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Science identity development trajectories in a gateway college chemistry course: Predictors and relations to achievement and STEM pursuit

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Abstract

This investigation of undergraduates' heterogeneous science identity trajectories within a gateway chemistry course identified three latent classes (*High and Stable, Moderate and Slightly Increasing, Moderate and Declining*) using growth mixture modeling. Underrepresented minorities were more likely to exhibit *Moderate-and-Slightly-Increasing* science identities versus *High-and-Stable* patterns. Students with higher perceived competence were more likely classified into the *High-and-Stable* class compared to the other classes. Students classified into the *High-and-Stable* class scored significantly higher on the final exam and appeared to be more likely to remain in a STEM major across fall and spring semesters compared to the other two classes. Results suggest that some students' identities shift within a single semester and supporting science perceived competence before college may support students' science identity development.

Keywords

science identity development; growth mixture modeling; expectancy-value; STEM pursuit

High attrition rates in college STEM fields (Koenig, 2009; Myers & Pavel, 2011; National Science Board, 2016; National Science Foundation, 2015) and initiatives to expand and diversify the STEM workforce in the United States (e.g., National Science and Technology Council, 2013) highlight the need to better understand motivation processes in STEM, particularly in difficult introductory courses (Perez, Cromley, & Kaplan, 2014; Seymour & Hoffman, 1997). Identity beliefs, including students' value for a domain because of its importance to their identity, can be a powerful source of motivation but there is little research examining their development and correlates in college. Prior work provides

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evidence of average declines in motivational constructs related to identity (Robinson, Lee, et al., 2018; Fredricks & Eccles, 2002; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Watt., 2004) suggesting a need for broad-based identity supports in college; however, more recent research identified heterogenous patterns of identity development across college such that not all students experienced a decline (Robinson, Perez, Nuttall, Roseth, & Linnenbrink-Garcia, 2018). Additional research is needed to consider and identify various patterns of development in order to understand what factors facilitate adaptive science identity development.

In the current study, we extend this prior work by examining trajectories of science identity development during a single semester in the context of a gateway college chemistry course. Studying science identity development during introductory coursework is important, as particularly competitive or challenging gateway courses in STEM may destabilize students' motivation during a key period of transition to the university or to a STEM major. Thus, the current study provides an important extension of Robinson, Perez et al. (2018) by focusing on short-term identity shifts and investigating whether science identity, which is thought to be largely stable during college (Eccles, 2009; Waterman, 1993), can shift within a single semester. To better understand individual differences in development and the adaptiveness of various developmental trajectories, we also examine whether demographic characteristics, competence beliefs, final exam grades, and STEM major retention are related to science identity trajectories. Understanding patterns of science identity development during a semester-long gateway science course, as well as key antecedents and academic outcomes associated with science identity development, can inform theoretical conceptualizations of identity development during college as well as the design of educational contexts to promote more equitable and motivationally supportive learning environments in STEM fields.

Theoretical Framework: Identity from an Expectancy-Value Perspective

Contemporary expectancy-value theory (Wigfield, Tonks, & Klauda, 2016) highlights the key role of identity-related motivation processes in predicting students' achievement and choices (Eccles, 2009). Broadly, expectancy-value theory posits that an individual's expectancy for success and perceptions of value are key proximal predictors of achievement and choice behavior (Wigfield et al., 2016). This means that students who highly value science and who feel confident that they will succeed at science are likely to persist in science majors and succeed in their science courses. Students who do not feel confident in their future success or who do not see the value in science are less likely to achieve high grades or continue pursuing science. Task value is differentiated to reflect three specific reasons why individuals engage in a task; a student may value a task because it is enjoyable or interesting (interest value), because it is useful to their current or future goals (utility value), or because it is important to their identity (attainment value).

Recent research and theorizing within contemporary expectancy-value theory advance a nuanced understanding of task value (Eccles, 2009; Gaspard et al., 2015; Perez et al., 2014). Of particular relevance to the current paper is the clarification of attainment value and its close connection to identity. For instance, Eccles' (2009) clarified the importance of multiple motivational constructs (e.g., goals, expectancies, all forms of task value) as identity components, with a specific emphasis on attainment value as a key indicator of identity, as it reflects whether an individual has incorporated a particular task or domain into his or her identity. Building from this work, Gaspard and her colleagues (2015) investigated differentiated forms of attainment value that go beyond earlier broad conceptualizations of attainment value as importance (Wigfield et al., 1997). Specifically, they found that students distinguish between broad importance of high achievement and more specific, personal importance. These more nuanced forms of attainment value were differentially associated with gender and other forms of motivation (Gaspard et al., 2015).

Identity-related attainment value shares characteristics with theoretical conceptualizations of identity in the broader identity literature (e.g., Luyckx, Goossens, Soenens, & Beyers, 2006; Marcia, 1993; Markus & Nurius, 1986; Schwartz, Zamboanga, Luyckx, Meca, & Ritchie, 2013; see Robinson, Perez et al., 2018 for a more detailed discussion), such as the focus on absolute salience or importance to one's identity. However, in contrast to conceptualizations of identity as a whole, or on identity processes regardless of contents, expectancy-value theory's focus on the identity contents in the context of a particular task or domain is a defining characteristic of this conceptualization (Eccles, 2009). Framing identity within an expectancy-value theory framework thus allows us to examine achievement-related choices within a domain (science), as enactments of highly valued aspects of a particular identity (e.g., science identity).

Development of Science Identity During College

College is a pivotal time for the development of academic and career-related identities; it can be a time of solidifying or, conversely, destabilizing highly valued identities (Côté, 2006; Eccles, 2009; Luyckx et al., 2006; Marcia, 1993; Roisman, Masten, Coatsworth, & Tellegen, 2004; Waterman, 1993). Indeed, expectancy-value theory indicates that identity importance, salience, and contents represent dynamic processes that change in response to experiences, information, and introspection (Eccles, 2009). Thus, difficult introductory "weed out" courses in STEM fields can present challenges to maintaining high and stable science identities (Seymour & Hoffman, 1997). Some students may begin to doubt their ability to succeed or their fit within science when encountering difficult coursework, competitive course climates, or even discrimination and activation of identity-based stereotypes (Cokley, 2002; Osborne, 1995; 1997; Seymour & Hoffman, 1997), leading to potentially dramatic changes in science identity and subsequent behavior. Other students may not experience these challenges or may maintain robust science identities in the face of challenges, thus exhibiting patterns of stability or even increased salience of science identity (Robinson, Perez et al., 2018). There is little empirical evidence to inform our understanding of how science identity changes over time, including the prevalence of various science identity trajectories and their relations to predictors and outcomes.

Though little research has examined the development of science identity in college, several studies have documented average declines in attainment value in other domains throughout K-12 and during college (Robinson, Lee, et al., 2018; Fredricks & Eccles, 2002; Jacobs et al., 2002). One study examining engineering identity alongside expectancy, other task values, and perceived costs found average declines throughout the first two years of college, but identity declined at a slower rate than expectancy and other task values (Robinson, Lee, et al., 2018). Jacobs and colleagues (2002) documented declines in math-related task value (a composite of interest, utility, and broad importance) from first through twelfth grade. Lastly, Fredricks and Eccles (2002) noted declines in “importance,” a composite of utility and broad importance, for math from first through twelfth grade. Notably, these prior studies considered average development for the entire sample and, with the exception of Robinson, Lee, et al., 2018, did not examine identity-related attainment value specifically. These observed declines would suggest that broad-based motivation interventions are needed to support identity development for all students, and that attainment value may not change much in the short-term or even throughout college.

