

Student Integration into STEM Careers and Culture: A Longitudinal Examination of Summer Faculty Mentors and Project Ownership

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ABSTRACT

It is widely recognized that the United States needs to attract and retain more people in science, technology, engineering, and mathematics (STEM) careers. Intensive undergraduate research experiences (UREs) are one of the few strategies shown to improve longitudinal student interest and persistence in STEM-related career pathways; however, less is known about the underlying process linking activities to positive outcomes. The tripartite integration model of social influences (TIMSI) provides a framework for understanding the social influence processes by which students integrate into STEM careers and culture. The current study used a longitudinal design and latent growth curve modeling to examine and predict the development of scientific research career persistence intentions over the course of an intensive summer URE. The latent growth curve analysis showed that student persistence intentions declined and rebounded over the course of the summer. Furthermore, the positive impact of faculty mentor role modeling on growth trajectories was mediated through internalization of science community values. In addition, project ownership was found to buffer students from the typical trend of declining and rebounding persistence intentions. The TIMSI framework illuminates the contextual features and underlying psychological processes that link UREs to student integration into STEM careers and culture.

INTRODUCTION

It is widely recognized that the United States needs to attract and retain more people in science, technology, engineering, and mathematics (STEM) careers in order to drive innovation and broaden economic prosperity (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine [NAS *et al.*], 2007; Holdren and Lander, 2012). At the undergraduate level, national statistics show high attrition from STEM majors and career paths (~50%; Hurtado *et al.*, 2009; Chen, 2013; Olson and Riordan, 2012). Even among high-achieving STEM majors, longitudinal evidence indicates that student aspirations to pursue STEM-related research careers lessen as they advance toward graduation (Schultz *et al.*, 2011). Although stakeholders and researchers have begun to identify a variety of promising curricular and cocurricular strategies to support student persistence in STEM (e.g., learning communities, inquiry-based curriculum; Russell *et al.*, 2007; Kuh, 2008; Graham *et al.*, 2013; Estrada *et al.*, 2016), undergraduate research experiences (UREs) are one of the few strategies shown to improve longitudinal interest in STEM-related careers and persistence rates (Nagda *et al.*, 1998; Hathaway *et al.*, 2002; Russell *et al.*, 2007; Schultz *et al.*, 2011; Eagan *et al.*, 2013; Rodenbusch *et al.*, 2016; National Academies of Sciences, Engineering, and Medicine [NASEM], 2017; Hernandez *et al.*, 2018). Thus, engaging students in

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authentic UREs has become a cornerstone of individual and institutional efforts to improve learning and persistence in STEM (Lopatto, 2003; Russell *et al.*, 2007; Laursen *et al.*, 2010; Linn *et al.*, 2015; Mervis, 2016; NASEM, 2017). Despite growing evidence of the effectiveness of UREs, less is known about the key contextual features of these experiences and the psychological factors that explain how, why, and for whom UREs enhance interest and persistence (NASEM, 2017). Therefore, the current study examined the influence of key contextual features (e.g., faculty mentor psychosocial support) and psychological factors (e.g., scientific identity) that are hypothesized to influence the longitudinal growth of STEM career persistence intentions.

Characteristics and Benefits of UREs

Undergraduate research experiences vary widely in their goals and contextual features (e.g., targeted student population [lower division vs. upper division], duration [number of months or semesters], intensity [number of hours per week], level of project ownership and independence, timing [academic year vs. summer], structure [traditional faculty apprenticeship vs. course based]; Seymour *et al.*, 2004; Auchincloss *et al.*, 2014; Linn *et al.*, 2015; NASEM, 2017). However, the common themes that define UREs concern engaging students in authentic scientific practices and in discovery that is of interest to the larger scientific community (Seymour *et al.*, 2004; Sadler *et al.*, 2010; Auchincloss *et al.*, 2014; NASEM, 2017). UREs that engage students in authentic practices and discovery are associated with diverse benefits for learning (e.g., deeper conceptual understanding) and higher rates of persistence in STEM majors and career pursuits (Lopatto, 2004, 2007; Russell *et al.*, 2007; Schultz *et al.*, 2011; Thiry *et al.*, 2012; Eagan *et al.*, 2013; Graham *et al.*, 2013; Linn *et al.*, 2015; NASEM, 2017; Hernandez *et al.*, 2018).

Longitudinal experimental and quasi-experimental studies have shown that, compared with peers without research experiences, undergraduates who engage in apprenticeship-style faculty-mentored UREs are significantly more likely to maintain higher aspirations for scientific careers, graduate with STEM baccalaureate degrees, enroll in STEM-related graduate programs, and engage in postbaccalaureate STEM-related careers (Nagda *et al.*, 1998; Hathaway *et al.*, 2002; Schultz *et al.*, 2011; Eagan *et al.*, 2013; Hernandez *et al.*, 2018). The benefits of UREs are particularly pronounced for students who engage in multiple high-intensity (10+ hours per week) experiences, such as intensive summer research programs (e.g., National Science Foundation-funded Research Experience for Undergraduates [NSF REU]; Hernandez *et al.*, 2018). The present study focused on apprenticeship-style faculty-mentored UREs in the context of an intensive summer research experience (i.e., typically 40 hours per week for 8 weeks).

There is a growing list of contextual features of UREs associated with beneficial outcomes (Hunter *et al.*, 2007; Lopatto, 2007; Sadler *et al.*, 2010; Thiry *et al.*, 2011, 2012); however, mentorship support and project ownership are increasingly seen as essential for enhancing student interest and persistence in STEM career pathways (Lopatto, 2003; Pfund *et al.*, 2006, 2016; Hanauer *et al.*, 2012; Hanauer and Dolan, 2014; Hernandez *et al.*, 2016; NASEM, 2017). Although definitions of mentorship vary, in undergraduate contexts, “mentorship” can be defined as

a developmental relationship between a more experienced person (mentor) and a less experienced person (protégé), wherein the mentor provides support to enhance the protégé’s professional development and integration into the field (Jacobi, 1991; Eby *et al.*, 2007; Crisp and Cruz, 2009). Studies of faculty–student mentoring relationships have shown that support can be operationalized in a variety of ways: psychosocial support (e.g., counseling), instrumental support (e.g., providing opportunities for skill development, learning, and advancement), role modeling (e.g., providing inspiration by being a relevant and attainable example of success), coauthoring experiences (e.g., collaborative presentations or publications), and overall relationship satisfaction (Jacobi, 1991; Lockwood and Kunda, 1997; Paglis *et al.*, 2006; Eby *et al.*, 2013; Hernandez *et al.*, 2016; Pfund *et al.*, 2016). Project ownership has been broadly defined as student perceptions of agency, personal responsibility, and commitment to and identification with a project (Hanauer *et al.*, 2012). A recent linguistic analysis of undergraduate STEM students’ discussions of their research projects revealed that project ownership entailed making connections between scientific inquiry and personal history, agency (i.e., support seeking) and mentorship, excitement toward inquiry, overcoming challenges, and expressions of satisfaction with personal scientific achievement (Hanauer *et al.*, 2012; Hanauer and Dolan, 2014). Both mentorship support and project ownership have been associated with beneficial outcomes, such as gains in science identity and persistence intentions (Hanauer and Dolan, 2014; Linn *et al.*, 2015; Estrada *et al.*, 2018).

