JOURNAL OF CHEMICAL EDUCATION

Article

pubs.acs.org/jchemeduc

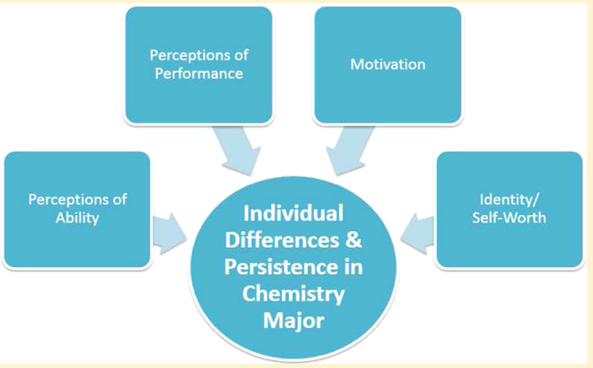
Who Leaves, Who Stays? Psychological Predictors of Undergraduate Chemistry Students' Persistence

Randi Shedlosky-Shoemaker*,† and Jessica M. Fautch‡

†Department of Behavioral Sciences and ‡Department of Physical Sciences, York College of Pennsylvania, York, Pennsylvania 17403, United States

Supporting Information

ABSTRACT: The number of undergraduate students completing degrees in STEM disciplines has been declining over the last few decades. With a growing body of research considering what predicts persistence in STEM fields, one approach is to consider individual differences as predictors of attrition in the major. The current study utilized a variety of individual difference measures related to perceptions of ability and performance, motivation, and identity as predictors of which undergraduate students would change from the initially declared chemistry major within their first two years. Results indicated that students who left the chemistry major tended to have higher self-doubt and greater desire to avoid failure (i.e., performance-avoidance orientation). Additionally, the degree to which competition and academic competence impacted participants' self-worth related to persistence. Results are discussed in the context of the growing body of research linking individual differences to student persistence in STEM.



KEYWORDS: *First-Year Undergraduate/General, Second-Year Undergraduate, History/Philosophy, Chemical Education Research, Testing/Assessment, Student/Career Counseling*

FEATURE: Chemical Education Research

BACKGROUND

In the past decade, concern regarding the number of students studying science, technology, engineering, and math (i.e., STEM) fields has grown. Fewer undergraduate students declare STEM[1] majors, and of those who do, around half leave the major by their second year, moving to either non-STEM fields or forgoing completion[2] of a degree. Numerous studies[3−7] have considered how gender and race relate to persistence in STEM majors. Still other studies[4,5,8−11] suggest that students with poorer academic performance, either previously in high school or early in college, may struggle most in STEM majors. More recently, a growing body of research is considering individual differences as predictors of persistence. Expanding on the approach of looking at students' ability and performance, some studies have considered that students' perceptions of their ability and performance may be meaningful. For example, previous research has found that students who feel less confident are more inclined to leave a STEM major.[12−15] Likewise, students who left a STEM major more often reported feeling discouraged following low grades as compared to those students who persisted in the major (i.e., 34% to 12%, respectively).[16]

Students' persistence may also be driven by motivation: students who found STEM fields intrinsically interesting, enjoyable, or valuable[9,12] stayed; although some research[16] suggests that many students who persisted in their STEM major experienced shifting interests (i.e., declining interest in STEM field or increasing interest in another field), suggesting that a decline in interest did not necessarily prompt change. At a broader level, male students driven by a desire to master knowledge were more likely to persist in a STEM field.[17] Finally, students' construction of their identity and self-worth may play a role. Students who perceived science as less central to their identity may be more readily swayed to a non-STEM major.[14,17]

CURRENT HYPOTHESES

The current study considers whether individual differences related to perception of ability and performance, motivation, and identity and self-worth, as measured at the beginning of students' undergraduate career, predict persistence in the chemistry major over two years. We do not expect that such individual differences predetermine one's choice to change majors, particularly as other social and structural factors also play a role in the decision. Regardless, based on previous research,[9,12−17] individual differences should be related to that choice. Additionally, individual differences can change over time; however, it is important to understand the relation between students' starting point and the outcome of their decision to pursue the chemistry major (i.e., persist or switch)

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX

for the possibility of improving the students' academic experiences.

Perceptions of Ability and Performance

Given that previous research identified confidence as a predictor of persistence,[12−15] we expected that students who changed majors would have initially reported higher self-doubt, or questioning of their academic ability[18] and would be more likely to perceive intelligence as fixed (i.e., entity theorists[19]). Such entity theorists may perceive any experience of difficulty as a sign that they lack ability and, believing ability is unchangeable, they leave the major. Feelings of discouragement following low grades may prompt some students to change majors.[16] Subsequently, we expected that students who changed majors would initially report a greater focus on performance (i.e., performance-approach or performance-avoidance orientation[20]) and report more concern about their performance.[18]

Motivation

Some students may be more driven to conquer challenging material.[17] Thus, we expected that students who changed majors would initially report less mastery-orientation, or less desire to understand the content of their major,[20] as well as a lower need for cognition or less inclination to seek-out and enjoy effortful thought.[21] Further, we anticipated that students who changed majors would initially report lower intrinsic motivation to study their major, as determined by five different variables:[22] lower perceived choice, greater feelings of pressure, lower intentions to invest effort, lower perceived major-related competence, and lower value of the major.

