Accentuating Advantage: Developing Science Identity during College

M. Kevin Eagan*, Sylvia Hurtado, Juan C. Garibay, and Felisha Herrera

University of California, Los Angeles

*Contact: M. Kevin Eagan, 405 Hilgard Ave., 3005 Moore Hall, University of California, Los Angeles, CA 90095-1521; Phone: (310) 825-1925; Email: mkeagan@gmail.com

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Developing a commitment to a discipline early in college can have long-lasting effects on major persistence as students matriculate toward graduation. With the high attrition rates found in science, technology, engineering, and mathematics (STEM) disciplines (Higher Education Research Institute, 2010), practitioners and policymakers need to identify best practices that promote students' development of a stronger identity with their STEM major. The development of a strong science identity has been shown to improve science major persistence (Chang, Eagan, Lin, & Hurtado, 2011) and shape students' trajectories within scientific disciplines (Carlone & Johnson, 2007). We examine students' experiences and institutional contexts that shape the development of students' science identity across three time points during college. We also draw from the frameworks of cumulative advantage (Allison, Long & Krauze, 1982; Allison & Stewart, 1974; Cole & Cole, 1973; Merton, 1973a; 1973b; Zuckerman, 1988) and accentuation effects (Feldman & Newcomb, 1969; Nelson Laird, Engberg, & Hurtado, 2005) to examine and understand the long-term impact of pre-college and first-year experiences on science identity.

Influences on STEM Identity

Carlone and Johnson's (2007) model of science identity contains three overlapping components: competence, performance, and recognition. Students with strong science identities are those who demonstrate competence in the discipline, possess the skills to perform scientific practices, and achieve recognition (from oneself and from meaningful others as a "science person"). They conceptualize science identity as being both situationally emergent and dependent and, if habitually accessed, performed, and recognized, as potentially stable across time and context (Carlone & Johnson, 2007). As a negotiated self that is continuously under construction, an individual's STEM identity is shaped by the individual's own assertions, external ascriptions, and experiences in STEM (Carlone & Johnson, 2007; Martin, 2007).

Previous research underlines the importance of early learning experiences with science in the development of students' emerging STEM identities (Tran, Herrera, Gasiewski, 2011). Russell and Atwater (2005) found that taking more advanced science and mathematics courses during high school enhances interest and success in STEM fields. Science and math courses may provide students the ability to participate in scientific practices (i.e., thinking, speaking, acting), contexts that help promote students' development of science identities (Carlone & Johnson, 2007). Participation in pre-college research experiences also help students solidify their interest in STEM fields (Tran et al., 2011). Additionally, Tran et al. (2011) found that many successful students in STEM fields identified their parents as providing early childhood experiences that helped cultivate their identification with science. Students whose parents had a career in a STEM field described continuously being exposed to STEM-related subjects throughout their youth, which promoted positive STEM identities at a young age (Tran et al., 2011).

In addition to parental influence, other agents that are important in students' STEM identity formation are faculty and peers (Carlone & Johnson, 2007; Martin, 2007). Critical to students' STEM identity development and socialization into the sciences involves being seen by relevant others as a science person (Carlone & Johnson, 2007). The judgment and invitation of practicing scientists throughout students' educational trajectories are fundamental in the social process of becoming a scientist (Lewis, 2003). Being mentored, recognized, or validated as competent in science by faculty and peers can help students develop strong, positive STEM identities, while not receiving recognition may disrupt STEM identity development (Carlone & Johnson, 2007; Tran et al., 2011). Furthermore, although external recognition from meaningful others is significant as students develop their identification with STEM, a student's perception of her or his ability in science and math and recognizing oneself as a scientist are critical to developing strong science identities (Hurtado, Cabrera, Lin, Arellano, Espinosa, 2009; Carlone & Johnson, 2007). For example, despite the discouragement many women of color in STEM received by external others, Carlone and Johnson (2007) found that many of those women steadfastly maintained their interest in STEM.

Researchers also have highlighted several college experiences and contexts that influence science identity development. Hurtado et al. (2009) found that undergraduate research experiences enhance student interest in becoming a scientist, as students improve their knowledge and understanding of science (Sabatini, 1997) and develop their professional self-confidence (Lopatto, 2003; Mabrouk & Peters, 2000). The competitive culture of science may also influence students' science identities, as intense competition in introductory STEM courses often drives adept students to leave the sciences (Seymour & Hewitt, 1997).

