2193 (19.7%)	4348
Column total 2011		16,284	412	1169	938	4612	23,415

Table 5.3 Student transition behavior between 2009 and 2011

	No Preference Listed	Comp/Math	Arch/Eng	Phys/Bio	Health	Total
Total STEM intending 2009						6788
Total switching within STEM fields		168 (2.4%)	507 (7.5%)	411 (6.1%)	2474 (36.4%)	3650
Total leaving STEM (leavers)						3228
Total switching into STEM (newcomers)	3571					
Total STEM intending 2011						7131

expected increased across all motivation variables between 2009 and 2011. Stayers are a bit more random: They decreased slightly in mathematics identity, but increased slightly in science Identity over the two years, increased in utility in both subject areas, increased in Self-Efficacy and decreased in Interest for both mathematics and science.

Effort, interestingly decreased across all categories of students, and was especially low for non-STEM intending and Leavers. Some of this has to do with differences in mathematics and science attitudes and behaviors, compared with those for general academics, but it is also likely (though not testable with this data) that effort in mathematics and science decreased over the same period, in order to reach such a low negative value.

5.3.2 Volatility of STEM Career Intentions

One question that kept arising in examining the data across years was, “why is there so much volatility in students’ career intentions over just two years in high

Table 5.4 Means and standard deviations for motivation factors by STEM Intention

Motivation factor STEM intent	Mathematics		Science	
	2009 Mean (S)	2011 Mean (S)	2009 Mean (S)	2011 Mean (S)
<i>Identity</i>				
~STEM	−1.07 (2.77)	−1.60 (3.26)	−1.14 (2.78)	−1.73 (3.24)
Leavers	0.05 (1.35)	−2.05 (3.69)	0.18 (1.39)	−2.07 (3.69)
Newcomers	−1.34 (3.25)	0.03 (1.63)	−1.38 (3.22)	0.10 (1.67)
Stayers	0.30 (1.22)	0.22 (1.51)	0.038 (1.35)	0.43 (1.58)
<i>Utility</i>				
~STEM	−1.86 (3.33)	−1.63 (3.27)	−2.38 (3.49)	−1.64 (3.27)
Leavers	−0.65 (2.43)	−2.12 (3.66)	−0.96 (2.88)	−2.12 (3.66)
Newcomers	−1.98 (3.49)	−0.05 (1.67)	−2.46 (3.65)	−0.05 (1.67)
Stayers	−0.51 (2.39)	0.06 (1.60)	−0.76 (2.88)	0.07 (1.67)
<i>Self-efficacy</i>				
~STEM	−1.89 (3.37)	−1.67 (3.36)	−2.34 (3.54)	−1.79 (3.42)
Leavers	−0.67 (2.46)	−2.14 (3.70)	−1.06 (2.46)	−2.25 (3.76)
Newcomers	−1.99 (3.59)	−0.14 (1.93)	−2.42 (3.70)	−0.15 (1.97)
Stayers	−0.40 (2.39)	0.03 (1.73)	−0.81 (2.84)	−0.02 (1.94)
<i>Interest</i>				
~STEM	−2.02 (3.47)	−2.63 (3.72)	−2.50 (3.61)	−3.24 (3.79)
Leavers	−0.77 (2.67)	−2.83 (3.88)	−1.13 (3.01)	−3.27 (3.91)
Newcomers	−2.11 (3.65)	−1.07 (3.00)	−2.54 (3.74)	−1.53 (3.33)
Stayers	−0.53 (2.60)	−0.85 (2.91)	−0.93 (2.99)	−0.98 (3.10)
<i>Effort^a</i>				
~STEM	2.02 (0.69)	−2.53 (3.67)	–	−3.14 (3.79)
Leavers	1.98 (0.66)	−2.72 (3.86)	–	−3.19 (3.91)
Newcomers	1.95 (0.66)	−0.97 (2.87)	–	−1.48 (3.24)
Stayers	1.79 (0.62)	−0.74 (2.80)	–	−0.96 (2.99)

All $p < 0.01$

^aEffort (2009) reported here is general academic effort, not subject specific

school?” Patterns in the motivation data across categories of STEM intention show that there are significant differences in motivations corresponding to changes in students’ career intentions, but the reasons behind those correspondences is unclear. As an ad hoc analysis, we decided to examine if there might be any underlying relationships between motivation variables that could point to particular changes (e.g., lowering of self-efficacy, or increase in interest) that could explain the movement of students from STEM intending to Non-Intending or vice versa.