The benefit of engaging in UREs is increasingly clear; however, the developmental processes that link UREs and contextual features to persistence outcomes is not well understood (NASEM, 2017). This gap in the literature is due, in part, to the fact that much of the URE literature has been focused on effectiveness rather than process. More specifically, much of the extant literature has focused on changes in outcomes measured at the end or long after the URE, rather than on the developmental processes that occur within the context of the URE (Lopatto, 2007; Adedokun *et al.*, 2014; Fakayode *et al.*, 2014; Fuchs *et al.*, 2016; Hernandez *et al.*, 2018). Furthermore, social science theories of motivation and persistence have only recently begun to inform and describe the developmental processes linking URE activities to beneficial outcomes through changes in psychological processes (Lent *et al.*, 1994; Estrada *et al.*, 2011; Graham *et al.*, 2013; Wang and Degol, 2013; NASEM, 2017). A theory-driven and developmental process-focused approach can extend our understanding of the underlying psychological processes linking activities to outcomes.

Developmental Process of Integrating into STEM Careers and Culture

The tripartite integration model of social influences (TIMSI) describes the developmental process by which students integrate into STEM careers and culture (Estrada *et al.*, 2011, 2018). TIMSI extends Kelman’s social influence theory of how individuals socialize into social groups (or systems) to STEM careers and culture (Kelman, 2006; Estrada *et al.*, 2011). Kelman’s social influence theory posits that individuals socialize into a group through three distinct processes: compliance (i.e., adhering to rules and norms to garner rewards and avoid punishment), identification (i.e., constructing a social identity that

incorporates the activities of the group), or internalization (i.e., adopting and sharing the values of the group; Kelman, 2006). The TIMSI model operationalizes these processes in terms of science efficacy, science identity, and internalizing scientific community values, respectively (Estrada *et al.*, 2011). Science efficacy describes individuals' confidence that they can successfully execute scientific practices and thereby receive rewards in academic settings (Bandura, 1977; Estrada *et al.*, 2011). Science identity describes the degree to which individuals see themselves as scientists, that is, the psychological centrality of the scientist social identity (Chemers *et al.*, 2011; Estrada *et al.*, 2011). Internalization of science community values represents the degree to which individuals authentically value the objectives of the scientific community (e.g., scientific discovery; Estrada *et al.*, 2011). The process of socializing into a group develops over time, and thus, the social influence and integration processes need to be measured over time.

Faculty-mentored research experiences can function as influence agents to integrate students into STEM careers and culture (Estrada *et al.*, 2011, 2018; Hernandez *et al.*, 2016). That is, UREs and mentors can draw students into STEM careers and culture through the provision of experiences and support that encourage students to internalize the norms, behaviors, attitudes, identity, and values of the scientific community (Bauer and Green, 1994; Thiry and Laursen, 2011; Kardash and Edwards, 2012; Woodcock *et al.*, 2015). A preponderance of empirical research has shown positive associations between science self-efficacy, science identity, scientific community values, and STEM persistence (Byars-Winston *et al.*, 2010; Chemers *et al.*, 2011; Estrada *et al.*, 2011, 2018; Graham *et al.*, 2013; Merolla and Serpe, 2013; Robnett *et al.*, 2015). Among studies that included all three social influence processes, evidence typically shows that science identity and science community values uniquely predict persistence (Estrada *et al.*, 2011, 2018; Hanauer *et al.*, 2016). However, little empirical research

has examined the impact of URE contextual features on STEM persistence through changes in science efficacy, science identity, and science community values (i.e., the TIMSI social influence processes or mediators; Estrada *et al.*, 2018). To date, one study has examined the impact of mentorship support on postbaccalaureate persistence in a STEM career, finding that the impact of mentorship was mediated through science identity (Estrada *et al.*, 2018). Research questions and hypotheses about the direct effects of mentorship support and project ownership in the context of the URE on integration into STEM careers and culture, as well as their indirect effects on integration through the social influence processes of science efficacy, identity, and community values, have yet to be empirically tested.

Current Study

The current study was designed to examine the processes by which students are drawn into STEM careers and culture, while also attending to methodological and theoretical limitations in the extant research. Specifically, the current study used longitudinal design within the context of intensive summer UREs (SUREs) to measure changes in STEM career persistence intentions over the course of the experience. In addition, the current study was guided by the TIMSI model to assess the psychological processes that link URE contextual features to student integration into STEM careers and culture (i.e., persistence intentions). The present study addresses the following TIMSI-informed research questions and hypotheses.

1. How do scientific research career persistence intentions change over the course of an intensive summer research experience (i.e., times 1, 2, and 3)?
2. To what degree do the qualities of faculty mentorship, project ownership, science self-efficacy, science identity, and scientific community values (measured at time 2) predict final scientific persistence intentions (time 3) and growth in persistence intentions?

3. To what degree are the effects of faculty mentorship support and project ownership on scientific persistence intentions mediated through science self-efficacy, science identity, or science community values (controlling for initial levels of efficacy, identity, and values)? On the basis of TIMSI, we hypothesized that faculty mentorship support, project ownership, science self-efficacy, science identity, and science community values would all be positively correlated with scientific research career persistence intentions.
- On the basis of TIMSI, and as shown in Figure 1 (*a* paths), we hypothesized that faculty mentorship support and project ownership would positively predict the TIMSI social influence processes (i.e., mediators) of science self-efficacy, identity, and community values over and above baseline levels of each (i.e., predict changes in efficacy, identity, and values). Furthermore, as shown in Figure 1 (*a* × *b* mediated effect), we hypothesized