Cumulative Advantage & Accentuation Effects

Given previous literature on science identity we utilize two frameworks to help understand the development of science identity over the course of students' undergraduate careers. Cumulative advantage (Allison, Long & Krauze, 1982; Allison & Stewart, 1974; Cole & Cole, 1973; Merton, 1973a; 1973b; Zuckerman, 1988) provides a framework to examine patterns of inequality in STEM identity development among individuals or groups. The principle of accentuation (Feldman & Newcomb, 1969; Nelson Laird et al., 2005) allows us to acknowledge and comprehend how students' predispositions are accentuated during college. The next sections further explain these two frameworks.

Cumulative Advantage

Cumulative advantage theory (Allison, Long & Krauze, 1982; Allison & Stewart, 1974; Cole & Cole, 1973; Merton, 1973a; 1973b; Zuckerman, 1988) provides a mechanism for understanding inequality across a temporal process (e.g., high school, undergraduate education, lifetime) in which a favorable relative position facilitates further relative gains (DiPrete & Eirich, 2006). For example, research on the career trajectories of scientists demonstrates a pattern of growing or the maintenance of inequality with respect to productivity, recognition, and performance, as early career success attracts new resources and rewards that promote continued high levels of achievement (Allison and Stewart, 1974; Zuckerman, 1988).

In education, a cumulative advantage process is "capable of magnifying small differences over time and makes it difficult for an individual or group that is behind at a point in time in educational development…to catch up" (DiPrete & Eirich, 2006, p. 272). For STEM students' developing science identities, cumulative advantage theory suggests that students who, prior to college, have access to particular resources or experiences (i.e., parent in a STEM career, pre-college research experiences, recognition as highly competent in STEM) that helped develop relatively stronger STEM identities early on are more likely to have even stronger relative STEM identities in the future especially since they tend to gain greater access to those important resources and activities during college. Understanding the impact of the initial strength of STEM identity on future STEM identity is crucial, as cumulative advantage may produce inequality in STEM identity development as the cohort of students grows older.

Accentuation Effects

Students enter college with predispositions and characteristics that are likely to be accentuated during their time in college, as students have much liberty in choosing their peer groups and extracurricular activities they take part in (Feldman & Newcomb, 1969). Students often find peers with mutual interests and seek opportunities that meet their goals and interests, which are likely to accentuate their predispositions. For STEM students entering college with an identification with STEM fields, there are certain activities and experiences that may accentuate their STEM identities. However, not every setting, experience, or activity will accentuate every students' predispositions (Feldman & Newcomb, 1969; Nelson Laird, Engberg, & Hurtado, 2005). According to Feldman & Newcomb (1969), the principle of accentuation is conditional based upon whether students' predispositions are valued and nurtured in the particular settings in which they choose to participate. Thus, entering STEM students' science identity may be accentuated during college by settings or individuals (i.e. academic major, peers, departmental clubs, research experiences, faculty) that value such STEM identification.

Given the significance of the development of a strong science identity on science major persistence (Chang, Eagan, Lin, & Hurtado, 2011) and trajectories (Carlone & Johnson, 2007), it is important to understand how STEM students' experiences may accentuate their identification with STEM fields. Feldman and Newcomb's (1969) accentuation framework may help to understand how particular activities and settings can serve to solidify students' STEM identity during college. Using longitudinal data at three time points, we model and control for the accentuation of students' STEM identity to understand the long-term benefits of pre-college and first-year experiences on science identity.

Methods

Data and Sample

This study draws from a sample of 1,133 aspiring STEM majors who completed the 2004 Freshman Survey (TFS), the 2005 Your First College Year survey (YFCY), and the 2008

College Senior Survey (CSS). URM students were purposefully sampled beginning with the 2004 TFS, and subsequent response rates resulted in an unweighted sample of 58% (664) White/Asian and 42% (468) URM students who responded to all three surveys. The male/female splits was 30% Male and 70% female, as women are typically more likely to respond to student surveys than men (Sharkness, 2012).