Identity and Self-Worth

In the construction of their identity, or sense of self, students may vary in how much they value different experiences;[17] such values may contribute to their persistence in related domains. For example, we expected that students who changed majors would initially report that science was less central to their identity.[14,23] Similarly, though, students may draw their self-worth from different sources.[24] We expected that students' weighting of competition, academic competence, approval from others, and family support would be most relevant to their academic decisions; however, we were not certain as to the direction of the relationship and, thus, made no specific hypotheses regarding what students who left the major would report at the start of the academic year.

RESEARCH METHODS

Research Design

The study used a correlational design, surveying the population of incoming first-semester chemistry students to examine what factors may relate to a later decision to leave the chemistry major. Quantitative data were collected from self-reported measures (described below) as well as academic records.

Participants

Of the 38 students within the population of incoming first-semester chemistry students in Fall 2012, 35 completed the survey (92%). There were 16 males and 17 females, with 2 students not indicating gender. Most reported that they were Caucasian (n = 26, 74%), with 3 not indicating race.[25] First-generation students accounted for 31% of the sample (n = 11), and 91% of participants self-identified as traditional students, defined to participants as having attended college continuously after completing high school (n = 32). Students declared as chemistry (34%), forensic chemistry (51%), or medical laboratory science (14%) majors. As part of the informed consent, 32 participants gave permission to the researchers to access their academic records through the registrar. Participants received a $5 bookstore gift card as an incentive for completing the survey.

Procedure

After receiving IRB approval, we recruited participants through advising orientation at the start of the semester. They received a link for the online survey, which they could complete at the end of the afternoon advising session in a computer lab or on their own at any time during their first week of school. Participants who completed the survey on their own could complete it at their own pace and had the opportunity to finish it in multiple sittings.

Outcome Measures

To measure students' persistence, student status was recorded at the end of their second year: still in the major (i.e., "persister"), in a new major (i.e., "switcher"), or no longer at the college (i.e., "leaver").

Predictor Variables

Social Influences. Participants were provided a list, generated by the researchers, of people (i.e., family and friends, college professors/advisors, high school teachers, other teachers outside of high school or college, guidance/career counselors, and media figures) and were asked to indicate whether anyone from each group influenced their decision to pursue the major.

Intentions in the Major. Based on the investment model,[26] four single-item statements were developed to measure satisfaction with the participants' current major, feeling of investment in their current major, perceived availability of appealing alternatives (academic or otherwise), and level of commitment to current major. The investment model[26] suggests that the former three variables predict the fourth, which in turn predicts persistence, albeit in interpersonal relationships. Additionally, to measure participants' own forecasting of their likelihood to persist, three single-item statements were developed, requiring participants to rate likelihood of completing their current major, a bachelor's degree, and a graduate degree (master's or higher).

Individual Differences. Measures were selected from previously validated scales. Scores for all scales and subscales were calculated by taking a mean score based on responses to all items. Scale ranges and reliability for all measures are included in the Supporting Information.

Subjective Overachievement Scale. The subjective over-achievement scale[18] includes two subscales. The eight-item self-doubt subscale focuses on uncertainty about ability (e.g., "More often than not I feel unsure of my abilities"), including feelings about the implications of failure vs success (e.g., "For me, avoiding failure has a greater emotional impact [e.g., sense of relief] than the emotional impact of achieving success [e.g., joy, pride]") and lack of understanding how outcomes are achieved (e.g., "Sometimes I feel that I don't know why I have succeeded at something"). The nine-item concern for performance subscale focuses on desire to achieve a successful outcome or avoid a failure (e.g., "It is important that I succeed in all that I do"; "Failure is unacceptable to me", reverse-scored).

Implicit Theory of Intelligence. The three-item measure of implicit theory of intelligence[19] measures whether individuals

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX

see intelligence more as a fixed entity (i.e., entity theorists) or as a flexible, changing ability (i.e., incremental theorists).

Achievement Goal Orientation. The achievement goal orientation inventory[20] includes three subscales, which describe different motivations related to achievement: performance-approach goals (six items, e.g., "I am motivated by the thought of outperforming my peers in my classes"), performance avoidance goals (five items, e.g., "I just want to avoid doing poorly in my classes"), and mastery goals (six items, e.g., "I prefer course material that really challenges me so I can learn new things").

Need for Cognition. The need for cognition brief scale[21] includes 18 items aimed at gauging participants' desire to seek out and tendency to enjoy activities that require a great deal of thinking (e.g., "I only think as hard as I have to", reverse-scored).