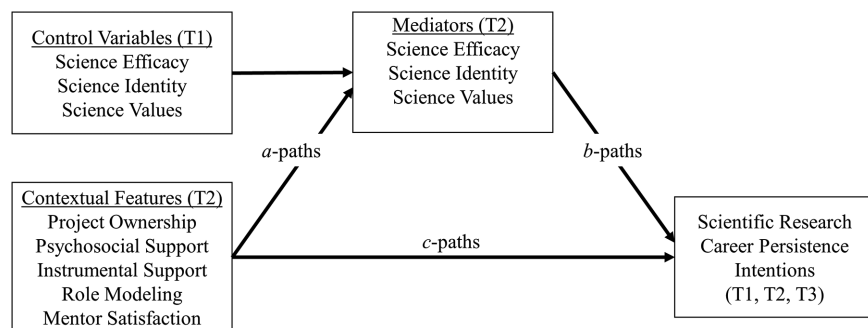


FIGURE 1. Conceptual model relating mentor supports and project ownership to scientific career persistence intentions through changes in scientific efficacy, science identity, and science community values. *a*-paths: the effect of mentor supports and project ownership (contextual features) on science efficacy, identity, and values (mediators), controlling for initial levels of science efficacy, identity, and values; *b*-paths: the effects of the science efficacy, identity, and values on the growth in science career persistence intentions (outcome), controlling for mentor support and project ownership; *ab*: the effects of mentorship and project ownership on growth in science career persistence intentions through their impact on science efficacy, identity, and values (not shown); and *c*-paths: the effects of mentorship and project ownership on growth in science career persistence intentions, controlling for science efficacy, identity, and values; T1: measurement occurred at time 1 (typically week 1 of 8), T2: measurement occurred at time 2 (typically week 4 of 8), T3: measurement occurred at time 3 (typically week 8 of 8).

that the positive effect of faculty mentorship support and project ownership on scientific career persistence intentions would be mediated through identity and values.

METHODS

Participants and Procedures

Two hundred three undergraduate students at a U.S. university participated in the study (59.6% female; median age = 20 years; 4.9% African American, 8.9% Asian, 2.5% Hispanic, 71.9% white non-Hispanic, 11.8% other). Most participants were students of the host institution (87%), and most were either rising seniors or rising juniors (47.8 and 37.4%, respectively). Students self-reported majoring in a variety of STEM disciplines across the life sciences (e.g., animal science, biology, immunology, neuroscience; 36%), physical sciences (e.g., chemistry, geology, physics; 29%), social sciences (e.g., psychology, political science; 8%), and computer science and engineering (e.g., aerospace, mechanical; 27%).

Participants were in the following programs for their summer research experience: a Cancer Institute research experience (2.5%), a McNair summer research experience (9.9%), NSF REUs for Nanotechnology (12.3%) and Chemistry (9.9%), a state-funded SURE (55.5%), or a local summer undergraduate research internship (10.3%). All programs provided financial support in the form of a stipend. However, the programs varied (slightly) in terms of their length (8–10 weeks) and in the types and intensity of supports they provided for student research experiences. Each program offered some degree of support for team-building activities, mentoring workshops and support from program managers, networking events, and scientific communication opportunities (e.g., communication training and judged poster presentations). For example, the REU Nanotechnology program emphasized accountability of research progress through weekly group meetings facilitated by Web conferencing. Other programs, such as SURE, offered participants a variety of opportunities for specific trainings (e.g., responsible conduct of research, scientific search engines) and career mentoring seminars.

Students were assessed at the beginning, midway, and end of their SURE (approximately weeks 1, 4, and 8 of the summer experience). Questionnaires were administered when students attended group meetings for their respective programs. At each time point, participants completed paper-and-pencil questionnaires that assessed the quality and characteristics of their research and mentoring experiences with their faculty mentors (e.g., project ownership, psychosocial support), science career persistence intentions, science self-efficacy, science identity, science community values, and demographics. Participants also completed several measures unrelated to the current study (e.g., university belonging). Participation was voluntary, and participants did not receive any compensation. All procedures were approved by the local university's institutional review board.

Measures

Outcome

Scientific career persistence intentions (Woodcock *et al.*, 2015): This is a two-item scale that measures student intent to pursue a science career. Participants responded to the

following items: “To what extent do you plan to pursue a science-related graduate degree?” and “What is the likelihood of you obtaining a science-related undergraduate degree?” on a scale from 1 (definitely will not) to 10 (definitely will). A composite score was created by averaging all items together, such that higher scores indicated greater intent to pursue a science career.

Social Influence Processes (Mediators)

Science self-efficacy (Chemers *et al.*, 2011): This is a five-item scale that assesses confidence and abilities to function as a scientist. Participants rated their confidence that they could complete a series of scientific tasks (e.g., “Use technical science skills”); the complete list of items is provided in the Supplemental Material) on a scale from 1 (not at all confident) to 5 (absolutely confident). A composite score was created by averaging all items together, such that higher scores indicated greater science self-efficacy.

Science identity (Chemers *et al.*, 2011): This is a three-item scale that assesses the extent to which individuals think of themselves as scientists. Participants responded to the items (e.g., “I have come to think of myself as a scientist”); the complete list of items is provided in the Supplemental Material) on a scale from 1 (strongly disagree) to 5 (strongly agree). A composite score was created by averaging all items together, such that higher scores indicated greater science identity.

Science community values (Estrada *et al.*, 2011): This is a four-item scale that assesses the extent to which individuals value science. Participants rated the degree to which statements were like themselves (e.g., “A person who thinks discussing new theories and ideas between scientists is important”); the complete list of items is provided in the Supplemental Material) on a scale from 1 (not at all like me) to 5 (very much like me). A composite score was created by averaging all items together, such that higher scores indicated greater science values.

URE Contextual Features

Faculty mentorship role modeling (Hoyt *et al.*, 2012): This four-item scale was adapted to the current summer research context to assess the extent to which individuals identified their faculty mentor as a role model (e.g., “I identify with the life of my mentor”). Participants responded to items on a scale from 1 (strongly disagree) to 5 (strongly agree). A composite score was created by averaging all items together, such that higher scores indicated identification of their faculty mentor as a role model.

Faculty mentorship satisfaction (Ensher and Murphy, 1997): This three-item scale assesses the extent to which individuals were satisfied with their faculty mentoring relationship (e.g., “My mentor met my expectations”); the complete list of items is provided in the Supplemental Material). Participants responded to items on a scale from 1 (strongly disagree) to 5 (strongly agree). A composite score was created by averaging all items together, such that higher scores indicated greater satisfaction with the faculty mentoring relationship.

Faculty psychosocial and instrumental mentorship support (Dreher and Ash, 1990; Hernandez *et al.*, 2016): The faculty mentorship psychosocial support subscale consisted of four items (e.g., “To what extent has your mentor encouraged you to talk openly about anxieties and fears?”), while the instrumental support subscale consisted of six items (e.g., “To what extent has your mentor helped you improve your writing skills?”; the complete list of items is provided in the Supplemental Material). Participants responded to the items on a scale from 1 (not at all) to 5 (a very large extent). The items were averaged together to create subscales scores; higher scores indicated greater faculty mentor psychosocial or instrumental support.

Project ownership (I. Hernandez and A. Woodcock, personal communication): This nine-item scale assesses the extent to which individuals perceive ownership of and independence in the conduct of their research project (i.e., “Was I in control of my research project?”). This scale emphasizes the agency and mentorship facets of the ownership construct (a complete list of item contents is provided in the Supplemental Material). Participants responded to items on a scale from 1 (not at all) to 5 (to a very large extent). A composite score was created by averaging all items together, such that higher scores indicated greater ownership over the research project.