The 2004 Freshman Survey constituted the baseline sample for the study and was administered to incoming students during summer orientation or the first few weeks of the fall term in 2004. The 2004 Freshman Survey collected information about students' experiences in high school, aspirations and goals for their education and career, and background characteristics. The 2005 YFCY survey was administered in the spring of 2005 as students finished their first year of college. This survey collected information about students' experiences in their first year of college, their plans for their future, and a number of goals and commitments. Finally, the 2008 CSS was administered to students during the spring of 2008, as students completed their fourth year of college. The CSS collected information on students' college experiences, plans for post-college life, and longer-term goals and commitments. (For more information about the 2005 YFCY survey and the 2008 CSS sampling designs see Chang, Eagan, Lin, & Hurtado, 2011, Espinosa, 2011, Chang, Hurtado, Sharkness & Newman, in review).

Measures

This study focuses on changes in students' STEM identity during college. In creating the measure of STEM identity, we draw from Carlone and Johnson's (2007) conceptualization of STEM identity and from the operationalization of STEM domain identification by Chang et al. (2011). Using a confirmatory factor analytic model in MPlus software, we identified the latent construct of STEM identity through four indicator variables related to students' rating of the personal importance of: making a theoretical contribution to science; being recognized by colleagues for contributions to their special field, becoming an authority in my field; and finding a cure to a health problem. Table 1 presents the results of the measurement model, which includes the factor loadings for each of the indicator variables at each time point.

We include a number of exogenous variables in the model to account for variation in STEM identity at each of the three time points as well as to estimate the shorter- and longer-term impacts of specific experiences and attributes. Based on work by Russell and Atwater (2005), we include in the model students' pre-college participation in research programs and the number of years that students studied biology in high school as measures for students' prior preparation in and early exposure to science. Additionally, we examine the relationship between students' self-rated math ability and their science identity at each time point. Further, the model estimates the relationship between students' interest in preparing for graduate school and their STEM identity.

Among students' first-year experiences, we examine how participation in a structured health-science research program, membership in a pre-professional or departmental club, and work on a professor's research project relate to their STEM identity in 2005 and in 2008. These activities allow students to perform as scientists, be recognized by their peers and faculty as scientists, and further develop competence in conducting research (Carlone & Johnson, 2007). Additionally, the model includes students' frequency of interacting with faculty during office hours and studying with other students, as we expect that students who demonstrate greater engagement with their faculty and peers in STEM will develop a stronger STEM identity. We also include a measure of whether students switched majors during their first year of college. Although we do not have a measure of students' actual, or intended, major at the end of their freshman year, we believe that including this measure of switching majors indicates a possible lack of commitment to STEM and thus detracts from students' STEM identity.

In predicting STEM identity in 2008, we include measures of structured research program participation as well as the extent to which students reported conducting research with faculty, as both variables represent opportunities to perform as scientists. Additionally, the model examines the relationship between students who received encouragement from faculty to pursue graduate or professional school and STEM identity, as such recognition from faculty may enhance students' identity as scientists (Carlone & Johnson, 2007). Measures of institutional control and selectivity control for the campus context students encounter. Finally, we include in the model a measure of STEM major persistence through four years of college, as we expected that students who left STEM to have lower scores on the STEM identity construct compared to their peers who remained in STEM disciplines. The appendix has the full list of endogenous and exogenous variables.

Analyses

To estimate the short- and long-term effects of students' characteristics, pre-college experiences, and college activities on changes in the STEM identities during college, we relied on structural equation modeling (SEM). SEM uses estimated covariance matrices to generate parameter estimates for variables in the model and accounts for measurement error among variables in the model (Bentler, 2006). SEM requires consideration of model fit, and we relied on two fit indices: comparative fit index (CFI) and root mean square error of approximation (RMSEA). Raykov, Tomer, and Nesselroade (1991) suggest that CFI values above 0.90 indicate adequate model fit whereas RMSEA scores below 0.06 indicate an appropriate level of fit.

Our analytic approach began with a confirmatory factor analysis that tested the adequacy of our measurement model. As mentioned above, the measurement model included the observed indicator variables and the latent construct of STEM identity for each of the three surveys: 2004 Freshman Survey; 2005 YFCY; and 2008 CSS. This model confirmed the factor structure of the STEM identity construct at each of the three time points. Next, we added to the measurement model all of the hypothesized predictors and paths to test the full structural model. We used LaGrange Multiplier tests, in conjunction with prior literature and theory, in considering whether to add paths between variables to improve model fit.