Table 5.5 Principal components scores for motivation variables by year

Variable	Component	
	1	2
<i>2009</i>		
Math identity	0.190	0.753
Math utility	0.221	0.809
Math self-efficacy	0.252	0.806
Math interest	0.247	0.794
Science identity	0.177	0.752
Science utility	0.238	0.798
Science self-efficacy	0.252	0.795
Science interest	0.253	0.787
<i>2011</i>		
Math effort	0.773	−0.120
Science effort	0.739	−0.080
Math identity	0.877	−0.220
Math utility	0.856	−0.230
Math self-efficacy	0.848	−0.207
Math interest	0.776	−0.118
Science identity	0.864	−0.218
Science utility	0.852	−0.249
Science self-efficacy	0.834	−0.206
Science interest	0.743	−0.084

To examine these relationships, we performed Principle Components Analysis (PCA) on each of the mathematics and science-related scale scores for each respondent. This analysis extracted two significant components accounting for close to 65% of the total variation in the data. When the scale scores of all the motivational variables in the dataset are correlated with these two “true” principle components, we see that they fall out clearly by year. The Principle Component scores presented in Table 5.5 show that students’ motivations in 2009 are closely related to each other, but these 2009 motivations are only weakly associated with the same variables in 2011. What does this mean? Essentially, it may suggest that students’ motivations are highly located in the moment. Their experiences in mathematics and science in one year may not be related strongly to their experiences in another year, and their motivations, being tied to the experiences at hand, seem to be highly unstable. Indeed, when Pearson correlations are computed for these variables across years, *none* of the 2009 scale scores correlates strongly with *any* of the 2011 scores (no correlations showed a magnitude greater than 0.20). See Table 5.6.

Table 5.6 Pearson correlations among motivation variables by year and subject

Math	2009					2011				
	Id 09	Util 09	Eftr 09	Int 09	Eftr 09	Id 11	Util 11	Eff 11	Int 11	Eftr 11
Id 09	1	0.61	0.63	0.60	0.78	0.18	0.12	0.12	0.10	0.07
Util 09	0.61	1	0.86	0.81	0.58	0.11	0.10	0.07	0.10	0.06
Eftr 09	0.63	0.86	1	0.82	0.58	0.14	0.09	0.09	0.11	0.17
Int 09	0.60	0.81	0.82	1	0.60	0.13	0.10	0.09	0.12	0.14
Eftr '09	0.78	0.58	0.58	0.60	1	0.07	0.06	0.07	0.04	0.04
Id '11	0.18	0.11	0.14	0.13	0.07	1	0.57	0.44	0.30	0.24
Util 11	0.12	0.10	0.09	0.10	0.06	0.57	1	0.37	0.25	0.22
Eftr 11	0.12	0.07	0.09	0.09	0.04	0.44	0.37	1	0.39	0.29
Int 11	0.10	0.10	0.11	0.12	0.04	0.30	0.25	0.39	1	0.80
Eftr 11	0.07	0.06	0.17	0.14	0.04	0.24	0.22	0.29	0.80	1

Science

Id 09	1	0.55	0.55	0.53	0.76	0.15	0.07	0.10	0.11	0.06
Util 09	0.55	1	0.89	0.85	0.50	0.10	0.06	0.07	0.15	0.07
Eftr 09	0.55	0.89	1	0.85	0.49	0.11	0.06	0.08	0.16	0.06
Int 09	0.53	0.85	0.85	1	0.53	0.10	0.06	0.08	0.15	0.04
Eftr 09	0.76	0.50	0.49	0.52	1	0.06	0.07	0.06	0.04	0.04
Id 11	0.15	0.10	0.11	0.10	0.11	1	0.48	0.43	0.30	0.26

(continued)

Table 5.6 (continued)

Math	2009				2011			
	Id 09	Util 09	Efft 09	Int 09	Efft 09	Id 11	Util 11	Efft 11
Util 11	0.07	0.06	0.06	0.06	0.15	0.48	1	0.35
Efft 11	0.10	0.07	0.08	0.08	0.16	0.43	0.35	1
Int 11	0.11	0.15	0.16	0.15	0.16	0.30	0.21	0.34
Efft 11	0.12	0.15	0.16	0.16	0.05	0.26	0.20	0.26