Demographics: Participants were also asked to provide demographic information (e.g., age, gender, URE program).

Missing Data, Nesting, Statistical Assumptions, and Model Fit

The response rate varied slightly across the three survey administrations; see Table 1. Descriptive analysis showed that 65.5% of participants completed all three surveys, 28.6% completed two surveys, and 5.9% completed one survey. Missing data analyses were conducted to identify the missing data mechanism (i.e., missing completely at random [MCAR], missing at random, or not missing at random; Enders, 2010, 2011). Little’s MCAR test (Little, 1988) revealed that the data were missing completely at random, $\chi^2(73) = 77.55, p = 0.34$; therefore, our analysis plan proceeded using maximum-likelihood estimation without adjustments for missing data (e.g., auxiliary variables; Enders, 2010).

These data were collected from students nested within several different SURE programs (e.g., Cancer Institute). Nested data structures can violate the assumption of independent errors, as evidenced in intraclass correlations (ICCs), which results in biased model estimates (Raudenbush and Bryk, 2002). A preliminary analysis revealed that between 7 and 17% of the variability in scientific persistence intentions was accounted for by summer programs (i.e., $ICC_{\text{time } 1} = 0.07, ICC_{\text{time } 2} = 0.13, ICC_{\text{time } 3} = 0.17$). Therefore, the nesting variable representing the six URE programs was recoded into a set of five dummy-coded variables and entered into all statistical models to control for nesting (Cohen *et al.*, 2003). In addition, all continuous predictor and control variables were centered in substantive analyses.

Preliminary data screening, statistical assumption checking, and missing data analysis were conducted in SPSS v. 23. Outlier analysis using leverage values, Studentized deleted residuals, and Cook’s *D* values indicated no extreme outlier cases

(Judd *et al.*, 2009). In addition, residual diagnostics indicated that the assumptions of linearity, normality of residuals, and homoscedasticity were met.

All subsequent data analyses were conducted in a structural equation modeling (SEM) framework using maximum-likelihood estimation in *Mplus* v. 7.4 (Muthén and Muthén, 1998–2017). The SEM framework offers distinct advantages over other multivariate statistical methods for assessing the fit of theoretically derived hypotheses to data. SEM allows the researcher to specify the conceptual or theoretical model and provides a variety of indicators that describe the adequacy of the model–data fit. The various indices of model–data fit allow researchers to evaluate the degree to which the data speak against the model (Kline, 2016). For example, the present study will test the model–data fit of our conceptual model (Figure 1), wherein the social influence processes and contextual features predict scientific persistence intentions over time. In addition, the SEM framework allows for direct comparisons of alternative (nested) models based on their model–data fit. For example, the present study will compare the model fit of the conceptual model versus an alternative (null) model, wherein the social influence processes and contextual features do not predict scientific persistence intentions over time.

Model fit was assessed using a variety of indices, including the chi-square goodness of fit test (χ^2), root-mean-square error of approximation (RMSEA; i.e., a parsimony index), the comparative fit index (CFI; i.e., an incremental index), and the standardized root-mean-square residual (SRMR; i.e., an absolute fit index). Consistent with current standards, we evaluated model fit indices relative to recommended cutoff values (Hu and Bentler, 1999): RMSEA values at or below 0.05 (or nonsignificant *p*-value for close fit [p_{close}] test), CFI values at or above 0.95, and SRMR values at or below 0.08 indicated good model–data fit.

Finally, we implemented a Bonferroni correction on the basis of the number of outcome variables in our models to evaluate the statistical significance of parameter estimates (alpha level = $0.05/5 = 0.01$). We took this precaution to control the type I error rate, as it has been shown that large structural equation models with many parameters and exploratory analyses can inflate the type I error rate (Green and Babyak, 1997; Cribbie, 2000).

RESULTS

Persistence Intentions Exhibit Quadratic Growth over Summer UREs

Before testing hypotheses, we examined the descriptive statistics for changes in scientific career persistence intentions over time. The average level of persistence intentions declined from time 1 ($M = 7.67$) to time 2 ($M = 7.46$), then bounced back in time 3 ($M = 7.64$). The pattern of decline followed by rebound indicated a quadratic growth trend, which we modeled in SEM.

Structural equation model 1 (SEM 1) was designed to formally address research question 1 (i.e., the degree to which persistence intentions change over the course of a summer research experience). We used latent growth curve analysis to model the pattern of decline followed by a rebound in scientific career persistence intentions over time (i.e., analysis of linear and quadratic growth trends), while statistically controlling for any potential differences across summer programs (i.e., controlling for nesting of students within programs). The results

TABLE 1. Summary of descriptive statistics and correlations among variables in the models^a

Variable ^b	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Persistence intentions (T3)	0.80													
2 Persistence intentions (T2)	0.68**	0.76												
3 Persistence intentions (T1)	0.52**	0.68**	0.73											
4 Science efficacy (T2)	0.03	0.11	0.07	0.79										
5 Science identity (T2)	0.25**	0.30**	0.16*	0.42**	0.84									
6 Science values (T2)	0.36**	0.35**	0.25**	0.32**	0.46**	0.80								
7 Psychosocial support (T2)	0.02	0.00	-0.05	0.38**	0.19*	0.16*	0.82							
8 Instrumental support (T2)	-0.03	0.01	-0.02	0.47**	0.20**	0.14	0.67**	0.81						
9 Role modeling (T2)	0.17	0.25**	0.09	0.35**	0.41**	0.38**	0.43**	0.49**	0.85					
10 Satisfaction (T2)	0.18*	0.19**	0.11	0.39**	0.31**	0.22**	0.61**	0.61**	0.53**	0.83				
11 Project ownership (T2)	0.04	0.10	-0.06	0.41**	0.24*	0.27*	0.36**	0.41**	0.37**	0.34**	0.85			
12 Science efficacy (T1)	0.03	0.09	0.03	0.57**	0.29**	0.26**	0.18*	0.27**	0.25**	0.23**	0.27*	0.77		
13 Science identity (T1)	0.24**	0.20**	0.32**	0.22**	0.59**	0.38**	-0.03	0.00	0.20**	0.18*	0.01	0.23**	0.84	
14 Science values (T1)	0.24**	0.27**	0.23**	0.22**	0.25**	0.56**	0.08	0.03	0.15	0.15*	0.22*	0.23**	0.45**	0.75
N	157	167	203	167	167	167	167	167	167	167	85	203	202	203
M (SD)	7.64 (2.33)	7.46 (2.32)	7.67 (1.96)	3.60 (0.69)	4.29 (0.65)	4.59 (0.50)	3.55 (1.01)	3.56 (0.88)	3.89 (0.72)	4.27 (0.67)	3.60 (0.76)	3.12 (0.68)	4.06 (0.67)	4.51 (0.51)
Skew (kurtosis)	-1.23 (1.46)	-0.90 (0.21)	-1.08 (1.56)	0.09 (-0.71)	-0.80 (0.43)	-1.68 (3.83)	-0.48 (-0.35)	-0.58 (0.10)	-0.64 (1.33)	-0.90 (0.21)	-0.47 (-0.03)	-0.24 (-0.25)	-0.75 (1.48)	-1.13 (0.92)

^aitalicized values on diagonal of the correlation matrix are coefficient alpha values.