Intrinsic Motivation Inventory. Broadly, intrinsic motivation describes an internal drive or desire to complete a task. The intrinsic motivation inventory[22] identifies several factors related to intrinsic motivation. We adapted the items on the subscales of the inventory to be relevant to participants' majors: perceived choice (seven items, e.g., "I felt like it was not my own choice to pursue my current major"), pressure/tension experienced while doing the activity (five items, e.g., "I feel very relaxed about my performance in my current major", reverse-scored), planned effort (five items, e.g., "I plan to try very hard in my current major"), perceived competence (six items, e.g., "I feel pretty competent regarding my ability to do well in my major classes"), and value/usefulness (seven items, e.g., "I think my current major is important to pursue because it can help me in the future").

Science Self-Concept. Students' self-concept may vary in what domains they see as defining of themselves, and which aspects are less relevant to their identity. Adapted from the chemistry self-concept scale,[23] the 10-item scale measures students' perceptions of themselves as "learners of science" (e.g., "I find science concepts interesting and challenging").[27]

Self-Contingencies. Self-contingencies describe internal and external sources of self-esteem. For instance, someone with a self-esteem contingent on academic competence will experience self-esteem increases and decreases as a result of academic outcomes (e.g., grades), whereas someone who lacks this contingency will not experience changes in self-esteem following the same outcomes. The self-contingencies scale[24] includes several subscales aimed at measuring the internal and external sources that influence individuals' self-esteem. The subscales were included for competition (five items, e.g., "I feel worthwhile when I perform better than others on a task or skill"), academic competence (five items, e.g., "My opinion about myself isn't tied to how well I do in school", reverse-scored), approval from others (five items, e.g., "I don't care if other people have a negative opinion about me", reverse-scored), and family support (five items, e.g., "Knowing that my family members love me makes me feel good about myself").

Survey Checks

At five random points during the survey, participants were asked to indicate a specific response (i.e., "To ensure that you are paying attention as you complete these questions, select...").

Secondary Measures. Though not the primary focus of our study, for students who granted permission to access their academic records, we attempted to record gender, race/ethnicity, and a variety of academic measures described below. All records were not necessarily available for all participants; when data were not available, those participants were not included in the specific analyses.

Academic Preparation Measures. To assess preparation for the major, students' high school GPA, rank, and SAT scores (composite, math, and verbal) were collected through the registrar. Additionally, students self-reported their previous experience with math and science by indicating which classes they had taken from a list of common areas of math and science. Finally, they self-reported whether they had credit for any Advanced Placement (AP) or College-Level Examination Program (CLEP) STEM-related courses from a provided list.

Academic Performance Measures. To assess academic performance, students' first and second semester GPAs, as well as cumulative GPA, were recorded. Performance in two required major courses taken during the first semester, CHM130 (First Year Colloquium) and CHM134 (General Chemistry I), was also recorded. The purpose of CHM130, which brings incoming chemistry majors together, is to discuss issues and skills related to being successful in the chemistry major and field. The purpose of CHM134 is to introduce chemistry, biology, and engineering students to the basics of chemistry and, thus, is more content-based. Finally, warning grades during their first semester were recorded; these grades are assigned at the midpoint of the semester to students earning less than 70% in the class. It was noted whether the warning grades were in STEM-related classes (i.e., math or science) or non-STEM classes (e.g., writing).

Data Analysis

Data analyses were conducted using SPSS. First, participants were divided into three groups: "persisters" remained in the chemistry program during the entire two year period; "switchers" changed to a nonchemistry major; and "leavers" left the college. Switchers included students who switched to other STEM majors as well as non-STEM fields. An analysis of variance (ANOVA) was conducted using group as a between-subject variable to identify differences on continuous variables. When statistically significant differences appeared, Fisher's least significant difference (LSD) post-hoc test was used to identify which of the groups differed from one another. For categorical variables, including program of study and social influence, Fisher Exact Test was used to identify differences between groups. Finally, a multinomial logistic regression analysis was conducted to predict whether students would persist in the major, switch majors, or leave the college using variables that were identified as differing between groups. Statistically significant findings ($p < 0.05$) are presented; a full report of results, along with reliability of measures, can be found in the Supporting Information.

RESULTS

Descriptive Statistics

Outcome Variables. Looking at student persistence, 10 participants (29%) were persisters, 10 (29%) were switchers, and 15 (43%) were leavers.[28] The loss of 71% of initial chemistry majors is well above NSF's report of a 53% loss in STEM cohorts from 1994 to 2000.[2] Our study's observed two-year retention rate of 58% (combining persisters and switchers) was slightly lower than the college's overall two-year retention rate of 63% and was in line with the two-year retention among all STEM majors at the college (59%).[29] Additionally, the percentage of switchers in the sample was higher than the

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX

overall number of switchers at the college (approximately 20% during the first two years of college).

Survey Completion. Twenty-five (71%) participants chose to complete the survey at the end of the advising session; for these students, completing the survey in a single-sitting took between 14 and 29 min (M = 21.84, SD = 4.24). For the remaining 10 participants who completed the survey on their own, they took between 25 min and 10 h 18 min (M = 121.10, SD = 181.59), suggesting that many did not complete the survey in a single sitting. A Fisher Exact Probability test revealed that switchers and leavers were more likely to complete the survey in the group following the advising sessions, while persisters were equally likely to complete the survey in the group or on their own (p = 0.05; Table 1). All participants correctly answered all five survey checks.