However, recent research from a person-oriented perspective suggests that there is heterogeneity in task value trajectories during childhood, adolescence, and young adulthood (Archambault, Eccles, & Vida, 2010; Robinson, Perez et al., 2018; Musu-Gillette, Wigfield, Harring, & Eccles, 2015), including in studies that examined science identity and broad personal importance. For example, although subgroups of students exhibited declines in task value (Archambault et al., 2010; Musu-Gillette et al., 2015) and science identity (Robinson, Perez et al., 2018), the full samples in these studies did not display this pattern of decline. Most relevant to the current study is a longitudinal study examining change in science identity in a sample of elite college students throughout college; results indicated that declines in science identity were relatively rare, suggesting that educators may want to target interventions specifically on students who exhibit declines rather than the whole college population (Robinson, Perez et al., 2018). This prior study also speaks to the dual nature of identity: its relative stability, with very slow change for the majority of students, but with the potential for rapid change during college for some. The unique sample of elite undergraduates used in this prior study and the four-year time scale limit its generalizability to other samples and to understanding how gateway STEM courses may shape science identity as students begin their studies in STEM, highlighting the need for further research to replicate and extend these findings. Indeed, it remains an open question whether science identity can be destabilized within a single semester, particularly in the context of a difficult, gateway science course. Such research is needed to inform our theoretical understanding of the malleability of science identity during a key developmental period for shaping academic and career identities, as well as to inform practical efforts to support science identity during college.

Predictors of Science Identity Trajectories

To better understand why and how students’ science identity trajectories may differ, and to understand mechanisms for supporting science identity development, it is important to examine key predictors related to its development. Expectancy-value theory richly articulates mechanisms of identity development processes (Eccles, 2009; Wigfield et al., 2016), but these processes have gone largely unexamined in relation to identity development for college students. Broadly, expectancy-value theory assumes that cultural and social processes shape the development of both expectancies and task values (Wigfield et al., 2016). A large body of expectancy-value research also indicates that students’ expectancies for success may play a key role in supporting science identity (Wigfield & Cambria, 2010;

Wigfield et al., 2016). Specifically, while expectancies and task values are often conceptualized as reciprocally related (Marsh & Yeung, 1997, 1998; Wigfield & Cambria, 2010), results from two studies suggest that competence beliefs exert a stronger directional effect on task values than task values on competence beliefs (Jacobs et al., 2002; Marsh, Köller, Trautwein, Lüdtke, & Baumert, 2005). Eccles (2009) further suggests that task values (including identity-focused attainment value) act as mediators between expectancy and achievement outcomes, such that a high expectancy for success in a domain is a necessary prerequisite for adopting that domain as part of one's identity.

Thus, undergraduate students who begin a semester feeling unsure about their science abilities may be especially vulnerable to instability in their science identities. Indeed, prior research has supported these relations, suggesting that research experiences can support science identity via increased self-efficacy for scientific tasks (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; Robnett, Chemers, & Zurbriggen, 2015) and that lower self-efficacy for science tasks *and* lower perceived academic competence in science at the beginning of college predict a greater likelihood of declines in science identity across four years of college (Robinson, Perez et al., 2018). Narrowing the focus to a single semester allows us to test whether this same mechanism holds in the short term and highlights the key role of gateway science courses, particularly introductory chemistry courses (Perez et al., 2014), in shaping students' beliefs about themselves in relation to science (Cromley, Perez, & Kaplan, 2016; Dai & Cromley, 2014; Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012). Such research also has implications for whether identity development supports in a semester-long course can be expected to shift identity trajectories in the short-term, or whether supports should be administered and evaluated through longer-term programmatic efforts.

Second, students of different genders, races, and ethnicities are subject to different socialization processes via cultural milieu, important others, and classroom activities before and during college (Eccles, 2005; Wigfield et al., 2016). These differing socialization processes can lead to differences in both initial levels of science identity and rates of change over time. In STEM fields specifically, women and students from underrepresented racial/ethnic groups may face discrimination, subtle cues signaling a lack of belonging, and stereotype threat that act as barriers to identifying with and pursuing science. These barriers are evidenced by higher attrition and lower representation in certain STEM fields for these groups (Koenig, 2009; Myers & Pavel, 2011; National Science Board, 2016; National Science Foundation, 2015; Riegle-Crumb & King, 2010). However, there is scant and mixed empirical support for demographic differences in science identity development. It is necessary to understand the nature of these differences in order to effectively support identity development opportunities for all students.

While little research has examined demographic differences in college students' science identity development, Robinson, Perez et al., (2018) found that gender and race/ethnicity predicted differential science-identity trajectories across four years. Specifically, men were more likely than women to exhibit very high and slightly increasing patterns of science identity, while women were more likely to report slightly lower but stable science identity throughout college. Students from underrepresented racial/ethnic minority groups were more likely than racial/ethnic majority students to exhibit moderately low and declining patterns of science identity development rather than high and stable or increasing patterns. These findings are complemented by cross-sectional person-oriented research from Simpkins and Davis-Kean (2005) suggesting that high school boys had higher overall task value for science (a composite of utility, interest, and attainment value conceptualized as broad importance) than girls. Taken together, these two studies suggest a pattern of more adaptive science identity development for racial/ethnic majority males in science. In contrast, other studies on younger students found no gender or racial/ethnic differences in overall task value for science during middle school (Britner & Pajares, 2001) or science attainment value during high school (DeBacker & Nelson, 2000). Further, science identity differences across demographic groups may appear in some STEM fields but not others, with chemistry appearing to show fewer differences than physics, for example (Hazari, Sadler, & Sonnert, 2013). Thus, the current evidence is very limited and does not consistently support gender or racial/ethnic differences in task value. Therefore, it is unclear whether gender or racial/ethnic differences in science identity development would be observed in the context of the current study.

Taken together, extant theory and research suggest a consistent pattern of relations between competence beliefs and science identity, but it is less clear how demographic characteristics relate to science identity development, particularly in college. While gender and racial/ethnic disparities in science fields suggest that supports for science identity development would be especially useful for women and underrepresented minority students (e.g., Carlone & Johnson, 2007), it is important to establish empirical evidence to identify whether subgroups of students may need additional support for science identity development.

Outcomes Related to Science Identity Trajectories

Students' science identity beliefs can be viewed through an expectancy-value lens as a powerful source of motivation to persist and succeed in science. Expectancy-value theory's conceptualization of identity aligns with other theoretical conceptualizations indicating that identity acts as an underlying framework used by the individual to organize self-perceptions, worldviews, and behavior (Eccles, 2009; Kaplan & Flum, 2012; Oyserman, 2015; Rosenberg, 1979). Specifically, when students highly value science as a part of their identity, they are more likely to persist on challenging science tasks and continue to choose science as a field of study. Furthermore, declines in appraisals of science identity importance throughout a semester may act as precursors or correlates of disengagement from coursework and declining intentions to pursue science. As yet, very little research has examined this proposition empirically.

While prior research lends preliminary support for links between science identity and science achievement outcomes in college, including links between identity development processes and achievement in an introductory chemistry course (Perez et al., 2014), most extant research is limited to cross-sectional designs (Andersen & Ward, 2013; Chemers et al., 2011; Hazari, Sonnert, Sadler, & Shanahan, 2010) or examines these relations at longer time scales, such as over a year (Estrada et al., 2011) or over four years of college (Robinson, Perez, et al., 2018). Further, the relations of heterogeneity in developmental patterns of science identity with science outcomes have been specifically examined in only one prior study (Robinson, Perez, et al., 2018). A similar study in a different sample and with a different time scale is needed to understand what patterns of science identity development are observed in the short-term, and to provide stronger implications for theory and practice. Namely, such research is needed to provide additional evidence of heterogeneity in science identity development and of the prevalence of various patterns.

Examining developmental processes within a single semester and relating them to proximal and distal outcomes across a year of college can inform theoretical conceptualizations of attainment value's stability in the short-term while also providing implications for practice. Specifically, should semester-long change patterns in science identity be differentially related to grades in a course and/or pursuit of science majors the following semester, it would pinpoint science identity as a valuable construct to support in promoting higher achievement and retention in science for students in the course. Existing intervention approaches from an expectancy-value perspective have focused primarily on utility value (e.g., Harackiewicz & Priniski, 2017) and have not yet explored supports for identity-based forms of value. Some experimental evidence suggests that identity-related beliefs can be supported in middle school through messages about the congruence of personal and aspirational future identities (Destin & Oyserman, 2010; Elmore & Oyserman, 2012), and correlational studies have focused on potential supports for science identity in college via extracurricular involvement in science enrichment experiences and/or mentoring (Chemers et al., 2011; Hernandez et al., 2018). Science identity supports embedded within a semester-long college course have not been explored and it is unknown whether a students' identities shift within a single semester. Thus, a key first step to exploring the utility of course-based science identity interventions is to examine whether patterns of decline are observed and whether there are correlates of decline that can be targeted for intervention efforts.