^bT1, construct measured at time 1; T2, construct measured at time 2; T3, construct measured at time 3.

* $p \leq 0.05$.

** $p \leq 0.01$.

*** $p \leq 0.001$.

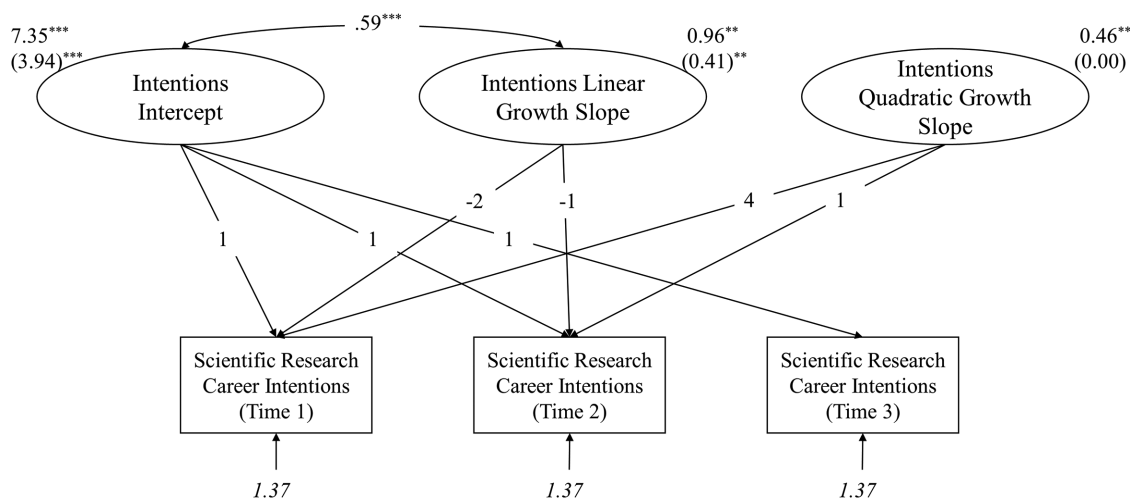


FIGURE 2. Results of the latent growth curve model of scientific research career persistence intentions (SEM 1). Values outside parentheses represent estimates of growth in science career persistence intentions (i.e., latent intercept = 7.35 = average persistence intentions at time 3; linear slope = 0.96 = decline in persistence intentions from time 1 to time 2; quadratic slope = 0.46 = rebound in persistence intentions from time 2 to time 3); values inside parentheses represent variances of the estimate of growth in science career persistence intentions; italicized values represent residual variance in persistence intentions at each time point; and values on paths represent how time was coded to model growth over time in SEM. All other variables in the analysis were allowed to correlate with growth parameters but are not shown in this diagram for the sake of parsimony. **, $p \leq 0.01$; ***, $p \leq 0.001$.

showed that the model (SEM 1) adequately fitted the data, $\chi^2(69) = 115.83$, $p < 0.001$, RMSEA = 0.06, $p_{\text{close}} = 0.23$, CFI = 0.95, SRMR = 0.06.

The latent growth curve analysis formally tested the trends identified from the descriptive statistics. Consistent with the descriptive statistics, the latent growth curve revealed that students' persistence intentions exhibited a statistically significant decline from the beginning to the midpoint of the SURE (Figure 2, Intentions Linear Growth Slope = 0.96), followed by a statistically significant rebound from the midpoint to the end of summer (Figure 2, Intentions Quadratic Growth Slope = 0.46). By the end of the SURE, students reported persistence intentions had basically returned to where they were at time 1 (Figure 2, Intentions Intercept = 7.35 on a 1–10 scale). The analysis also revealed that students exhibited significant variability in how much their persistence intentions declined from time 1 to time 2 (Figure 2, Intentions Linear Growth Slope = 0.41) and significant variability in their end of summer persistent intentions (Figure 2, Intentions Intercept = 3.94).

Scientific Community Values Influence Final Summer Persistence Intentions

Next, we addressed research question 2, concerning the predictive utility of scientific mediators and contextual features. We hypothesized that the scientific mediators and contextual features at time 2 would be significantly and positively correlated with persistence intentions at time 3. Partially consistent with our hypothesis, students with higher levels of scientific identity, higher levels of scientific community values, higher satisfaction with their faculty mentors, and higher perceptions of their faculty mentors as role models also reported higher levels of persistence intentions (see Table 1). The bivariate correlations between persistence intentions at time 3 and some of the scientific mediators and contextual features at time 2 were

small to moderate in magnitude using Cohen's proposed metrics for interpreting magnitude of correlations (i.e., small = 0.10, medium/moderate = 0.30, large = 0.50; Cohen, 1992).

To formally test our research question about the predictive utility of the scientific mediators and contextual features, we compared the model–data fit of two additional nested structural equation models (i.e., SEM 2 and SEM 3). To begin, we tested the model–data fit of our conceptual model (Figure 1; SEM 2), which hypothesized that students' science self-efficacy, science identity, science community values (Figure 1, Mediators), experiences of faculty mentorship support, and project ownership at time 2 (Figure 1, Contextual features) would predict scientific career persistence intention at time 3. The model fit statistics indicated that SEM 2 provided acceptable fit to the data, $\chi^2(73) = 121.56$, $p < 0.001$, RMSEA = 0.06, $p_{\text{close}} = 0.24$, CFI = 0.91, SRMR = 0.06 (parameter estimates shown in Table 2). Next, we tested the model–data fit of a null model (SEM 3), which hypothesized that neither the mediators nor the contextual features would predict scientific career persistence intention (Figure 1, b paths and c paths = 0). If the null model (SEM 3) did not worsen model fit compared with the conceptual model (SEM 2), we could conclude that the scientific mediators and contextual features provide no predictive utility in explaining growth in persistence intentions. The model fit statistics indicated that the null model (SEM 3) did not provide acceptable fit to the data, $\chi^2(91) = 161.43$, $p < 0.001$, RMSEA = 0.06, $p_{\text{close}} = 0.11$, CFI = 0.87, SRMR = 0.08, and had significantly worse model fit compared with the conceptual model, $\Delta\chi^2(18) = 39.87$, $p = 0.002$. Consistent with our expectations, a comparison of the model–data fit of the conceptual model versus the null model revealed that students' science self-efficacy, science identity, science community values, experiences of faculty mentorship support, and project ownership are important factors in explaining growth in scientific career persistence intention over time.