Id Identity, Util Utility, Efft Efficacy, Int Interest, Efft Effort

Note: All bolded correlations are significant, $p < .05$

5.4 Discussion

Results show clearly that US high schoolers typically change their career intentions between grade 9 and 11. This two-year period is one of high volatility, with people originally STEM intending no longer remaining interested, while others not originally STEM intending beginning to see STEM as a potential future pathway. Motivationally, the interest, identity, and beliefs about utility and efficacy of these Leavers and Newcomers reflect their changing views towards mathematics and science subject matter. Leavers tended to grow more disillusioned with STEM, while Newcomers tended to grow more enamored. These two years are critical for STEM student cultivation, and special attention should be taken in the development of curriculum for them such that STEM fields remain an attractive career option to reduce attrition and potentially increase the number of students that gravitate towards them.

Our results are consistent with those of Sadler et al. (2012), who also found that STEM career intention is highly volatile over the high school years. Like us, they found that “By far the most dominant factor influencing engineering or science career interest at the end of high school is student interest at the start of high school” (p. 422), although we also found Utility to be a strong predictor, and the others to be significant predictors of STEM intention. Their data, however, is retrospective survey data of college-level students, and their recollections of their early high school attitudes and interests may be colored by their more recent experiences. Nevertheless, together these studies show that volatility is the norm, and that loss of students’ interest in STEM during this period is a serious roadblock for students’ continued STEM career pathways.

The role of mathematics motivations specifically is more muddled. Wang (2013) showed that intent to major in STEM is strongly related to exposure to (more advanced) mathematics and science courses, and math self-efficacy beliefs. In our own study, the relatively disconnected motivations between students’ first year and their 3rd year of high school, and the disconnect between subjects would indicate that students’ college major and career intentions are changing during this period, and that potential career pathways are becoming more solidified by the end of their 3rd year. This makes sense, as students in the United States often have options for more advanced, “College-Preparatory” courses such as Advanced Placement Calculus and Physics in their 3rd and 4th year of high schools, and if interest, effort, utility beliefs and self-efficacy plummet in this period, it is likely that academic performance and the ability to enroll in such courses is likewise curtailed, limiting students’ options for future careers.

In practical terms, we speculate that students’ experiences in mathematics and science coursework greatly determine their motivations towards that subject matter, and subsequently towards the amount of effort they are willing to expend, and ultimately the extent to which a career in a STEM field might be considered a possibility. It is likely that Leavers who had initially positive STEM experiences in the elementary and middle grades may have confronted difficulties in early high school that convinced them to be less enamored with STEM and potential STEM-related

careers. Likewise, Newcomers may have encountered excellent teachers, or mentors in extracurricular activities, and changed their beliefs for the better. There may have been opportunities for some students to take courses that had a strong effect on their beliefs and intentions. Physics has a particularly strong effect on students' intentions to major in a STEM field, as Bottia et al. (2015) uncovered in their research, as students' experiences in physics class tend to influence a student's opinion of STEM as a whole. Or there may be an issue of how the curriculum is written, explained in textbooks, or the methods by which it is taught. There is even the possibility that the reasons behind them are entirely social in nature, given the stereotype of the high school years as an important and influential time for a student's life. More research must be done in this vein to determine if the factors behind the interest change are more easily controllable through education.

Moreover, the fact that there is a general decrease in Interest, Identity, Self-Efficacy and Utility for Leavers, and a general increase across these variables for Newcomers indicates that whatever experiences students may have had in between the time in which they enrolled in High School, and the beginning of their third year, these experiences are interpreted, motivationally, through these variables. Middleton (2013) shows that these variables are highly interconnected in predicting mathematics performance in high school, and that Utility in particular plays an important role in connecting Interests and Achievement, while Self-Efficacy is critically implicated in predicting Identity. As Wang (2013) found in her research, Self-Efficacy produces strong effects on STEM interests and STEM choice, Math Self-Efficacy especially. Examining the results of her study and this one, one can follow the connection between Math Self-Efficacy and STEM intention through Math Identity. In short, relatively short-term motivations appear to greatly impact career aspirations. An effort should be made to make STEM curricula continuously attractive in new ways throughout a student's high school education, given the volatility of STEM career intentions. It is as-of-yet unclear how robust students' career aspirations remain following the first couple of years of high school, but given the ease with which students shift from one category to another, one should consider it to be far less robust than is desirable. As the HSLs study continues through transcript studies and follow-up after students graduate high school, we will be able to augment these analyses with (hopefully) some predictive models of career transition.