Results

Table 2 provides the direct effects for the final model, and Figure 1 provides a visual depiction of the final model. The model has adequate model fit with a CFI of 0.93 and an RMSEA of 0.03. Considering the direct effects on 2004 STEM identity, the results show that women have a lower STEM identity than men when they enter college. Students who participated in a pre-college research program begin college with a higher score on STEM identity, and those who had more years of exposure to high school biology also had significantly stronger STEM identities. Tutoring other students more often in high school predicted stronger STEM identity for entering college students in 2004; however, the strongest predictor of 2004 STEM identity was students who enrolled in college to prepare for graduate or professional school. Respondents who reported that they came to college to prepare for post-baccalaureate degrees had significantly higher scores on the 2004 STEM identity construct than their counterparts who did not express this sentiment.

Not surprisingly, the strongest predictor of 2005 STEM identity was students' STEM identity when they first entered college, which connects to the cumulative advantage lens framing this study. Having a stronger STEM identity upon college entry corresponds with higher scores on STEM identity at the end of the first year of college. The second strongest predictor of STEM identity in 2005 was students' decision to switch majors during their first year of college, as students who indicated on the 2005 YFCY that they had changed majors during their first year of college had significantly lower scores on 2005 STEM identity compared to their peers who persisted in their same majors. This negative relationship is not surprising given the likelihood that students who switched majors moved into a non-STEM field (Chang et al., 2011).

Although participating in a health-science research program did not significantly predict 2005 STEM identity, students who spent more time working on research with professors scored significantly higher on the 2005 STEM identity construct. Conducting research with faculty enables students to perform as scientists, which Carlone and Johnson (2007) suggest can further develop an individual's science identity. Likewise, students who joined pre-professional or departmental clubs in the first year of college had significantly stronger STEM identities in 2005 than their peers who did not join such clubs. Furthermore, students who spent more time interacting with faculty during office hours or studying with other students reported significantly higher scores on 2005 STEM identity than their peers who engaged in these activities less frequently. Likewise, being more successful at adjusting to the academic demands of college predicted higher scores on 2005 STEM identity. Finally, students who reported greater math self-confidence in 2005 also identified more strongly with STEM.

The two strongest predictors of students STEM identity in 2008 were their STEM identity in 2004 and 2005, as students who scored higher on these constructs in 2004 and 2005 also had significantly higher scores by the end of their fourth year in college. Students who persisted in STEM through four years of college had significantly stronger STEM identities in

2008 than their peers who left STEM, which connects to the conditional property that Feldman and Newcomb (1969) describe as being important to accentuating students' predispositions. Students' science identities are likely to be accentuated while in a STEM major, as opposed to a non-STEM major, as these settings are more likely to value and nurture their science identities. Participation in a structured undergraduate research program during college and working with a professor on research accentuated students' STEM identity in 2008, as respondents who engaged in these activities reported being more strongly identified with STEM compared to their peers who did not participate in a research program or a professor's research project. Receiving encouragement from faculty to pursue graduate or professional school corresponded with higher scores on the STEM identity construct in 2008, as such encouragement from faculty may have served as recognition of students' competence in science. Finally, the results suggest that students at more selective institutions had significantly weaker STEM identities compared to their peers at more selective institutions.

Table 3 provides results for indirect effects of variables in the model. These indirect effects provide additional insight into the longer-term accentuation effects of specific activities as well as how engaging in certain activities earlier in one's educational career can have compounding effects. Students who participated in pre-college research programs had significantly stronger STEM identities in both 2005 and 2008, and these indirect effects underscore the value of exposing STEM students to research opportunities at a young age to enable them to begin performing and identifying as scientists.

Likewise, academic preparation, as measured by the number of years spent studying biology in high school, has significant, long-term indirect effects on STEM identity in both 2005 and 2008. Students who spent more time studying biology in high school had significantly stronger STEM identities at the end of their freshman year and at the end of four years of college. Furthermore, having an early commitment to pursuing graduate or professional school has a lasting significant effect on students' STEM identity development, as students who came to college in 2004 with these ambitions reported significantly stronger STEM identities in 2005 and in 2008.