TABLE 2. Summary of fixed effects for SEM 2 predicting latent growth in persistence intentions and predicting scientific mediators (efficacy, identity, and values; N = 203)^a

Predictor	Science efficacy (T2)			Science identity (T2)			Science values (T2)			Intercept			Linear growth			Quadratic growth			
	b	SE		b	SE		b	SE		b	SE		b	SE		b	SE		
1. Intercept	-1.29***	0.18		-0.02	0.03		-0.01	0.03		7.36***	0.23		0.96**	0.34		0.45**	0.16		
2. Psychosocial support (T2)	0.04	0.06		0.02	0.05		0.01	0.04		-0.20	0.25		0.35	0.37		0.15	0.17		
3. Instrumental support (T2)	0.15	0.07		-0.003	0.06		-0.02	0.05		-0.22	0.31		-0.08	0.45		0.04	0.21		
4. Role modeling (T2)	0.04	0.07		0.20**	0.07		0.23***	0.05		0.19	0.31		-0.49	0.45		-0.31	0.26		
5. Overall satisfaction (T2)	0.06	0.08		0.04	0.08		-0.01	0.06		0.61	0.38		0.35	0.53		0.10	0.24		
6. Project ownership (T2)	0.15	0.08		0.12	0.07		0.01	0.06		-0.31	0.33		-1.55**	0.55		-0.75**	0.25		
7. Science efficacy (T2)										0.10	0.34		0.41	0.51		0.22	0.22		
8. Science identity (T2)										0.22	0.31		-0.49	0.45		-0.23	0.21		
9. Science values (T2)										1.41***	0.39		0.58	0.57		0.15	0.26		
10. Science efficacy (T1)	0.41***	0.06																	
11. Science identity (T1)				0.52***	0.06														
12. Science values (T1)							0.50***	0.06											
13. Program code 1										0.00	0.00		-0.17	1.55		0.10	0.73		
14. Program code 2										1.07	0.55		-0.90	0.81		-0.30	0.37		
15. Program code 3										1.21	0.53		0.29	0.90		0.05	0.42		
16. Program code 4										0.98	0.58		-0.95	0.83		-0.45	0.38		
17. Program code 5										0.17	0.68		-1.89	0.98		-0.87	0.41		
R ²		0.45			0.45			0.40			0.26			0.79					

^aT1, construct measured at time 1; T2, construct measured at time 2; program codes are dummy-coded indicators of program membership.

**p ≤ 0.005.

***p ≤ 0.001.

Our second hypothesis related to predictive utility was that science self-efficacy, identity, and community values would act as mediators and would be the only factors to significantly predict persistence intentions. If our hypothesis was accurate, the structural regression coefficients for science self-efficacy, identity, and community values would be positive and statistically significant, while the faculty mentoring and project ownership coefficients would be nonsignificant. We inspected the statistical significance of the structural regression coefficients to determine the pattern of uniquely predictive mediators and contextual features. Partially consistent with our hypothesis, students' internalization of scientific community values uniquely and positively predicted their end-of-summer scientific research career persistence intentions, when we controlled for the other predictors (Table 2, science community values predicts the intercept of persistence intention $b = 1.41$). Inconsistent with our hypothesis, students' ownership of their projects directly affected the pattern of growth in their intentions to persist in science (Table 2; e.g., project ownership negatively predicts linear decline in persistence intentions $b = -1.55$). Figure 3 shows the growth trajectories for students of low, average, and high levels of project ownership. Higher levels of project ownership (dotted line) were associated with high and steady persistence intentions, whereas low levels of project ownership (solid line) were associated with the typical decline and rebound in persistence intentions. There were no significant differences between those with low, average, or high project ownership at either the beginning or end of the summer experience—only a difference in the growth trajectory (i.e., decline and rebound).

Role Modeling Supports Persistence Intentions through Scientific Community Values

Next, we addressed research question 3 (i.e., degree to which the quality of faculty mentorship and project ownership

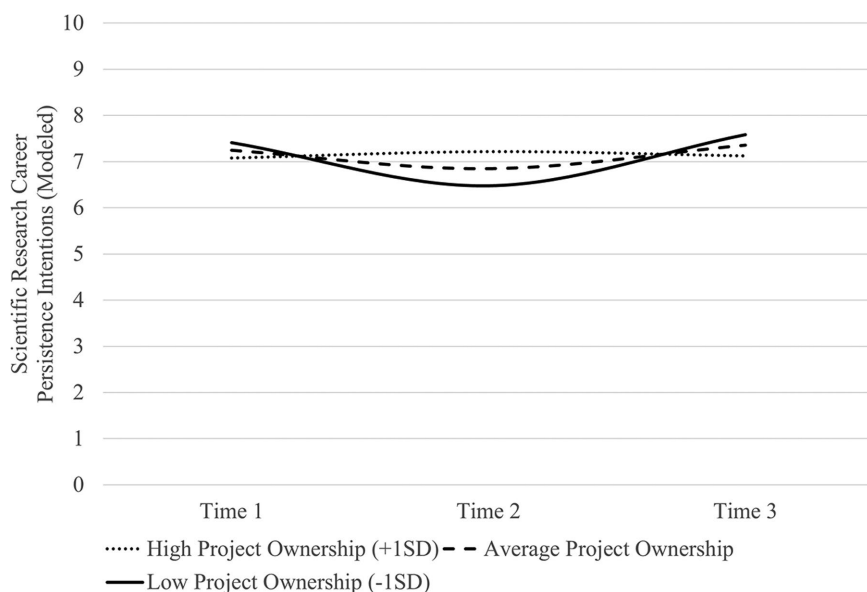


FIGURE 3. Project ownership predicts growth of scientific career persistence intentions. Growth trends modeled with project ownership at the average (i.e., mean of project ownership), below average (1 SD below average), and above average (1 SD above average).

influences persistence intentions indirectly through scientific mediators). Consistent with expectations, the bivariate correlations showed that, at time 2, students with higher levels of faculty mentorship support and higher levels of project ownership reported higher levels of science self-efficacy, science identity, and internalization of scientific community values (i.e., contextual features exhibited small-to-moderate bivariate correlations with the scientific mediators; Table 1).

However, we hypothesized that faculty mentorship support and project ownership would predict the scientific mediators over and above baseline levels of science self-efficacy, identity, and community values. To formally test our hypothesis, we compared the model–data fit of two additional nested structural equation models (i.e., SEM 2 and SEM 4). As described earlier, our conceptual model (SEM 2) hypothesized that the qualities of faculty mentorship support and project ownership would predict science self-efficacy, science identity, or science community values when controlling for baseline levels of the scientific mediators. Therefore, we tested the model–data fit of a null model (SEM 4), which hypothesized that neither the qualities of faculty mentorship support nor project ownership would predict science self-efficacy, science identity, or science community values (Figure 1, a-paths = 0). If the null model (SEM 4) did not worsen model fit compared with the conceptual model (SEM 2), we could conclude that the contextual features do not improve the prediction of the scientific mediators over and above baseline levels of the scientific mediators. The model fit statistics indicated that the null model (SEM 4) did not provide acceptable fit to the data, $\chi^2(88) = 193.15$, $p < 0.001$, RMSEA = 0.08, $p_{\text{close}} = 0.002$, CFI = 0.81, SRMR = 0.09, and significantly worsened model fit compared with the conceptual model (SEM 2), $\Delta\chi^2(15) = 71.59$, $p < 0.001$. Consistent with our expectations, a comparison of the model–data fit revealed that students' experiences of faculty mentorship support and project ownership are important factors in explaining science self-efficacy, science identity, and science community values over and above their initial science self-efficacy, science identity, and science community values.