Present Study

This study examined identity-related attainment value longitudinally in a semester-long gateway undergraduate chemistry course at a large, public university. Our first research aim was to identify the patterns of change in science identity for undergraduates enrolled in introductory chemistry. Based on prior research examining long-term and semester-long trajectories of motivation broadly (Jacobs et al., 2002; Kosovich et al., 2017; Watt et al., 2002) and science identity more specifically (Robinson, Perez, et al., 2018; Hernandez et al., 2013), we expected that the overall sample would exhibit a relatively stable pattern, potentially showing slight average declines, across the semester. We also hypothesized that initial science identity would be high or moderately high, as students choosing to begin their studies in a science field by taking introductory chemistry would presumably do so as a result of high identification with science. However, because the course was a required prerequisite, because of difficult coursework or identity threat-inducing experiences already taking place early in the semester, or because some students may have enrolled for other reasons such as high perceived utility, some students may have reported lower science identity in the first wave. This and prior research indicating heterogeneity in patterns of science identity development (Robinson, Perez, et al., 2018) led us to hypothesize that multiple, distinct science identity trajectories would be observed, that these trajectories would differ in terms of both intercepts and slopes, with at least some students declining in science identity across the semester.

Our second research objective focused on predictors of science identity trajectories. Specifically, we were interested in how gender, race/ethnicity, and expectancy for success in science at the beginning of the semester predicted GMM class membership. We hypothesized that White and Asian students would be more likely than underrepresented minority (URM) students to exhibit high and stable patterns of science identity throughout the semester. Similarly, we also hypothesized that men would be more likely than women to exhibit high and stable patterns of science identity. Conversely, we expected that women and URM students would be more likely to report initially lower levels and experience declines rather than stability in science identity over time. However, due to scant and inconsistent findings regarding gender differences in students' beliefs and varying representation of gender and racial/ethnic groups in specific STEM and science fields (Riegle-Crumb & King, 2010; Leslie, Cimpian, Meyer, & Freeland, 2015), these hypotheses regarding demographic differences were tentative. In particular, some evidence suggests that demographic groups are fairly equitably represented in chemistry (Cheryan, Ziegler, Montoya, & Jiang, 2016) and that science identity specifically may not differ across demographics groups in chemistry (Hazari et al., 2013). However, our sample consisted of a variety of majors in a chemistry course rather than only chemistry majors, so these prior findings may or may not apply to our sample.

We conceptualize expectancy for success in terms of students' academic perceived competence, or their perceptions about whether or not they will successfully learn the content in their science courses (Schunk & Pajares, 2005). Based on prior research (Robinson, Perez, et al., 2018; Chemers et al., 2011; Robnett et al., 2015) and theorized links between competence beliefs and identity (Eccles, 2009), we expected that higher academic perceived competence at the beginning of the semester would predict membership in higher and/or more stable or increasing patterns of science identity.

The chemistry course was geared toward first-year students but was not entirely comprised of first-year students. Developmental processes may differ for first-year students compared to upperclassmen; thus, we also examined whether first-year status predicted GMM class membership. Due to the lack of prior research on science identity as a function of students' year in college, we did not make specific hypotheses about first-year status and GMM class membership. As attainment value tends to decline over time (Jacobs et al., 2002; Fredricks & Eccles, 2002), it could be that upperclassmen would be more likely to report lower and/or declining patterns of science identity over time. However, because first-year students may be at greater risk for destabilized motivation as they transition to the higher workload, demands, and competitiveness of college, first-year students may have been more likely to experience declines in science identity.

The final goal of the study involved examining outcomes related to heterogeneous science identity trajectories. Specifically, we examined whether membership in GMM classes predicted chemistry course performance and STEM major status the following semester. Based on prior research (Robinson, Perez, et al. (2018); Andersen & Ward, 2013; Chemers et al., 2011; Hazari et al., 2010) and theoretical expectations (Eccles, 2009), we expected that higher and more stable or increasing patterns of science identity development would be associated with higher course exam grades and a greater likelihood of being in a STEM major the following semester.

The present study makes several unique contributions to the literature. First, the majority of developmental research in the expectancy-value literature has been conducted in K-12 settings and focused on other forms of value, including prior conceptualizations of attainment value. The present study addresses this gap in the literature by examining science identity development during a key transition to science studies in college. Second, the current study extends prior work by Robinson, Perez, et al. (2018), who examined science identity trajectories across four years of college, by investigating whether science identity can shift in a particular context within a single semester. This smaller time scale is particularly informative for considering whether classroom-based interventions might be used to shift science identity in a meaningful way. Third, the present study also adds to the scant literature on demographic differences in identity beliefs during college by examining gender, racial/ethnic, and year-in-school differences in science identity development. Such research has implications for understanding the mechanisms, timing, and target populations for interventions to support students' success in science via science identity development. Fourth, by examining differences in chemistry exam grades and STEM major statuses, we also add theoretical and practical understanding of the role of identity beliefs in predicting key science outcomes, which is in need of empirical support. Finally, the use of growth mixture modeling enables us to consider potential heterogeneity in patterns of science identity development, which helps to provide a more nuanced understanding of patterns of development and may be particularly useful for developing more targeted interventions.

Method

Participants and Procedure

Data for the current study were obtained as part of a larger, ongoing longitudinal study examining college students' pursuit of STEM careers. Participants were undergraduate students (N = 1,669) enrolled in an introductory chemistry course in the fall of 2016 at a large, public university in the United States (54.6% female; 13.7% first-generation college students; 73% White, 13.7% Asian/Asian American, 6.0% Black, 1.9% Hispanic or Latino/a, 5.9% multiracial, Native American, Pacific Islander, or other). The chemistry course used a reformed curriculum titled *Chemistry, Life, the Universe and Everything*, or CLUE (Cooper & Klymkowsky, 2013) which is focused on progressions of four core ideas that are central to chemistry knowledge. The course is a prerequisite for students aiming to pursue majors in the natural sciences and certain engineering majors. Students completed three online surveys for homework credit in the course and were given the opportunity to provide informed consent for the use of their survey responses in the current study, with no penalties for opting out of the study. The surveys were completed during weeks 2 (Time 1), 8 (Time 2), and 14 (Time 3) of the 15-week introductory chemistry course.

Students aged 18 and over were eligible to participate. Students who did not complete one survey were still invited to participate in subsequent surveys. Results of missing data analyses are provided in the results section. The study was deemed exempt by the university's Institutional Review Board (IRB No. x16-881e).

Measures

Data for the study were obtained from self-report surveys, the course instructor, and university records. Science identity and science academic perceived competence items were measured on a 5-point Likert-type scale, with 1 = *strongly disagree*, 5 = *strongly agree*. All scale items are listed in the Appendix. Participants also reported their demographic information at Time 2 (T2).

Science identity.—At all three time points, participants responded to four items assessing individual appraisals of the personal importance or value of science to one's identity (α = .85-.87). The measure, previously used in Robinson, Perez, et al. (2018), was adapted from two scales: a science identity scale developed by Pugh, Linnenbrink-Garcia, Koskey, Stewart, and Manzey (2009) and an attainment value scale developed by Conley (2012). A sample item from the scale is: "Being involved in science is a key part of who I am." Confirmatory factor analyses including all three correlated time points indicated that the model fit the data well, χ^2 (51) = 380.36, RMSEA = .06, CFI = .96, TLI = .94.

Science academic perceived competence.—Students' perceived confidence in their ability to succeed at academic work in science was measured at T1 using a five-item scale adapted from Midgley et al., 2000 (α =.87). A sample item for this scale is, "Even if the work in science is hard, I can learn it." The original scale from Midgley et al. (2001) is titled "Academic Efficacy" however, its description states that it refers to "students' perceptions of their competence to do their class work" (p. 20). We refer to this construct as academic perceived competence to be consistent with conceptualizations that emphasize the task specificity of self-efficacy in contrast to the more general nature of academic perceived competence (Bong & Skaalvik, 2003). Confirmatory factor analyses indicated acceptable model fit, χ^2 (5) = 37.03, RMSEA = .09, CFI = .98, TLI = .97.