The fact that Leavers, Newcomers, and Stayers made up equal proportions of students in the nationally representative sample means that there was only small increase in overall STEM intending numbers between 2009 and 2011. Instead of growing stability, these developmental years show tremendous volatility in career choices, and the extent to which mathematics and science experiences in those years influence this volatility is a hypothesized mediating variable. More research must be done to establish key factors in curriculum and instruction, as well as social norms and expectations of family and community, to paint a fuller picture of why many students choose to continue with rigorous STEM coursework and why most do not (see Froiland & Davison, 2016). Given the importance of consistent STEM intent for predicting actual STEM occupations after college, it is highly likely that little net increase in the STEM workforce is upcoming in the near future in the US.

References

- Adelman, C. (1998). *Women and men of the engineering path: A model for analyses of undergraduate careers*. US Government Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, D.C., 20402-9328.
- Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing in mathematics worlds. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (Vol. 1, pp. 171–200). Westport, CT: Greenwood.
- Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational behavior*, 23(3), 329–345.
- Bottia, M. C., Stearns, E., Mickelson, R. A., Moller, S., & Parker, A. D. (2015). The relationships among high school STEM learning experiences and students' intent to declare and declaration of a STEM major in college. *Teachers College Record*, 117(3), 1–46.
- Cass, C. A., Hazari, Z., Cribbs, J., Sadler, P. M., & Sonnert, G. (2011, October). Examining the impact of mathematics identity on the choice of engineering careers for male and female students. In *Frontiers in Education Conference (FIE)* (pp. F2H-1). IEEE.
- Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). A retrospective analysis of stem career interest among mathematics and science academy students. *International Journal of Learning, Teaching and Educational Research*, 10(1). Available Online: <http://www.ijlter.org/index.php/ijlter/article/view/226>.
- Diekmann, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science*, 21(8), 1051–1057.
- Froiland, J. M., & Davison, M. L. (2016). The longitudinal influences of peers, parents, motivation, and mathematics course-taking on high school math achievement. *Learning and Individual Differences*, 50, 252–259.
- Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education*, 20(3), 261–273.
- Harackiewicz, J. M., Barron, K. E., Tauer, J. M., Carter, S. M., & Elliot, A. J. (2000). Short-term and long-term consequences of achievement goals: Predicting interest and performance over time. *Journal of Educational Psychology*, 92(2), 316.
- Husman, J., & Hilpert, J. (2007). The intersection of students' perceptions of instrumentality, self-efficacy, and goal orientations in an online mathematics course. *Zeitschrift für Pädagogische Psychologie*, 21(3/4), 229–239.
- Lent, R. W., Lopez, F. G., & Bieschke, K. J. (1991). Mathematics self-efficacy: Sources and relation to science-based career choice. *Journal of Counseling Psychology*, 38(4), 424.
- Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy. *Journal of Engineering Education*, 98(1), 27–38.
- Middleton, J. A. (2013). More than motivation: The combined effects of critical motivational variables on middle school mathematics achievement. *Middle Grades Research Journal*, 8(1), 77–95.
- Middleton, J. A., Jansen, A., & Goldin, G. A. (2017). The complexities of mathematical engagement: Motivation, affect, and social interactions. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 87–119). Reston, VA: National Council of Teachers of Mathematics.
- National Center for Education Statistics. (2011). *High school longitudinal study of 2009 (HSLS:09). Base year data file documentation*. Washington, D.C.: NCES. Available Online: http://nces.ed.gov/surveys/hsls09/pdf/2011328_1.pdf.
- Priess-Groben, H. A., & Hyde, J. S. (2017). Implicit theories, expectancies, and values predict mathematics motivation and behavior across high school and college. *Journal of Youth and Adolescence*, 1–15.
- Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*, 96(3), 411–427.

- Suárez-Álvarez, J., Fernández-Alonso, R., & Muñiz, J. (2014). Self-concept, motivation, expectations, and socioeconomic level as predictors of academic performance in mathematics. *Learning and Individual Differences*, 30, 118–123.
- US Bureau of Labor Statistics. (2010). *2010 SOC user guide*. Washington, D.C.: US Bureau of Labor Statistics.
- VanLeuvan, P. (2004). Young women's science/mathematics career goals from seventh grade to high school graduation. *The Journal of Educational Research*, 97(5), 248–268.
- Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and post-secondary context of support. *American Educational Research Journal*, 50(5), 1081–1121.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.