Additionally, students who spent more time interacting with faculty during office hours during their first year of college experienced a lasting, positive benefit on their STEM identity in 2008 from these interactions. Similarly, engaging with faculty in research during the freshman year also had lasting positive benefits on 2008 STEM identity. Finally, students who felt they were successful at adjusting to the academic demands of college during the freshman year reported significantly higher STEM identity scores four years after entering college.

Discussion

Our results emphasize the importance of developing strong science identities early, as students with a stronger STEM identity at college entry and at the end of their first year of college had significantly stronger connections to science later in college. This finding connects to cumulative advantage theory (Allison, Long & Krauze, 1982; Allison & Stewart, 1974; Cole & Cole, 1973; Merton, 1973a; 1973b; Zuckerman, 1988) as arriving at college with a stronger STEM identity not only puts students in a better position at the start of college but also appears to accelerate students' STEM identity development during college. This also provides support for the accentuation framework (Feldman & Newcomb, 1969), as students' initial science identities are accentuated during college when they participate in activities and experiences that value and nurture their STEM identities.

Specifically, our findings indicate that early experiences with research, both pre-college and during students' first year of college, accentuate science identity as students progress through college. We found direct and indirect effects of early research opportunities on students' science identity at the end of their first year of college and at the end of four years of college, which supports work by Tran et al. (2011). Early research opportunities may provide for further talent development or at least stem the attrition rates from STEM fields (Chang et al., 2011). These research opportunities allow students to develop greater competence as scientists and apply those competencies in labs. Furthermore, conducting research with faculty provides students with an opportunity to connect with and get to know their professors in ways that may not be possible in the classroom.

These connections with faculty can provide further reinforcement and recognition for students, thus strengthening their STEM identities. Early contact with and recognition from faculty directly and positively affected students' science identity at the end of their first year and indirectly affected this construct at the end of their fourth year of college. Carlone and Johnson (2007) emphasize the importance of being recognized as a "science person" by meaningful others, particularly faculty. Our results underscore the lasting benefits of making early connections with faculty, either through research opportunities or interacting with professors during office hours, as such early contact has an immediate strengthening effect on students' STEM identity as well as a longer-term impact.

In addition to early contact with and recognition from faculty, students who had stronger preparation in high school had stronger STEM identities in 2004, and this additional preparation had a lasting, indirect effect on their subsequent STEM identity in 2005 and 2008. This finding, like that of having early research opportunities, connects with the cumulative advantage framework (Allison, Long & Krauze, 1982; Allison & Stewart, 1974; Cole & Cole, 1973; Merton, 1973a; 1973b; Zuckerman, 1988). Students who have access to stronger preparation, whether in the form of formal classroom instruction or research experiences, enter college with stronger STEM identities and appear more likely to continue to access in college these critical resources that further strengthen their connections to STEM disciplines. While providing greater access to these important resources early on is critical to eliminating inequities in the educational process of STEM students, it is probable that many students, particularly from low-income communities, may continue to lack access to these significant resources. As such, if colleges seek to increase the retention rates of all STEM students they must be proactive in providing access to these educational opportunities and resources during college for students who did not have access prior to entering college.

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Table 1

Factor Loadings from the Measurement Model for STEM Identity

	Loading
STEM Identity 2004	
Become recognized as an authority in my field	0.52
Make a theoretical contribution to science	0.67
Be recognized by colleagues for contributions to my special field	0.59
Find a cure to a health problem.	0.58
STEM Identity 2005	
Become recognized as an authority in my field	0.51
Make a theoretical contribution to science	0.70
Be recognized by colleagues for contributions to my special field	0.57
Find a cure to a health problem.	0.60
STEM Identity 2008	
Become recognized as an authority in my field	0.47
Make a theoretical contribution to science	0.72
Be recognized by colleagues for contributions to my special field	0.47
Find a cure to a health problem.	0.50

Note: CFI = 0.97 and RMSEA = 0.02.

Source: Analysis of data from 2004 Freshman Survey, 2005 Your First College Year survey, and 2008 College Senior Survey.