Our second mediational hypothesis was that faculty mentorship support and project ownership would increase students' scientific career persistence intentions, because those factors increased science identity and science community values. If our hypothesis was accurate, the various types of faculty mentorship support and project ownership would have statistically significant indirect effects on persistence intentions through science identity and community values. Partially consistent with our hypothesis, student perceptions of their faculty mentors as inspirational role models positively affected science identity and internalization of science community values (Table 2; e.g., role modeling predicts values (T2) $b = 0.23$). Furthermore, students with higher levels of scientific community values had higher levels of scientific research career

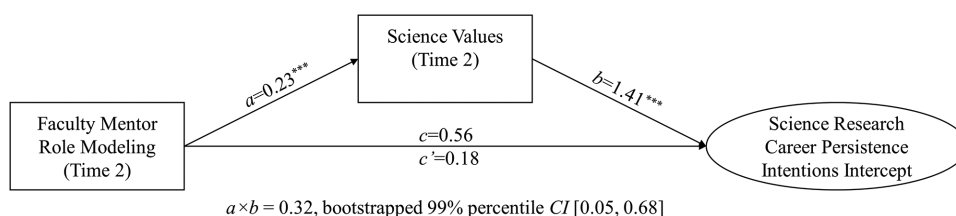


FIGURE 4. Mediation model showing the positive effect of faculty mentor role modeling on science career persistence intentions at the end of summer through its positive influence on science community values. *a*-path: positive effect of faculty mentor role modeling on science community values (controlling for baseline levels of values); *b*-path: positive effect of science community values on science career persistence intentions at the end of summer (controlling for all other predictors in the model); *c*-path: total effect role modeling on persistence intentions (not controlling for other factors in the model); *c'*-path: direct effect of role modeling on persistence intentions (controlling for all other factors in the model); $a \times b$: indirect or mediated positive effect of faculty mentor role modeling on science career persistence intentions at the end of summer through its positive influence on science community values; nonsignificant paths and contrast-coded indicators of program not included in this diagram for the sake of parsimony. ***, $p < 0.001$.

persistence intentions at the end of the SURE. Consistent with best practices, we formally tested the statistical significance of the indirect effect of faculty role modeling on persistence intentions through scientific community values using a bootstrapping procedure with 10,000 repetitions to construct percentile confidence intervals around the mediated effect shown in Figure 4 (Shrout and Bolger, 2002; MacKinnon *et al.*, 2007). The mediation analysis revealed that faculty role modeling had a statistically significant positive indirect effect on students' end-of-summer scientific research career persistence intentions through science community values (Figure 4, $a \times b = 0.32$, and confidence intervals do not include 0).

DISCUSSION

The current study used a longitudinal design to measure developmental growth in students' scientific career persistence intentions over the course of a single intensive summer apprenticeship-style faculty-mentored research experience. In addition, the current study used the TIMSI model to examine the psychological processes that link URE activities to student integration into STEM careers and culture. Student growth trends over the summer did not conform to a simple narrative of continuous growth toward a scientific career. Rather, students' growth was more erratic, defined by declines and rebounds. Furthermore, faculty mentor support and student ownership over their research projects related to growth in science career persistence intentions differently. Project ownership directly supported growth in student aspirations to pursue scientific careers; however, faculty mentorship support operated in a more nuanced way. Faculty mentor support helped students to internalize scientific community values and to see themselves as "scientists," and these values and self-beliefs in turn galvanized their commitment to a scientific career.

A key finding from this research was that student intentions to pursue scientific careers declined and then rebounded over the course of the SURE (i.e., a quadratic developmental growth trend). This finding is novel, in part, because the SURE literature has relied heavily on posttest only or pre-post research designs to identify "gains" over the summer (e.g., Lopatto, 2004, 2007; Fuchs *et al.*, 2016; Kolber *et al.*, 2016). However, the posttest only and pre-post designs have many well-established methodological and statistical limitations to detect

developmental processes or change over time via gain scores (Cronbach and Furby, 1970; Shadish *et al.*, 2002; Maxwell and Delaney, 2004). Adding one or more intermediate measures between pretest and posttest allows researchers to detect and describe patterns of individual growth over time (Chan, 1998; Venter *et al.*, 2002). In the present study, for example, it would have been impossible to document the drop in persistence intentions followed by a rebound in persistence intentions under a pre-post design. A simple gain score analysis (i.e., $M_{\text{gain}} = M_{\text{posttest}} - M_{\text{pretest}} = 7.64 - 7.67 = -0.03$; Table 1) would have revealed nothing about the pattern of growth that took place over the summer. Researchers interested in describing and explaining the role that research experiences play in developing the next generation of scientific professionals should strongly consider adding intermediate time points to their study design (at least one intermediate time point, but three intermediate time points would maximize statistical power; Maxwell, 1998; Venter *et al.*, 2002).

The decline in persistence intentions from the first time point to the midpoint of summer was surprising and concerning, as one of the goals of SUREs is to promote scientific research careers. However, several factors may help to explain and mitigate the decline. It is possible that the social and interpersonal dynamics involved in transitioning into a new research lab with a new faculty mentor and lab coworkers caused turbulence that initially dampened students' interest in science careers. It is also possible that the first half of the SUREs involve particularly challenging and ambiguous aspects of authentic scientific research (e.g., reading background literature, defining a research problem with an unknown solution that is of interest to the scientific community, learning new protocols and equipment to carry out the research). In addition, authentic research is accompanied by setbacks, experiments that do not work as planned, equipment or instruments that break and hold up the experiment, and the need for supplies that have been ordered and have not yet arrived. Often students experience these setbacks in the middle of their project (time 2). Students new to research often do not realize that research is made up of lots of experiments that do not work but culminates in the one or two experiments that do work. The challenges and ambiguities in authentic research may initially dampen students' enthusiasm for scientific careers. By contrast, the second half of the SUREs

may involve research processes that reinvigorate enthusiasm for scientific careers (e.g., gaining traction on discovery through iteration, mastery of new protocols and equipment, sharing research results at an end-of-summer poster presentation). Aspects of our findings *hint* at support for this explanation.