Table 1. Completion of Survey

	n		
Completion of Survey	Persisters	Switchers	Leavers
Completed survey in group	4	9	12
Completed survey on own	6	1	3

Differences among Persisters, Switchers, and Leavers

Program of Study. A Fisher Exact Probability test revealed that no single major was more vulnerable to participants changing their major or leaving the college (p = 0.46; Table 2).

Table 2. Number of Students in Each Program of Study

	n		
Program of Study	Persisters	Switchers	Leavers
Chemistry	2	4	6
Forensic Chemistry	5	6	7
Medical Laboratory Science	3	0	2

Of the four chemistry major switchers, three (75%) changed to biology and the remaining student switched to public relations. Of the six forensic chemistry switchers, three (50%) changed to criminal justice and the other three switched to psychology, finance, and hospitality.

Intentions in the Major. Persisters, switchers, and leavers did not differ in their rating of satisfaction with the major, level of investment, availability of appealing alternatives, and level of commitment to the major (p > 0.15). Further, no statistically significant differences emerged between the three groups on estimates of likelihood to complete the current major, complete a bachelor's degree, or complete a graduate degree (p > 0.25).

Social Influences. In deciding to pursue their initial major, switchers reported feeling influenced by more sources of social influence (M = 3.80, SD = 1.87) than persisters (M = 2.31, SD = 1.58; p = 0.02) or leavers (M = 2.10, SD = 1.37; p = 0.01), F(2, 44) = 4.29, p = 0.02, η_p^2 = 0.16; the two latter groups did not differ from one another (p = 0.68). In particular, switchers appeared more likely to be encouraged by guidance counselors (80%) than persisters (20%) or leavers (40%), p = 0.03.

Individual Differences. Most scales demonstrated acceptable reliability (Cronbach's α > 0.70); all scale reliabilities are included in the Supporting Information. Statistically significant results are presented in Table 3. Switchers tended to begin their academic career with higher self-doubt and greater performance-avoidance orientation (i.e., desire to avoid failure) than either persisters or leavers (p < 0.05). Persisters reported lower self-contingency related to competition, as compared to both switchers and leavers. Leavers reported higher self-contingency related to academic competence, as compared to persisters, though not switchers (p < 0.05). All other individual difference measures did not vary based on student persistence (p > 0.05).

When entering the four individual differences that appeared to differ across the three groups into a multinomial logistic regression analysis, the overall model reached statistical significance, $\chi^2(34)$ = 50.61, p = 0.03. However, self-contingency related to competition emerged as the only statistically significant predictor of categorization as a persister, switcher, or leaver, $\chi^2(10)$ = 26.90, p = 0.003.

Secondary Measures. A Fisher Exact Probability test revealed no statistically significant gender or racial differences among persisters, switchers, and leavers (p > 0.10).[31] Whether students described themselves as traditional vs nontraditional students and whether they were first-generation or not was unrelated to persistence (p > 0.60). However, the sample included few students who identified as nonwhite (Black, n = 3; Hispanic, n = 3) or nontraditional students (n = 3).

Academic Preparation Measures. Switchers had the highest high school GPA, whereas persisters and leavers were similar on this measure (p < 0.05). In looking at rank, leavers were lower than both persisters and switchers, with the latter two groups not varying from one another (p < 0.05; Table 4). No significant differences emerged between the three groups on SAT scores (composite, math, and verbal), number of AP/CLEP credits earned, or number of science or math classes students previously had taken (F < 2.00, p > 0.20).

As high school GPA and rank differed across the three groups, we again performed a multinomial logistic regression analysis, this time including GPA, which was higher for switchers than persisters or leavers, with the four individual differences identified in Table 3. The overall model reached

Table 3. Comparison of Individual Differences at the Beginning of the First Year in College

		Mean Values (SD)			
Individual Difference Measures	Scale Reliability, Cronbach's α Values	Persisters, n = 10	Switchers, n = 10	Leavers, n = 15	F-Test Values, Effect Size
Self-Doubt[a]	0.83	2.98 (0.51)	3.98 (0.99)	3.16 (0.85)	$F(2,32)$ = 4.41, p = 0.02, η_p^2 = 0.22
Performance-Avoidance Orientation[b]	0.78	2.74 (0.77)	4.02 (0.47)	3.20 (1.04)	$F(2,32)$ = 6.00, p = 0.01, η_p^2 = 0.27
Self-Contingency: Competition[c]	0.86	3.80 (1.10)	4.86 (1.16)	5.01 (1.01)	$F(2,32)$ = 4.12, p = 0.03, η_p^2 = 0.21
Self-Contingency: Academic Competence-Revised[30]	0.78	4.14 (0.77)	4.52 (0.66)	4.81 (0.43)	$F(2,32)$ = 3.69, p = 0.04, η_p^2 = 0.19

[a]The scale values range from 1 (disagree very much) to 6 (agree very much). [b]The scale values range from 1 (not at all true of me) to 5 (very true of me). [c]The scale values range from 1 (strongly disagree) to 7 (strongly agree).