Demographic information.—Participants provided demographic information at T2, including their self-identified gender and race/ethnicity. Specific race/ethnicity categories were collapsed into a binary variable indicating membership in a racial/ethnic group that is underrepresented in STEM fields (African American, Hispanic/Latino, etc.) or membership in a racial/ethnic majority group in STEM (White or Asian/Asian American). Students' year in school was obtained from university records.

Outcome variables.—Chemistry exam scores were obtained from the course instructor. We selected the final exam as the performance indicator because it took place after the T3 survey and was a cumulative exam assessing knowledge from throughout the semester and so would reflect students' overall experience in the course. Major status at the end of Fall semester (Fall 2016) and at the end of the academic year (Spring 2017) was obtained from university records. The university classified individual majors as STEM (1) or non-STEM (0) in alignment with federal classifications of instructional programs that emphasize research, innovation, and the development of new technologies to distinguish STEM fields

(National Center for Education Statistics, 2010). Notably, health and clinical majors such as pre-nursing, pre-medical, and veterinary, and "applied" STEM fields such as forestry and agriculture, were not counted as STEM fields. To capture different patterns of student major decisions, we created a four-level categorical variable indicating whether students were non-STEM majors in both semesters (category 1), STEM majors in both semesters (category 2), switched from a STEM major to a non-STEM major (category 3), or switched from a non-STEM major to a STEM major (category 4).

Analytic Plan

All analyses were conducted using Mplus Version 8 (Muthén & Muthén, 1998-2017) and missing data were handled using full information maximum likelihood (FIML) estimation. Prior to fitting latent growth models and growth mixture models, preliminary analyses included missing data analysis and measurement invariance testing, results of which are presented below, and an examination of individual trajectory plots to inform the modeling process (Ram & Grimm, 2009).

Latent growth model.—The first step of the analysis involved latent growth modeling of the overall mean science identity trajectory for the entire sample, representing a one-class growth mixture model. The selected model was used as a baseline model for GMM (Masyn, 2013; Ram & Grimm, 2009). Intercept-only (no growth) and linear models were fit to the full sample to find the best-fitting representation of change for the overall sample. Quadratic models were not attempted, as a minimum of four time points is needed to examine quadratic change and our study included only three time points.

Growth mixture models.—Next, second-order growth mixture modeling (GMM) was used to identify heterogeneous classes of change in science identity (Grimm & Ram, 2009a; Nylund, Asparouhov, & Muthén, 2007). Rather than using a single growth curve model, which would assume all participants belonged to a single population, or relying on multi-group models with sub-groups defined *a priori*, GMM was used to identify distinct classes of students within the sample with similar semester-long patterns of change. Bayesian Information Criterion (BIC; Nylund et al., 2007), with smaller values of BIC indicating better fit, and theoretical interpretability were used as criteria to select the class solution (Grimm & Ram, 2009b).

There are a variety of approaches used to examine predictors (termed covariates in the GMM literature) and distal outcomes of GMM class membership. The one-step method, in which the covariates or distal outcomes are added directly to the GMM models, is typically used when covariates or distal outcomes are assumed to influence the estimation of the GMM. However, this method often changes the class solution, making interpretation difficult, particularly when researchers aim to understand predictors or outcomes of class membership (Vermunt, 2010). A second approach involves a three-step procedure: after the GMM is specified (Step 1), each case is assigned to the most likely class based on probabilities of latent class membership (Step 2). Class membership is then used as a categorical variable which can be modeled as a predictor or an outcome (Step 3). However, because this method treats latent class membership as known, standard errors and estimates of model parameters are biased (Vermunt, 2010).

To leverage the affordances of the three-step approach without the additional bias introduced by assigning class membership, we used an updated three-step approach (Asparouhov & Muthén, 2014; Muthén & Muthén, 1998-2018) to introduce covariates (gender, race/ethnicity, science perceived competence, and first-year status) and distal outcomes (final exam scores and STEM major statuses). This approach is similar to the earlier three-step approach, but the updated approach takes into account the uncertainty of classification in the second step using logit probabilities. This updated three-step procedure has been shown to result in less biased estimates than the original three-step procedure while maintaining a stable class solution for the GMM and interpretable coefficients for predictors and outcomes of class membership (Asparouhov & Muthén, 2014). The command R3STEP was used for covariates, the BCH command was used for the exam score outcome, and the DCATEGORICAL command was used for the STEM major outcome, as recommended by Muthén & Muthén (1998-2017; see also Asparouhov & Muthén, 2012; Vermunt, 2010).

Results

Preliminary Analyses

Descriptive statistics and correlations.—Table 1 presents correlations and descriptive statistics for the study variables. As expected, repeated measures of science identity were positively correlated over time and were positively correlated with T1 perceived competence and final exam scores. With regard to categorical variables, 70.2% of participants were first-year (non-transfer) students. The distribution of students across the four-level STEM major variable was as follows: 485 students (29.0%) were non-STEM majors in both semesters, 1002 (60.0%) were STEM majors in both semesters, 74 (4.4%) were STEM majors in the first semester but non-STEM majors in the second semester (switched out of STEM), and 97 (5.8%) were non-STEM majors in the first semester but STEM majors in the second semester (switched into STEM).

Missing data.—The mid-semester (week 8) survey was administered as part of a larger long-term longitudinal research project, and therefore students were reminded several times about the survey and were notified that they may be given the opportunity to earn gift cards for taking surveys in future years. In contrast, the surveys taken at the beginning (week 2) and end (week 14) of the semester were administered as stand-alone surveys for the purpose of understanding students' motivation within the course, and so students did not receive reminders or additional incentives beyond course credit to complete these surveys. Institutional data were collected as part of the longer-term study and thus were also only available for students who completed the T2 survey. Thus, we used T2 survey completion as our criteria for enrollment in the study. Of the full sample enrolled in the study ($N = 1{,}669$), 884 (53%) took the T1 survey and 843 (51%) took the T3 survey. Those who did not complete the T1 survey had significantly lower science identity at T2 (M = 3.70) compared to those who completed the T1 survey (M = 3.81), $t = -2.95$, $p = .003$. Those who did not complete the T3 survey did not differ significantly on T2 science identity from those who

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completed the T3 survey, $t = -1.35$, $p = .177$. Women were more likely than men to complete the T1, $\chi^2 = 22.57$, $p < .001$, and T3 surveys, $\chi^2 = 6.35$, $p = .01$. White and Asian students were also more likely to take the T1, χ = 12.73, $p < .001$, and T3 surveys, $\chi^2 = 22.35$. $p < .001$, compared to underrepresented minority students. First-generation college student status was not associated with survey completion at T1, $\chi^2 = 1.54$, $p = .22$, but first-generation college students were less likely to take the T3 survey, $\chi^2 = 4.63$, $p = .031$ compared to continuing-generation college students. To assist in FIML estimation, all of these covariates were included in the final models to reduce bias due to systematic patterns of missing data.

Measurement invariance.—To make inferences about change over time, it must first be established that the same construct is being measured over time, or in other words, that participants are perceiving the items in the same way at each measurement occasion (Widaman & Reise, 1997). To test this assumption, we successively constrained the overall factor structure (configural), factor loadings (weak), intercepts (strong), and residual variances (strict) of the science identity items to be equal across time points. The strict invariance model fit the data well, and model comparisons resulted in less than .01 change in CFI between models (see Table 2; Cheung & Rensvold, 2002), providing evidence that science identity was measured in the same way over time (Widaman, Ferrer, & Conger, 2010). The strict invariance model (invariant factor loadings, intercepts, and residual variances over time) was used as the measurement model for science identity in subsequent latent growth and growth mixture modeling analyses.