If challenges and ambiguity in research define the first half of the URE, then students with higher levels of research readiness should be better able to take ownership of their research projects and resolve the initial challenges. Prior research has shown that students engaged in challenging and ambiguous aspects of authentic research report lower project ownership than students engaged in more structured research projects with a known solution (i.e., research lab vs. traditional lab; Hanauer and Dolan, 2014). Consistent with this explanation, our data showed that students with high levels of science self-efficacy at the start of the SURE reported higher project ownership at the midpoint of the SURE ($r = 0.27$). Furthermore, students with high levels of project ownership at the midpoint of the SURE did not experience a drop in persistence intentions (Figure 3). Thus, students who begin the summer with higher levels of research readiness may be better prepared to take ownership of a project, resolve the challenges and ambiguity of the research project, and thus avoid the initial decline in their persistence intentions. More study is needed to substantiate this potential explanation for the initial decline in persistence intentions.

The beneficial effects of having high levels of project ownership also point to a potential area for intervention. That is, enacting policies and procedures that support students' project ownership may improve short-term outcomes (such as avoiding a decline in persistence intentions) and long-term persistence in scientific research careers (Hanauer *et al.*, 2017). Any interventions aimed at supporting students' project ownership will need to be sensitive to the qualities that define ownership. Science students' perceptions of ownership are defined by five qualities: making connections between one's personal history and scientific inquiry; agency and mentorship; excitement; overcoming challenges; and expressions of personal scientific achievement (Hanauer *et al.*, 2012; Hanauer and Dolan, 2014). Recent research has shown that the five elements of project ownership may be subsumed by two global factors of ownership defined by students' positive emotions toward the research project and their degree of agency over the research (Hanauer *et al.*, 2017). Thus, interventions aimed at improving students' levels of project ownership should take into account students' sense of agency (task choice, personal sense of responsibility) and support in overcoming challenges, as well as emphasizing relevance of the project to the larger scientific community.

Another key finding from this study concerned the mechanisms by which faculty mentors draw students into science careers. Informed by the TIMSI model, we hypothesized that faculty mentorship support would support growth in persistence intentions through the development of science self-efficacy, science identity, and science community values (Figure 1; Estrada *et al.*, 2011, 2018). However, the longitudinal TIMSI model revealed that faculty mentors primarily socialize students into science careers and culture through *role modeling* (as opposed to other types of mentorship support). That is, students who viewed their faculty mentors as more inspirational, in terms of identifying with a mentor's life and work, developed

a stronger commitment to scientific community values—even after controlling for the students' levels of commitment to science community values at the start of the summer experience. This finding aligns with research showing that role models inspire aspirants by providing an example of the attitudes, norms, and behaviors required to achieve similar success (Lockwood *et al.*, 2002). This finding also has implications for faculty mentors and URE programs, as the role modeling literature has identified several attributes of role modeling that promote inspiration, motivation, and persistence.

Role models are most effective and motivational when they are *relevant* (e.g., similar domain of shared interest [science career], similar gender), when their success is perceived to be *attainable* by identifiable pathways (Lockwood and Kunda, 1997, 1999; Lockwood *et al.*, 2002; Lockwood, 2006), when they normalize struggle and promote effort to achieve success in STEM (Shin *et al.*, 2016), and when they communicate that STEM careers are compatible with communal values (i.e., helping others; Clark *et al.*, 2016). Therefore, we expect that faculty mentors who intentionally talk about their journeys into their scientific careers would be most likely to be inspirational role models (e.g., highlights from their personal histories: similarities they share with their mentees, where they started, how they achieved success, challenges they overcame through effortful development of new skills, how their work helps people). Therefore, faculty mentors and URE program organizers may wish to intentionally design conversations and activities that highlight the similarities between mentors and mentees, stress the relevance of the work to the mentees' future career aspirations, emphasize the pathways to attain similar success, normalize the struggle and the processes to overcome challenges, underscore the importance of effort (rather than brilliance) in achieving success, and demonstrate how their work helps people. These conversations and activities need not all come from the faculty mentor; conversations and activities may be equally influential coming from other potential role models who are slightly farther ahead of the mentee on the path to a scientific career—postdocs, graduate students, and even more advanced undergraduate researchers. For example, summer research coordinators for the present study are implementing activities such as the mentor biography and setting mentor-mentee expectations and research expectations to improve opportunities for role modeling and mentorship (Branchaw *et al.*, 2010).

Although the present study addressed a number of theoretical and methodological gaps in the literature, there are limitations that require further study. For example, the present study focused on SURE participants enrolled in six distinct summer programs at one research-intensive university and used only self-reported measurements. Further study is needed to determine whether the same pattern of growth and stability of the effects on growth hold across multisemester or yearlong cocurricular or course-based undergraduate research experiences. To date, other studies of course-based and cocurricular research experiences have not tracked developmental growth in persistence intentions within the bounds of the URE (Lopatto, 2007; Adedokun *et al.*, 2014; Fakayode *et al.*, 2014; Fuchs *et al.*, 2016; Hernandez *et al.*, 2018). In addition, limited evidence from one study that tracked science majors over three academic years showed a similar quadratic pattern in persistence intentions, one marked by an overall

decline followed by a leveling off or slight rebound (Schultz et al., 2011). An additional limitation concerns the measurement of the outcome. Specifically, the current study operationalized persistence intentions in terms of students' aspirations to pursue a science career, while other studies have emphasized aspirations to pursue a research career. It is possible that this slight variation in focus on science versus research may have influenced some aspects of the findings. For example, prior work on the TIMSI model has shown that science identity, not science community values, was the most influential predictor of persistence intentions (Estrada et al., 2011, 2018). Further study will be needed to determine whether contextual features of the URE, the operationalization of persistence intentions, or other salient factors are the source of variability across the research literature. Related limitations concern the need to determine the degree to which these findings hold across a broader array of sources of mentorship support, types of summer programs, institutions, and methods of measurement. In particular, students involved in the current summer research programs likely received various types of support (psychosocial, instrumental, networking, etc.) from persons other than their faculty research mentors (program staff, graduate students, peers). More research is needed to better understand how support received from a network of mentors relates to beneficial outcomes. In addition, the present study only consisted of undergraduates engaged in a SURE. Further counterfactual evidence and evaluation of the TIMSI model would benefit from measuring the same processes in comparison samples of students engaged in low-intensity SUREs and among students not engaged in SUREs.

In summary, the present study was informed by the TIMSI model and addressed three research questions concerning changes in scientific career persistence intentions over time within a single intensive SURE. Our analysis showed that students tended to exhibit a swing (i.e., decline and rebound) in their persistence intentions over the course of the summer. However, students with high levels of project ownership exhibited steady persistence intentions, while those with lower project ownership experienced the downward and upward swing. Most importantly, the analysis revealed that faculty mentor role modeling increased students' internalization of science community values, and those values in turn increased students' scientific career persistence intentions.

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