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX

Table 4. Comparison of Academic Preparation from High School

Academic Preparation Measures	Mean Values (SD)			F-Test Values, Effect Size
	Persisters, n = 8	Switchers, n = 8	Leavers, n = 10	
High School GPA out of 4.0	3.54 (0.49)	3.93 (0.29)	3.31 (0.24)	F (2, 23) = 6.91, p = 0.004, η_p^2 = 0.38
High School Rank out of 100	73.18 (19.45)	81.10 (8.22)[a]	58.93 (9.05)	F (2, 22) = 6.29, p = 0.01, η_p^2 = 0.36

[a] n = 7.

Table 5. Comparison of Academic Performance During the First Year in College

Academic Performance Measures	Mean Values (SD)			F-Test Values, Effect Size
	Persisters	Switchers	Leavers	
Number of First-Semester Warning grades, STEM; n = 9, 9, and 14	0.00 (0.00)	0.67 (0.50)	0.93 (1.00)	F(2,29) = 4.65, p = 0.02, η_p^2 = 0.24
Number of First-Semester Warning grades, All; n = 9, 9, and 14	0.00 (0.00)	0.67 (0.50)	1.21 (0.97)	F(2,29) = 8.19, p = 0.002, η_p^2 = 0.36
CHM130 Course grade out of 4.0; n = 7, 7, and 9	3.93 (0.19)	3.61 (0.42)	2.44 (1.31)	F(2,22) = 7.33, p = 0.004, η_p^2 = 0.40
CHM134 Course grade out of 4.0; n = 8, 8, and 11	3.19 (0.59)	2.86 (0.46)	1.27 (0.88)	F(2,23) = 20.07, p < 0.001, η_p^2 = 0.64
First-Semester GPA out of 4.0; n = 9, 9, and 12	3.18 (0.54)	2.91 (0.58)	1.93 (0.96)	F(2,27) = 8.26, p = 0.002, η_p^2 = 0.38
Second-Semester GPA out of 4.0; n = 9, 9, and 8	2.94 (0.66)	3.14 (0.45)	1.92 (1.37)	F(2,23) = 4.44, p = 0.02, η_p^2 = 0.28
First-Year GPA out of 4.0; n = 9, 9, and 8	3.06 (0.59)	3.11 (0.33)	2.19 (0.68)	F(2,23) = 7.29, p = 0.004, η_p^2 = 0.39

statistical significance, $\chi^2(36) = 72.98$, $p < 0.001$. Self-contingency related to competition remained a statistically significant predictor of categorization as a persister, switcher, or leaver, $\chi^2(8) = 18.08$, $p = 0.02$. Additionally, performance-avoidance orientation, $\chi^2(8) = 15.66$, $p = 0.05$, and high school GPA, $\chi^2(8) = 26.14$, $p = 0.001$, emerged as statistically significant predictors, and self-doubt was marginally significant, $\chi^2(6) = 12.00$, $p = 0.06$. When conducting the multinomial logistic regression analysis including rank, which was lower for leavers than persisters or switchers, with the four individual differences, the overall model reached statistical significance, $\chi^2(46) = 67.92$, $p = 0.02$; however, only rank was a statistically significant predictor, $\chi^2(16) = 26.43$, $p = 0.05$.

Academic Performance. Persisters and switchers generally outperformed leavers during the first year ($p < 0.05$; Table 5), with the exception of warning grades, for which switchers and leavers did not statistically differ ($p > 0.05$). It was observed that persisters did not receive any warning grades and switchers only received warning grades in STEM-related classes (i.e., math or science).

For each of the statistically significant measures of academic performance, we conducted a multinomial logistic regression analysis with the four individual differences identified in Table 3. When including number of first-semester warning grades in STEM classes, the overall model reached statistical significance, $\chi^2(38) = 81.30$, $p < 0.001$. Self-doubt, $\chi^2(8) = 19.10$, $p = 0.01$, both self-contingency measures (competition: $\chi^2(10) = 38.33$, $p < 0.001$; academic competence: $\chi^2(6) = 21.90$, $p = 0.001$), and number of STEM warning grades, $\chi^2(6) = 32.98$, $p < 0.001$, emerged as statistically significant predictors. When including number of first semester warning grades in all classes, the overall model reached statistical significance, $\chi^2(38) = 77.58$, $p < 0.001$. Both self-contingency measures (competition: $\chi^2(10) = 34.83$, $p < 0.001$; academic competence: $\chi^2(6) = 20.09$, $p = 0.003$) and number of total warning grades, $\chi^2(6) = 29.27$, $p < 0.001$, emerged as statistically significant predictors. The overall model with the CHM130 grade and the four individual differences did not reach statistical significance, $\chi^2(40) = 51.83$, $p = 0.10$, and though the overall model with the CHM134 grade and the four individual differences reached statistical significance, $\chi^2(40) = 56.15$, $p = 0.05$, no statistically significant predictors emerged ($p > 0.20$). When including first semester GPA, the overall model reached statistical significance, $\chi^2(44) = 86.35$, $p < 0.001$. Self-doubt, $\chi^2(8) = 26.99$, $p = 0.001$, both self-contingency measures (competition: $\chi^2(10) = 41.86$, $p < 0.001$; academic competence: $\chi^2(6) = 26.68$, $p < 0.001$), and first semester GPA, $\chi^2(12) = 41.23$, $p < 0.001$, emerged as statistically significant predictors. When including second semester GPA, the overall model reached statistical significance, $\chi^2(40) = 77.58$, $p < 0.001$. All four individual differences emerged as statistically significant predictors (self-doubt, $\chi^2(6) = 13.58$, $p = 0.04$; performance-avoidance, $\chi^2(8) = 23.81$, $p = 0.002$; self-contingency: competition: $\chi^2(10) = 30.90$, $p = 0.001$; and self-contingency: academic competence: $\chi^2(6) = 26.21$, $p < 0.001$). When including cumulative GPA, the overall model reached statistical significance, $\chi^2(40) = 72.04$, $p = 0.001$; although only self-contingency related to competition, $\chi^2(10) = 28.57$, $p = 0.001$, emerged as a statistically significant predictor.