Unconditional second-order latent growth model.—To examine whether a no-growth (intercept-only) or linear pattern best fit the data for the full sample, we compared two latent growth models assuming strict measurement invariance over time. The no-growth model fit the data well, χ^2 (77) = 604.93, RMSEA = .064, CFI = .931, TLI = .941, SRMR = .092, and estimated a science identity mean of 3.67 (S.E. = .02) on a 5-point scale throughout the semester. The linear model also fit the data well, χ^2 (74) = 542.79, RMSEA = .062, CFI = .938, TLI = .945, SRMR = .076, indicating an initial average science identity of 3.67 (S.E. = .03) and a non-significant slope of −.001 (S.E. = .02). Covariance between intercept and linear slope was −0.07, $p < .001$, indicating that higher initial levels were associated with lower slopes. Both the no-growth and linear models indicated that the sample reported moderate levels of science identity on average at the beginning of the semester and remained stable throughout the semester. This suggests that an intercept-only model most parsimoniously describes the pattern of science identity development for the overall sample. However, because prior research (Robinson, Perez, et al., 2018) and an examination of individual trajectory plots (Ram & Grimm, 2009) indicated that linear change patterns could emerge for sub-groups within the sample, we used the linear model as the one-class baseline for testing GMMs.

Heterogeneous Science Identity Trajectories

We examined a series of 2-, 3-, 4-, and 5-class models, successively freeing parameters to be class-specific (see Table 3). A three-class solution was selected based on BIC and theoretical considerations such as substantive interpretability (see Table 3 and Figure 1). Specifically, the three-class solution with class-specific means, variances, and covariances of the latent slope and intercept and class-specific residuals of the observed indicators had the lowest BIC of the models that converged to interpretable solutions. In addition, the three classes exhibited distinct and theoretically interpretable patterns of intercepts and slopes. In contrast, the 2-class solution for Model 3 consisted of two classes that differed only in terms of level (high and moderate), both exhibiting non-significant linear slopes. Additionally, the 4-class solution for Model 1 included two classes that were substantively very similar, both exhibiting moderate initial levels with significant declines over time and together consisting of approximately 2% of the sample. Lastly, we considered Model 3 to be more theoretically plausible than Model 1 as it allowed for class-specific variances and covariances. In other words, Model 3 did not assume that individual variation would be equal across the three classes, which is an implausible assumption given the differences in means and sample sizes across classes.

Classification quality for the selected 3-class solution was acceptable, with average latent class probabilities for most likely latent class memberships ranging from .77 - .87. The first class, *High and Stable* (53.8% of the sample), was characterized by a high science identity intercept ($M = 4.03$, S.E. = 0.04, $p < .001$, 95% CI [3.95, 4.11]) and a non-significant slope ($M = 0.01$, S.E. = 0.02, $p = .44$, 95% CI [−0.03, 0.05]). The second class, *Moderate and Slightly Increasing* (40.5% of the sample), was characterized by moderate initial science identity ($M = 3.36$, S.E. = 0.05, $p < .001$, 95% CI [3.26, 3.46]) and a slight but significant positive slope ($M = 0.06$, S.E. = 0.03, $p = .04$, 95% CI [0.001, 0.12]). It should be noted, however, that overlapping confidence intervals of the slopes for the first two classes indicated that the slopes were not significantly different from one another. We characterize the second class as *Moderate and Slightly Increasing* due to its significant positive slope, however this should be interpreted with care considering the very small slope and the fact that it is not significantly different from the nonsignificant (i.e., flat) slope of the first class. The third class, *Moderate and Declining* (5.6% of the sample), exhibited moderate initial science identity ($M = 3.01$, S.E. = 0.21, $p < .001$, 95% CI [2.60, 3.42]) that significantly and sharply declined ($M = -0.56$, S.E. = 0.12, $p < .001$, 95% CI [−0.80, −0.33]). The covariance between intercept and slope was significant in the *Moderate-and-Slightly-Increasing* class (cov = −0.13, $p = .003$) and the *Moderate-and-Declining* class (cov = −0.93, $p = .001$), but was not significant in the *High-and-Stable* class (cov = −0.008, $p = .642$).

Predictors of Science Identity Trajectories

The three-step procedure in Mplus, which accounts for uncertainty in class assignments, was used to introduce gender, race/ethnicity (URM), first-year status, and T1 science academic perceived competence as covariates predicting GMM class membership.[1] Multinomial logistic regression results indicated that URM (e.g., Black and Hispanic) students were significantly more likely than White and Asian students to be in the *Moderate-and-Slightly-*

[1]Due to limitations of the 3-step procedure as implemented in Mplus, analysis of predictors and outcomes of GMM trajectories classes excluded those with missing data on the predictor or outcome variables. Specifically, the analysis of predictors included 868 (52% of sample), excluding 801 participants who were missing T1 perceived competence. The analysis of STEM major outcomes excluded 12 people who were missing major status, and the analysis of final exam scores excluded 35 participants who were missing final exam scores.

Increasing class than in the *High-and-Stable* class (*b* = .91, *p* = .02, O.R. = 2.48), but no URM differences were observed in the likelihood of membership in the *Moderate-and-Slightly-Increasing* class versus the *Moderate-and-Declining* class (*b* = .38, p = .58) or the *High-and-Stable* class versus the *Moderate-and-Declining* class (*b* = .53, p = .43).

First-year students were more likely than upperclassmen to be in the *High-and-Stable* class compared to the *Moderate-and-Declining* class (*b* = 1.22, *p* = .006, O.R. = 3.39) and the *Moderate-and-Slightly-Increasing* class compared to the *Moderate-and-Declining* class (*b* = 1.16, *p* = .014, O.R. = 3.19), with no year-in-school differences in the likelihood of membership in the *Moderate-and-Slightly-Increasing* versus the *High-and-Stable* class (*b* = −.06, *p* = .797). Gender did not significantly predict any class membership differences (*b* = .24-1.18, *p* = .07-.25).

Higher competence beliefs predicted a greater likelihood of membership in the *High-and-Stable* class as compared to the other two classes (*High-and-Stable* versus *Moderate-and-Slightly-Increasing: b* = .96, *p* < .001, O.R. = 2.61; *High-and-Stable* versus *Moderate-and-Declining*: *b* = 1.06. *p* = .001, O.R. = 2.88). This indicates that a one-unit difference in perceived competence (on a scale of 1 to 5) was associated with nearly three times the likelihood of being in the *High-and-Stable* class compared to the other two classes. In other words, students with higher perceived competence at the beginning of the semester were much more likely to report high and stable science identities throughout the semester. Perceived competence was not significantly associated with differential membership in the *Moderate-and-Slightly-Increasing versus Moderate-and-Declining* classes (*b* = .099, *p* = .77), indicating that students with lower perceived competence were equally likely to exhibit moderate and increasing or moderate and declining science identity development.

Outcomes Associated with Science Identity Trajectories

Finally, we examined whether students in the three classes of science identity development differed in terms of proximal (final course exam performance) and distal (STEM major status) outcomes. Due to constraints of the three-step procedure in Mplus, the two outcomes were examined separately. First, we used the BCH command to examine mean differences in exam scores across the three trajectory classes. Second, we used the DCATEGORICAL command to examine whether students in each class differed in their likelihood of remaining in, leaving, or joining a STEM major across fall and spring semesters.

The overall test comparing mean final exam scores across classes was significant, χ^2 (2) = 21.81, *p* < .001, indicating that class membership was associated with differential final exam performance. Specifically, students in the *High-and-Stable* class scored significantly higher on the course final exam (*M* = 72.66) than students in the *Moderate-and-Slightly-Increasing* (*M* = 68.48) and *Moderate-and-Declining* (*M* = 63.39) classes. Mean differences between the *Moderate-and-Slightly-Increasing* and *Moderate-and-Declining* classes were non-significant (*p* = .071).