Table 2

Direct Effects Predicting Changes in Students' STEM Identity Development During College

	b	B	S.E.	Sig.
STEM Identity 2004				
URM student	0.02	0.02	0.03	
Sex: Female	-0.07	-0.07	0.04	*
Participated in a pre-college summer research program	0.18	0.13	0.05	***
Years of studying biology in high school	0.08	0.17	0.02	***
Self-rating: Math ability 2004	0.03	0.06	0.02	
Frequency: Tutored another student in high school	0.05	0.07	0.02	*
Reason for coming to college: To prepare for graduate school	0.32	0.37	0.03	***
R^2	0.22			
STEM Identity 2005				
STEM Identity 2004	0.67	0.72	0.06	***
Participated in a structured health-science research program during 2004-2005 academic year	-0.03	-0.02	0.05	
Joined a pre-professional or departmental club	0.06	0.06	0.03	*
Worked on a professor's research project	0.06	0.10	0.02	**
Frequency: Interacted with faculty during office hours in 2004-2005	0.03	0.09	0.01	**
Success at adjusting to the academic demands of college	0.06	0.08	0.02	**
Frequency: Studied with other students	0.06	0.08	0.02	**
Self-rating: Math ability 2005	0.05	0.11	0.01	***
Decided to pursue a different major during 2004-2005	-0.13	-0.15	0.03	***
R^2	0.64			

Table 2 (continued)

	b	B	S.E.	Sig.
STEM Identity 2008				
STEM Identity 2004	0.21	0.25	0.08	**
STEM Identity 2005	0.33	0.36	0.10	***
Participated in a structured research program during undergraduate years	0.11	0.11	0.04	***
Self-rating: Math ability 2008	0.01	0.02	0.02	
Persisted in a STEM major through 2008	0.12	0.15	0.03	***
Worked on a professor's research project	0.09	0.17	0.02	***
Faculty provided encouragement to pursue graduate or professional study	0.08	0.14	0.02	***
Institutional selectivity	0.00	-0.09	0.00	**
Institutional control: Private	-0.02	-0.02	0.03	
R^2	0.52			
2008 Math Self-Rating				
2005 Math Self-Rating	0.39	0.41	0.03	***
2004 Math Self-Rating	0.28	0.30	0.03	***
R^2	0.43			
2005 Math Self-Rating				
2004 Math Self-Rating	0.66	0.67	0.02	***
R^2	0.45			

Note: CFI = 0.93 and RMSEA = 0.03

Source: Analysis of data from 2004 Freshman Survey, 2005 Your First College Year survey, and 2008 College Senior Survey.

Table 3

Indirect Effects Predicting Changes in Students' STEM Identity Development During College

	b	B	S.E.	P
STEM Identity 2005				
Sex: Female	-0.05	-0.05	0.02	*
Years of studying biology in high school	0.05	0.13	0.01	***
Participated in a pre-college summer research program	0.12	0.09	0.03	***
Frequency: Tutored another student in high school	0.03	0.05	0.02	*
Reason for coming to college: To prepare for graduate school	0.21	0.26	0.03	***
STEM Identity 2008				
Sex: Female	-0.02	-0.02	0.01	
Years of studying biology in high school	0.02	0.04	0.01	**
Decided to pursue a different major during 2004-2005	-0.04	-0.05	0.02	**
Self-rating: Math ability 2005	0.02	0.04	0.01	**
Frequency: Studied with other students	0.02	0.03	0.01	
2004 STEM Identity	0.22	0.26	0.07	***
Participated in a pre-college summer research program	0.04	0.03	0.02	**
Frequency: Tutored another student in high school	0.01	0.02	0.01	
Reason for coming to college: To prepare for graduate school	0.07	0.09	0.02	***
Participated in a structured health-science research program during 2004-2005 academic year	-0.01	-0.01	0.02	
Joined a pre-professional or departmental club	0.02	0.02	0.01	
Frequency: Interacted with faculty during office hours in 2004-2005	0.01	0.03	0.01	*
Success at adjusting to the academic demands of college	0.02	0.03	0.01	*
Worked on a professor's research project	0.02	0.04	0.01	*

Figure 1
Final Structural Equation Model Predicting Students' STEM Identity Development During College