DISCUSSION

The goal of the current study was to consider whether individual differences, including perceptions of ability and performance, motivation, and identity and self-worth, might predict who would leave the chemistry program. Within the context of perceptions of ability, as expected and similar to previous findings,[12−15] students who initially reported higher self-doubt appeared more likely to leave the major. Notably, this self-doubt was not specific to ability as a chemistry major, but rather ability in general. Further, this uncertainty about ability did not relate to objective measures of ability/performance collected in the study ($p > 0.10$), including those that differed for switchers. Similarly, regarding perceptions of performance, as expected, switchers initially reported a greater focus on performance, namely, avoiding a bad one. As with self-doubt, performance-avoidance orientation was unrelated to objective measures of ability/performance ($p > 0.20$).

Regarding motivation, contrary to expectations and previous research,[17] switchers did not appear to differ from persisters or leavers. Related to intrinsic motivation, switchers, as well as leavers, did not vary from persisters in their perceived value or usefulness of their major. It seems intuitive in recruiting students to a field to emphasize how useful that degree will be. Although it may be usefulness of the degree that attracts students to a major, based on the current findings, initial

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX

perceived value may not be sufficient in keeping students invested. Further, in relation to intrinsic motivation, though self-doubt was lower for switchers, perceived competence related to their chemistry major was not.

Regarding identity, contrary to expectations, the degree to which students perceived science as central to their identity did not appear to predict which students would leave the major. However, this may be because out of the 10 switchers, 3 went into a different STEM field (i.e., biology), suggesting they may still perceive science as related to their identity. Regarding self-worth, switchers, as well as leavers, appeared to have a higher self-contingency related to competition and academic competence, relative to persisters, suggesting that these two domains were more meaningful to their identity and self-worth. In comparing this finding with previous research,[16] given that the self-esteem of switchers and leavers may be more sensitive to competition and outcomes related to academic competence, they may also be more vulnerable to feeling demoralized in a competitive or academically challenging environment.

Other factors, such as academic preparedness, have been reported as predictors of success in STEM disciplines, with a range of outcomes. Math SAT scores, performance in high school chemistry, and performance on placement tests can potentially predict whether a college student will succeed in science.[32−37] Additionally, pedagogical technique and content-specific preparation (i.e., stoichiometry) have been coupled with persistence in STEM.[35,37] The current study did not identify academic preparedness but rather academic performance and several individual differences as predictors of persistence.

Limitations and Future Directions

The greatest limitation of the current study is its small single-institution sample, drawn from a medium-sized college. Though most incoming chemistry majors completed the survey and likely were representative of chemistry majors at the school, it is not certain that they would be representative of other STEM majors or of chemistry majors at larger institutions. The nature of the sample may in part explain the lack of observed gender and racial differences, despite previous research involving gender perceptions and differences in pursuing and persisting in STEM.[33,38−42] Further, the sample limits the study's ability to fully derive implications from the findings.

Another consideration is that students generally make decisions about which major they will pursue around the ages of 16−18. Though many of the chemistry majors did not persist in the path they selected at the start of their college career, this may in fact speak to a larger issue relevant to decision-making at this age. Thus, it is not clear based on the current study that the findings would be specific to only chemistry majors or, in fact, only STEM majors. A larger follow-up study is currently underway to include other STEM majors, as well as non-STEM majors and undeclared students, allowing for the ability to address some of the limitations above.

A further limitation of the study is its inability to consider how individual differences interact with other social and structural factors that may play a role in students' decision to stay in a major. For instance, in relation to previous work[16] suggesting switchers and persisters are equally likely to feel overwhelmed by the curriculum, to feel concerned that they are underprepared or unable to get assistance, and to struggle conceptually with STEM related subjects, it may be that self-doubt, performance-avoidance, and self-contingencies related to competition and academic competence magnify such concerns. Likewise, with previous research indicating that inadequate advising and poor teaching were concerns of many students (i.e., 75% and 90%, respectively) who changed out of a STEM major,[16] considering the interaction between individual differences and advising practices or pedagogy may be a valuable direction for future research. Finally, in considering that persisters' self-worth was less likely to be impacted by competition or outcomes relevant to academic competence, future studies may consider how these self-contingencies relate to interactions with peers in the major (e.g., likelihood of studying with others, reactions to group work).