Similarly, the overall test comparing the likelihood of being in each of the four STEM major categories across science identity trajectory classes was statistically significant, χ^2 (6) = 35.81, *p* < .001, indicating that class membership was associated with STEM major stability and shifts across the fall and spring semesters. Class-specific probabilities for the four major categories are displayed in Table 4. Pairwise comparisons indicated that probabilities for the *High-and-Stable* class were significantly different from major category probabilities for the *Moderate-and-Slightly-Increasing* class, χ^2 (3) = 20.77, $p < .001$ and for the *Moderate-and-Declining* class, χ^2 (3) = 16.272, $p = .001$. Probability distributions indicated that students best classified in the *High-and-Stable* class were most likely to be STEM majors in both semesters (67.3% “Always STEM”), whereas in the *Moderate-and-Declining* class, students appeared to be evenly distributed between “Never STEM” (49.9%) and “Always STEM” (41.9%) categories. Students best classified in the *Moderate-and-Slightly-Increasing* class had a 54.9% likelihood of being a STEM major both semesters, and a 33.3% likelihood of being a non-STEM major in both semesters. Probabilities of switching out of a STEM major to a non-STEM major (2.9-6.4%) or from a non-STEM major to a STEM major (3.9%-6.5%) were relatively small, but appeared to differ slightly across classes, with the lowest probabilities for switching out of STEM observed in the *High-and-Stable* class. Probabilities for the *Moderate-and-Slightly-Increasing* class were not significantly different from the probabilities in the *Moderate-and-Declining* class, χ^2 (3) = 4.974, $p = .17$, indicating that students were similarly distributed across the four STEM major pattern categories in these two classes.

Discussion

We examined heterogeneous changes in science identity over the course of a semester-long introductory chemistry course. We also related these patterns of change to demographic and motivational predictors, as well as final exam scores and major status the following semester. Broadly, our findings examining changes during a single semester at a large, public university exhibit some parallels to the results of Robinson, Perez, et al. (2018) examining science identity over four years at an elite university: three classes were identified, two of which were moderate-to-high and fairly stable, and the third with initially moderate and declining science identity. Demographics and competence beliefs were statistically significant predictors of science identity trajectory class memberships, and lastly, science identity trajectories were differentially related to final exam scores and retention in a STEM major.

First, while the one-class baseline model was not the primary focus of our study, the non-significant latent linear slope indicated that stability best described the pattern of development for the entire sample. This differs from Robinson, Perez, et al. (2018) which found slight average declines in science identity over four years. The contrast does appear to support conceptualizations of identity development as a long-term process (Eccles, 2009; Waterman, 1993), with changes taking place over the course of years rather than weeks or months when considering overall samples. However, similar to Robinson, Perez, et al. (2018), allowing for heterogeneity in patterns of change revealed that some students actually do decline rapidly in their science identity appraisals, even within a single semester. Given the difficulty of replication when using GMM, the similarities and differences between the findings of the two studies are striking and informative, lending robust support to the theoretical conceptualization of college as a time with the potential for solidifying career-related identities or for rather dramatically destabilizing identity beliefs.

Specifically, we identified three science identity trajectories, reflecting three groups of students with distinct patterns of change. The *High-and-Stable* class consisted of students reporting very high science identity throughout the entire semester, the *Moderate-and-Slightly-Increasing* class included students reporting moderately high science identity that increased very slightly throughout the semester, and the *Moderate-and-Declining* class reported moderate initial levels of science identity with rapid declines across the semester. While the positive slope observed in the *Moderate-and-Slightly-Increasing* class was significant, the non-significant difference between the slopes of the *High-and-Stable* class and the *Moderate-and-Slightly-Increasing* class reinforce the notion that the increases observed in the *Moderate-and-Slightly-Increasing* class are very slight and potentially not meaningfully different from the stability observed in the *High-and-Stable* class. Thus, the differences observed with regard to predictors and outcomes for these two classes may be more reflective of the overall initial mean differences in levels of science identity. The prevalence of each trajectory class provides an enlightening view of students' experiences throughout a semester, indicating that for this sample, as in prior research (Robinson, Perez, et al., 2018), students largely did not appear to decline in their science identity beliefs, but that a small proportion of the sample declined rapidly and could be targeted for additional supports.

Covariances between intercepts and slopes also provide some interesting information about relations between initial levels and change over time. The overall sample exhibited a significant and negative covariance between intercept and slope, which would suggest that higher initial science identity was associated with greater risk for declines. However, the three-class model indicated that the covariance between intercept and slope was not significant for the *High-and-Stable* class. Instead, negative covariances were only found in the *Moderate-and-Slightly-Increasing* and *Moderate-and-Declining* classes. In other words, it appears that only for some students does higher initial science identity appear to be related to declines in science identity and future research should examine which factors might moderate this relationship. While we were not able to explore this mechanism specifically with our analytical approach, relations between competence beliefs and the trajectories indicate that higher perceived competence may promote overall more adaptive patterns of science identity.

Predictors of Science Identity Trajectories

Students from underrepresented racial/ethnic groups in science exhibited a greater likelihood of being in the *Moderate-and-Slightly-Increasing* class versus the *High-and-Stable* class. We hypothesized that URM students would be more likely to experience declines than stability or increases, so observed increases though slight, are encouraging and could indicate that the chemistry course is effectively supporting science identity development for students of all ethnicities in the *Moderate-and-Slightly-Increasing* class. Conversely, this finding also indicates that URM students were more likely than racial/ethnic majority students to begin college with somewhat lower science identity. This supports the hypothesis that students from underrepresented racial/ethnic minority groups may face additional barriers to pursuing STEM before they begin college. However, it is important to consider the pairwise comparisons indicating that URM students were no more likely to exhibit *High-and-Stable* versus *Moderate-and-Declining* science identity and were also no more likely to report *Moderate-and-Slightly-Increasing* versus *Moderate-and-Declining* patterns of science identity. Additionally, our results reflect only a single semester, and prior research indicates that underrepresented minority students may be more at risk for long-term declines Robinson, Perez, et al. (2018). Therefore, results regarding URM students should be interpreted with care.

Counter to our hypotheses and prior research examining four-year trajectories in science identity Robinson, Perez, et al. (2018), there were no gender differences in class membership in this sample. While subsequent research should complement this finding by examining potential gender differences in specific growth parameters (e.g., intercepts or slopes rather than latent class) of semester-long identity trajectories, this finding aligns with some prior research finding no gender differences in two-year college engineering identity trajectories Robinson, Lee, et al. (2018), particularly when controlling for other factors such as race/ethnicity, first-generation college student status, prior achievement, and/or competence beliefs. This suggests that gender does not play the most salient role as science identities are shaped in an introductory college science class; it may be that gender plays a more important role during high school, when values and expectancies are beginning to solidify and many students opt out of pursuing STEM fields (Britner & Pajares, 2001; Simpkins & Davis-Kean, 2005). This finding could also reflect a developmental trend of narrowing gender gaps in STEM-related motivation, as some prior research has documented during adolescence (Fredricks & Eccles, 2002). However, prior research suggests that gender differences in science identity development may emerge across four years of college Robinson, Perez, et al. (2018). As research shows that gender representation and stereotypes vary across specific sub-fields of science (Leslie et al., 2015; Riegle-Crumb & King, 2010), future research is needed to examine whether science identity development trajectories may show gender differences in sub-fields such as physics where women remain the minority.

Our finding that first-year students were more likely to be classified in the *Moderate-and-Slightly-Increasing* or *High-and-Stable* patterns of science identity development may indicate that upperclassmen in the course took the course later because they were less academically prepared or less committed to studying science and thus at greater risk for declines in science identity. This finding could also indicate that changes in identity are more likely to happen after the first semester. The results of prior research examining students who took gateway science courses in their first year found that the most rapid declines in science identity seemed to occur in the first year or two Robinson, Perez, et al. (2018). Therefore, our findings do point to some potentially systematic differences between students who take the gateway chemistry course in the first year versus later, even controlling for demographic variables and perceived competence.

Results regarding perceived competence indicate that differences in perceived competence at the beginning of the semester predicted membership in the *High-and-Stable* class versus the other two classes, such that higher perceived competence predicted a much greater likelihood of reporting high science identity that remained stable throughout the semester. This aligns with theoretical expectations (Eccles, 2009) and prior empirical findings (Robinson, Perez, et al., 2018; Chemers et al., 2011; Robnett et al., 2015), supporting the notion that students' confidence in their ability to succeed in their science courses is an important correlate of sustained science identity beliefs. It is also interesting to note that at the beginning of the semester, first-year students may be drawing only on their high school experiences to inform their competence beliefs. Nevertheless, entering college with lower perceived competence may be at particular risk for declining science identities, with implications for their subsequent grades and retention in a STEM major.

Outcomes Related to Science Identity Trajectories

Our examination of both exam and major outcomes in science extends prior research and enables additional understanding of both proximal and distal outcomes as well as distinct processes (e.g., performance and choice) in relation to identity development. As we predicted, membership in the three different science identity trajectory classes was associated with differences in course final exam scores and in STEM major statuses across the two semesters. Specifically, students reporting *High-and-Stable* science identity throughout the fall semester had higher final exam scores and appeared to have a higher probability of being in a STEM major at the end of both semesters compared to the other two classes, who did not differ from each other. This contrasts somewhat with the findings of Robinson, Perez, et al. (2018), wherein students in the two highest classes were similarly likely to be in science fields after graduation, perhaps indicating that differences between high and moderate levels of science identity can be crucial in predicting outcomes earlier on in the STEM pipeline, whereas high and moderate levels are equally beneficial for later outcomes. While it is unsurprising that students in the *High-and-Stable* class would be most likely to succeed in science, it is somewhat surprising that the differences between the *Moderate-and-Slightly-Increasing* and *Moderate-and-Declining* classes were non-significant. This suggests that both students' initial levels of science identity and stability over time may be key for promoting academic success in college science fields.

It is also important to consider that the four categories of STEM major statuses do not indicate the variety of patterns and reasons that students may have shifted majors across the two semesters. For instance, students within the "stayed in STEM" category included students who shifted from a general, broad major such as Engineering No Preference or Natural Science No Preference to a specific major (e.g., Mechanical Engineering or Neuroscience), indicating that they became more sure or refined in their major choice across the two semesters. Within this same "stayed in STEM" category were students who changed from a science major to an engineering major or vice versa, or who may have shifted from a major they perceived to be too difficult or too boring based on their experiences in their introductory coursework. Thus, our four categories do not capture the variety of shifting major patterns, but rather indicates that broadly, being in the *High-and-Stable* class appeared to be most predictive of staying in a STEM major across the two semesters. We also note here that major status was gathered at the end of each semester, so within-semester major shifts, particularly during students' enrollment in the introductory chemistry course, are not described in our data. However, this analysis does shed light on a potentially hidden portion of the leaky STEM pipeline, wherein students interested in pursuing STEM fields indicate their interest only by taking an introductory course rather than officially reflecting their STEM interests in an official, university-recorded major status (e.g., 29.0% of the sample was classified as "never STEM" yet they were enrolled in a required introductory course for a variety of STEM majors).

Overall, results indicate that students who are committed to science as part of their identities are more likely to persist in science and succeed in science coursework. It may also be that students who are committed to science as part of their identities are less likely to perceive a mismatch between the competitive environments in introductory science courses and their own motivational needs. Future research should further explore contextual predictors of stability and instability in science identity beliefs and students' perceptions of contextual supports in order to understand how developing identities can best be supported by instructors and programs in STEM.

Implications for Practice

Our findings have several implications for how students' developing science identities can be supported in introductory chemistry, including implications for who may need additional support, when supports may be best administered, and promising mechanisms for intervention. First, we found that upperclassmen were more vulnerable to maladaptive patterns of science identity development than were first-year students. Additional motivational or academic supports may be needed for upperclassmen in introductory science courses, particularly as these courses often focus on the specific needs of first-year students and so may contribute to a low sense of belonging among these already seemingly at-risk students.

Second, differences between the latent classes on outcomes of interest, including non-significant differences between the *Moderate-and-Slightly-Increasing* and the *Moderate-and-Declining* classes on outcomes, indicate that both initial levels of science identity and stability over time are important for promoting optimal outcomes. Considering that students from underrepresented racial/ethnic groups were more likely to be in the *Moderate-and-Slightly-Increasing* class, supporting students' initial levels of science identity may be an important factor for mitigating representation gaps in STEM fields. This suggests that interventions to broaden participation in STEM via science identity may best be administered on a programmatic level or before beginning college to promote high science identity at the beginning of the semester, particularly for underrepresented students.

Lastly, the relations of competence beliefs at the beginning of the semester to more facilitative patterns of science identity development suggest a potential mechanism for intervention. Although further experimental research is needed to examine whether interventions can effectively shift these beliefs in introductory science courses, our results indicated that helping to ensure that students begin the semester with high competence beliefs may be a promising avenue for promoting science identity development throughout the semester. For example, instructors might prioritize providing opportunities for success early on and helping students hone their learning strategies in an effort to boost competence beliefs and subsequent science identity stability or growth (Linnenbrink-Garcia, Patall, & Pekrun, 2016). While only a small proportion of students exhibited declines in science identity throughout the semester, interventions may be most effective when used to boost initial levels of science identity, potentially mitigating the less adaptive outcomes associated with membership in the *Moderate-and-Slightly-Increasing* class, which consisted of almost half of the sample. However, students at risk for declines may be targeted for additional supports throughout the semester.

Limitations and Future Directions

It is encouraging to observe that the majority of students in our sample reported stable or slightly increasing patterns of science identity across a semester, as this could indicate that current university programming is effectively supporting science identity. Indeed, there is some evidence that the unique curriculum of this chemistry course is more supportive of students' learning and persistence in chemistry as compared to traditional chemistry courses (Williams, Underwood, Klymkowski, & Cooper, 2015). It could also be that the majority of students in this sample would remain stable or increase in science identity even without external supports, and indeed prior research in another setting also found that the majority of students did not experience declines in science identity Robinson, Perez, et al. (2018). Therefore, future research is needed to more closely examine the causal mechanisms underlying science identity development, particularly to determine whether external supports can encourage more positive trajectories for students beginning with lower science identity. Further, the relatively small size of the *Moderate-and-Declining* class and resulting larger standard errors may have prevented the detection of between-class differences on predictors and outcomes.

Although prior research identified quadratic change in 4-year science identity trajectories Robinson, Perez, et al. (2018) and in attainment value trajectories from 4th grade to college (Musu-Gillette et al., 2015), data for the present study contained only three time points and thus we were unable to examine quadratic change. While findings about linear change contribute important knowledge about the general trends of science identity development in this sample, future research examining quadratic change would allow researchers and science instructors to identify at what point in the semester students appeared to decline most rapidly and thus might need additional supports.

It is also important to acknowledge that due to the current capabilities of the three-step procedure as implemented in Mplus, the analyses examining predictors of science identity trajectories used listwise deletion and thus examined only those with T1 data. Our missing data analyses indicate that this listwise deletion resulted in overrepresenting the experiences of racial/ethnic majority students, women, and those with higher science identity in estimating relations among science identity trajectories and their correlates. Furthermore, our overall sample consisted of primarily White and Asian students, and so findings regarding the relations of race/ethnicity to science identity trajectories may not generalize to a more diverse sample. In particular, students from underrepresented racial/ethnic groups may, in fact, be more likely to experience sharper declines in science identity compared to majority peers, however this may not have been detected in our data due to low power for this comparison. Future research should continue exploring potential demographic differences in science identity development, as well as motivational correlates in order to most effectively understand and support positive developmental trajectories for students in STEM fields.

Conclusion

Introductory gateway courses can destabilize students' identities, particularly in challenging and often competitive STEM fields. While prior research has indicated that identity-related beliefs may decline on average in the long- and short-term, suggesting broad-based supports are needed to buffer students' motivational trajectories, we investigated heterogeneous semester-long trajectories of science identity in an effort to capture the nature and prevalence of typical development in a large introductory course. Building on prior research examining long-term trajectories (Robinson, Perez, et al. (2018); Robinson, Lee, et al., 2018), our findings inform the theoretical conceptualization of attainment value as largely stable, though with the potential for rapid change even within a single semester. Indeed, though identity-related beliefs are often conceptualized as relatively stable, our results indicate that some students in a gateway chemistry course experienced sharp declines in science identity within a single semester. Relations to predictors and outcomes indicate that both underrepresented minority students and upperclassmen were underrepresented in the *High-and-Stable* class, which exhibited the most adaptive outcomes with regard to final exam performance and STEM retention the following semester. This contrasts with and extends extant literature on demographic differences in science motivation, indicating that although a particular course may effectively support positive trajectories among sub-populations with lower initial science identity, prior experiences and initial levels of science identity may in fact be more powerful for students' achievement and major outcomes. Efforts to promote equity in science representation require additional understanding of how students' experiences shape their science identity development before their entry into key introductory courses. These results add to theoretical understandings of science identity development and point to the importance of high and maintained identification with science as a predictor of success in STEM fields. Results also indicate a need for additional supports for students from underrepresented racial and ethnic groups and for students taking gateway STEM courses as upperclassmen.