Finally, as the leavers' academic records could not be accessed after they left the college, this study could not address whether they discontinued their pursuit of just the chemistry major or of a college degree. A larger multi-institutional study would be suited to pursue this question, as well as address some of the previous limitations related to the smaller sample size.

CONCLUSION

The current study offers some insight into the minds of students who shift away from the chemistry major and, in turn, contributes to the growing body of research aimed at examining why colleges and universities are experiencing a decline in recruitment and retention in the STEM fields. In considering individual differences that may be predictive of changing majors, we identified factors related to perceptions of ability (i.e., self-doubt) and performance (i.e., performance-avoidance orientation), as well as self-worth (i.e., self-contingency related to competition and academic competence). Though factors beyond individual differences matter greatly in students' persistence, and individual differences alone cannot capture one's motivation for leaving a major, in the pursuit of increasing student persistence it is valuable to understand the mindset of students at the start of their academic experience. Future studies should continue to take such individual difference factors into consideration as researchers further explore why a student may persist or leave the field.

ASSOCIATED CONTENT

Supporting Information

A full list of results is reported, including descriptive and inferential statistics and reliability of individual scales. This material is available via the Internet at http://pubs.acs.org.

AUTHOR INFORMATION

Corresponding Author

*E-mail: rshedlos@ycp.edu.

Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

We thank Bill Steel, Carol Bair, and Renée Sefton for assistance in collecting data. We also thank the chemistry program for financial support.

REFERENCES

(1) Developing the STEM Education Pipeline. http://www.act.org/research/policymakers/pdf/ACT_STEM_PolicyRpt.pdf (accessed Jan 2015).