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APPENDIX: Full List of Scale Items

Science Identity

1. I consider myself a science person.
2. Being involved in science is a key part of who I am.
3. Being someone who is good at science is important to me.
4. Being good in science is an important part of who I am.

Academic Perceived Competence

1. I'm certain I can master the skills taught in science classes.
2. I'm certain I can figure out how to do the most difficult class work in science.
3. I can do almost all the work in science classes if I don't give up.
4. Even if the work in science is hard, I can learn it.
5. I can do even the hardest work in science if I try.

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Highlights:

- Science identity trajectories were examined in a gateway college science course.
- Three trajectory classes were identified.
- Demographics and perceived competence were related to trajectory class membership.
- The *High-and-Stable* class was most adaptive for achievement and major outcomes.

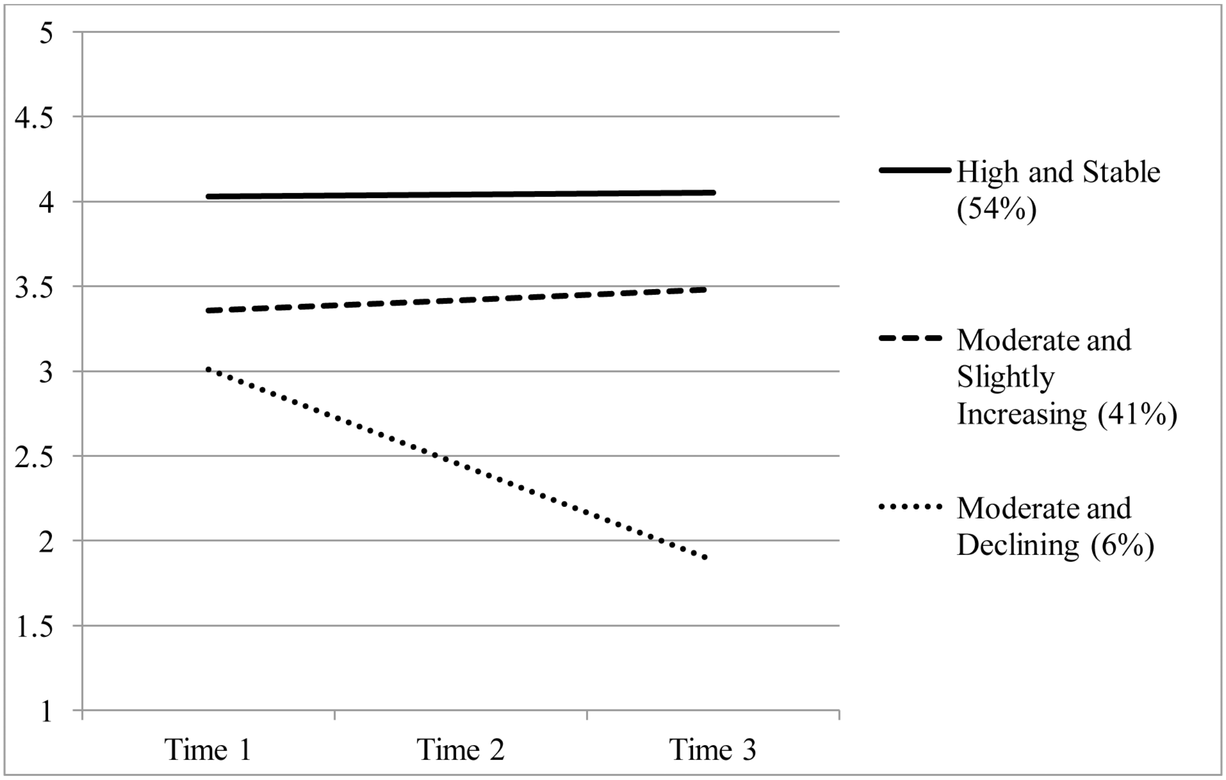

Figure 1.

Model-implied trajectories of science identity in a semester-long introductory chemistry course.

Table 1

Correlations and Descriptive Statistics for Study Variables

	1	2	3	4	5	6	7	8
1. SID T1								
2. SID T2	.70**							
3. SID T3	.50**	.59**						
4. PC T1	.39**	.53**	.33**					
5. Exam	.15**	.17**	.15**	.19**				
6. Gender	−.003	−.06*	−.04	−.09**	−.07**			
7. URM	−.04	−.05*	−.02	.02	−.19**	.04		
8. 1st Year	.09**	.13**	.03	.14**	.23**	−.02	−.11**	
n	885	1661	844	884	1635	1670	1655	1647
Min.	1	1	1	1	0	0	0	0
Max.	5	5	5	5	180	1	1	1
Mean	3.68	3.66	3.66	4.01	129.22	0.55	0.11	0.74
S.D.	0.79	0.79	0.85	0.62	28.08	0.50	0.32	0.44
Skewness	−0.58	−0.43	−0.63	−0.84	−0.78	-	-	-
Kurtosis	0.39	0.13	0.61	2.57	0.36	-	-	-

Note: All observed correlations, means, and SDs were calculated in SPSS. SID = Science identity. PC =Perceived competence, Exam = Final exam score, Major = STEM major status at the end of spring semester. Science identity and perceived competence variables ranged from 1-5; final exam scores ranged from 0 to 100.

** $p < .01$,

*** $p < .05$

Table 2

Results of Tests for Measurement Invariance of Science Identity Over Time

Model	χ^2 (df)	RMSEA	CFI	ΔCFI	TLI	SRMR
Configural	380.357 (51)	0.062	0.957	-	0.944	0.034
Weak	400.039 (57)	0.060	0.955	−.002	0.948	0.047
Strong	469.333 (63)	0.062	0.947	−.008	0.944	0.056
Strict	508.524 (71)	0.061	0.942	−.005	0.947	0.070

Table 3

Fit Statistics for Second-Order Linear Model and Second-Order Growth Mixture Models

	Class-Specific Parameters	# of classes	# of Parameters Estimated	BIC	Class Proportions (%)
Model 0	-	1	16	29582.376	100
Model 1	Means of latent slope & intercept	2	19	29494.181	1, 99
		3	22	29432.130	1, 98, 1
		4	25	29398.192	11, 1, 1, 88
		5	28	29411.034	11, 1, 1, 87, 1
Model 2	Means, variances, and covariances of latent slope & intercept	2	Non-interpretable solution		
		3	Non-interpretable solution		
		4	Non-interpretable solution		
		5	Non-interpretable solution		
Model 3	Means, variances, and covariances of latent slope & intercept; residuals of observed indicators	2	25	28146.531	54, 46
		3	**36**	**28086.671**	**54, 6, 41**
		4	Non-interpretable solution		
		5	Non-interpretable solution		
Model 4	Means of latent slope & intercept; residuals of observed indicators	2	23	28203.287	56, 44
		3	Non-interpretable solution		
		4	Non-interpretable solution		
		5	Non-interpretable solution		

Note: The selected solution is presented in bold.

Table 4

Model-Estimated Class-Specific Probabilities for Fall and Spring STEM Major Status Categories

Probabilities by Class	Probability	S.E.
High and Stable		
Never STEM	0.233	0.018
Always STEM	0.673	0.019
Switched out of STEM	0.029	0.651
Switched into STEM	0.065	0.009
Moderate and Slightly Increasing		
Never STEM	0.333	0.021
Always STEM	0.549	0.023
Switched out of STEM	0.064	0.011
Switched into STEM	0.054	0.010
Moderate and Declining		
Never STEM	0.499	0.067
Always STEM	0.419	0.068
Switched out of STEM	0.044	0.029
Switched into STEM	0.039	0.027