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX

(2) Hayes, R. Q. *2001−02 STEM retention report: The retention and graduation rates of 1994−2000 freshman cohorts entering science, technology, engineering and mathematics majors in 200 colleges and universities*; Consortium for Student Retention Data Exchange: Norman, OK, 2002.
(3) Cole, D.; Espinoza, A. Examining the Academic Success of Latino Students in Science Technology Engineering and Mathematics (STEM) Majors. *J. Coll. Stud. Dev.* **2008**, *49*, 285−300.
(4) Crisp, G.; Nora, A.; Taggart, A. Student Characteristics, Pre-College, College, and Environmental Factors as Predictors of Majoring in and Earning a STEM Degree: An Analysis of Students Attending a Hispanic Serving Institution. *Am. Educ. Res. J.* **2009**, *46*, 924−942.
(5) Griffith, A. L. Persistence of women and minorities in STEM field majors: Is it the school that matters? *Econ. Educ. Rev.* **2010**, *29*, 911−922.
(6) Kimmel, L. G.; Miller, J. D.; Eccles, J. S. Do the Paths to STEMM Professions Differ by Gender? *Peabody J. Educ.* **2012**, *87*, 92−113.
(7) Mau, W.-C. Factors That Influence Persistence in Science and Engineering Career Aspirations. *Career Dev. Q.* **2003**, *51*, 234−243.
(8) Levin, J.; Wyckoff, J. Predicting persistence and success in baccalaureate engineering. *Education* **1991**, *111*, 461−468.
(9) Maltese, A. V.; Tai, R. H. Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Sci. Educ.* **2011**, *95*, 877−907.
(10) Mendez, G.; Buskirk, T. D.; Lohr, S.; Haag, S. Factors Associated With Persistence in Science and Engineering Majors: An Exploratory Study Using Classification Trees and Random Forests. *J. Eng. Educ.* **2008**, *97*, 57−70.
(11) Zhang, G.; Anderson, T. J.; Ohland, M. W.; Thorndyke, B. R. Identifying Factors Influencing Engineering Student Graduation: A Longitudinal and Cross-Institutional Study. *J. Eng. Educ.* **2004**, *93*, 313−320.
(12) Besterfield-Sacre, M.; Atman, C. J.; Shuman, L. J. Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering. *J. Eng. Educ.* **1997**, *86*, 139−149.
(13) Marra, R. M.; Rodgers, K. A.; Shen, D.; Bogue, B. Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy. *J. Eng. Educ.* **2009**, *98*, 27−38.
(14) Andersen, L.; Ward, T. J. Expectancy-value models for the STEM persistence plans of ninth-grade, high-ability students: A comparison between black, Hispanic, and white Students. *Sci. Educ.* **2014**, *98*, 216−242.
(15) Perez, T.; Cromley, J. G.; Kaplan, A. The role of identity development, values, and costs in college STEM retention. *J. Educ. Psychol.* **2014**, *106*, 315−329.
(16) Seymour, E.; Hewitt, N. M. *Talking About Leaving: Why Undergraduates Leave the Sciences*; Westview Press: Boulder, CO, 1997.
(17) Ackerman, P. L.; Kanfer, R.; Beier, M. E. Trait complex, cognitive ability, and domain knowledge predictors of baccalaureate success, STEM persistence, and gender differences. *J. Educ. Psychol.* **2013**, *105*, 911−927.
(18) Oleson, K. C.; Poehlmann, K. M.; Yost, J. H.; Lynch, M. E.; Arkin, R. M. Subjective Overachievement: Individual Differences in Self-Doubt and Concern With Performance. *J. Pers.* **2000**, *68*, 491−524.
(19) Dweck, C. S.; Chiu, C.; Hong, Y. Implicit Theories and Their Role in Judgments and Reactions: A Word From Two Perspectives. *Psychol. Inq.* **1995**, *6*, 267−285.
(20) Elliot, A. J.; Church, M. A. A hierarchical model of approach and avoidance achievement motivation. *J. Pers. Soc. Psychol.* **1997**, *72*, 218−232.
(21) Cacioppo, J. T.; Petty, R. E.; Feng Kao, C. The Efficient Assessment of Need for Cognition. *J. Pers. Assess.* **1984**, *48*, 306−307.
(22) Ryan, R. M. Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory. *J. Pers. Soc. Psychol.* **1982**, *43*, 450−461.
(23) Bauer, C. F. Beyond "Student Attitudes": Chemistry Self-Concept Inventory for Assessment of the Affective Component of Student Learning. *J. Chem. Educ.* **2005**, *82*, 1864.
(24) Crocker, J.; Luhtanen, R. K.; Cooper, M. L.; Bouvrette, A. Contingencies of Self-Worth in College Students: Theory and Measurement. *J. Pers. Soc. Psychol.* **2003**, *85*, 894−908.
(25) During the survey semester the college reported the incoming student population as 49% female, 51% male, 82% Caucasian.
(26) Rusbult, C. E.; Martz, J. M.; Agnew, C. R. The Investment Model Scale: Measuring commitment level, satisfaction level, quality of alternatives, and investment size. *Pers. Relat.* **1998**, *5*, 357−387.
(27) This scale was reworded as there were students from science majors besides chemistry as part of a larger study.
(28) Among the leavers, there were two students who had enrolled during their fourth semester but did not register for the following semester. All other leavers enrolled three or fewer semesters.
(29) With regards to retention among all STEM majors, students who switched from one STEM major to another were counted as retained.
(30) Due to low reliability, the self-contingency academic competence scale was revised to exclude a single item; see Supporting Information.
(31) Unlike what was observed in our sample, in retention of all STEM majors at the college, it did appear that males were slightly more likely to stay in their STEM major as compared to females (60% vs 56%, respectively), and white students were more likely to persist in the STEM majors, as compared to nonwhite students (61% vs 42%, respectively).
(32) Coley, N. R. Prediction of success in general chemistry in a community college. *J. Chem. Educ.* **1973**, *50*, 613.
(33) Hazari, Z.; Tai, R. H.; Sadler, P. M. Gender differences in introductory university physics performance: The influence of high school physics preparation and affective factors. *Sci. Educ.* **2007**, *91*, 847−876.
(34) McFate, C.; Olmsted, J. Assessing Student Preparation through Placement Tests. *J. Chem. Educ.* **1999**, *76*, 562.
(35) Sadler, P. M.; Tai, R. H. High School Chemistry Instructional Practices and Their Association with College Chemistry Grades. *J. Chem. Educ.* **2007**, *84*, 1040.
(36) Spencer, H. E. Mathematical SAT Test Scores and College Chemistry Grades. *J. Chem. Educ.* **1996**, *73*, 1150.
(37) Tai, R. H.; Ward, R. B.; Sadler, P. M. High School Chemistry Content Background of Introductory College Chemistry Students and Its Association with College Chemistry Grades. *J. Chem. Educ.* **2006**, *83*, 1703.
(38) Hughes, W. J. Percieved Gender Interaction and Course Confidence Among Undergraduate Science, Mathematics, and Technology Majors. *J. Women Minor. Sci. Eng.* **2000**, *6*, 14.
(39) Ceci, S. J.; Williams, W. M.; Barnett, S. M. Women's underrepresentation in science: Sociocultural and biological considerations. *Psychol. Bull.* **2009**, *135*, 218−261.
(40) Diekman, A. B.; Brown, E. R.; Johnston, A. M.; Clark, E. K. Seeking Congruity Between Goals and Roles: A New Look at Why Women Opt Out of Science, Technology, Engineering, and Mathematics Careers. *Psychol. Sci.* **2010**, *21*, 1051−1057.
(41) Miyake, A.; Kost-Smith, L. E.; Finkelstein, N. D.; Pollock, S. J.; Cohen, G. L.; Ito, T. A. Reducing the Gender Achievement Gap in College Science: A Classroom Study of Values Affirmation. *Science* **2010**, *330*, 1234−1237.
(42) Stout, J. G.; Dasgupta, N.; Hunsinger, M.; McManus, M. A. STEMing the tide: Using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *J. Pers. Soc. Psychol.* **2011**, *100*, 255−270.

DOI: 10.1021/ed500571j
J. Chem. Educ. XXXX, XXX, XXX−XXX