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Work in Progress: Formation of an engineering identity in first-year students through an intervention centered on senior design projects

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Abstract

This "work in progress" paper describes a multiyear project to study the development of engineering identity in a chemical and biological engineering program at Montana State University. The project focuses on how engineering identity may be impacted by a series of interventions utilizing subject material in a senior-level capstone design course and has the senior capstone design students serve as peer-mentors to first- and second-year students. A more rapid development of an engineering identity by first- and second-year students is suspected to increase retention and persistence in this engineering program. Through a series of timed interventions scheduled to take place in the first and second year, which includes cohorts that will serve as negative controls (no intervention), we hope to ascertain the following: (1) the extent to which, relative to a control group, exposure to a peer mentor increases a students' engineering identity development over time compared to those who do not receive peer mentoring and (2) if the quantity and/or timing of the peer interactions impact engineering identity development. While the project includes interventions for both first- and second-year students, this work in progress paper focuses on the experiences of first year freshman as a result of the interventions and their development of an engineering identity over the course of the semester. Early in the fall semester, freshman chemical engineering students enrolled in an introductory chemical engineering course and senior students in a capstone design course were administered a survey which contained a validated instrument to assess engineering identity. The first-year course has 107 students and the senior-level course has 92 students and approximately 50% of the students in both cohorts completed the survey. Mid-semester, after the first-year students were introduced to the concepts of process flow diagrams and material balances in their course, senior design student teams gave presentations about their capstone design projects in the introductory course. The presentations focused on the project goals, design process and highlighted the process flow diagrams. After the presentations, freshman and senior students attended small group dinners as part of a homework assignment wherein the senior students were directed to communicate information about their design projects as well as share their experiences in the chemical engineering program. Dinners occurred overall several days, with up to ten freshman and five seniors attending each event. Freshman students were encouraged to use this time to discover more about the major, inquire about future course work, and learn about ways to enrich their educational experience through extracurricular and co-curricular activities. Several weeks after the dinner experience, senior students returned to give additional presentations to the freshman students to focus on the environmental and societal impacts of their design projects. We report baseline engineering identity in this paper.

Introduction

This work hypothesizes that 1) peer-based interventions implemented within the existing curriculum can help teach underclassman 'what it means to be an engineer' and 2) participation in these interventions will stimulate engineering identity formation during the first one and two years of the curriculum, which will better retain students. Multiple reports have expressed the concern that there will be at least a one-million-person deficit between the forecasted demand for STEM professionals and the number of STEM graduates (Chen, 2013; PCAST 2012). To overcome this deficit, the United States would need to increase its annual production of STEM graduates by more than 34% (PCAST, 2012). A longitudinal study conducted by the US

Department of Education examined the choice of major of over 25,000 college students and found that nearly 33% of bachelor-seeking students will change their major at least once (NCES, 2017). STEM majors were more likely to change majors than those declaring non-STEM (35% vs 29%). Of the students initially declaring a STEM major, nearly half selected a non-STEM major as their final choice (Chen, 2013). Efforts to retain students showing an interest in STEM fields in their first years at the collegiate level are critical because the college years are when the career decision-making process takes place or is finalized (Blimling, 2010).

At Montana State University (MSU), the Chemical and Biological Engineering (ChBE) department experienced significant growth, expanding from approximately 180 majors in 2007 to over 600 undergraduate students a decade later. Section sizes have doubled or tripled. Engineering is known for having its own values, and this culture and identity formation may be hindered in larger classroom environments. In the ChBE department, the freshman introductory chemical engineering course annually enrolls more than 120 students, and even when countering attrition with additional transfer students to the major, only 90 chemical engineers will complete the senior year, indicating a significant loss of majors. Similar attrition is observed nationally amongst engineering programs (Krause et al. 2015; Ohland et al., 2011; Ohland et al., 2008). However, it has been shown that students who make connections with other students or faculty in their chosen field exhibit more persistence in college and towards the degree than do students who remain isolated (Tinto, 1994). Students with a strong engineering identity are more likely to persist (Tonso, 2006). In a systematic and exhaustive review of the extant literature on engineering identity, Morelock (2017) was unable to locate any studies that tested a freshman-senior intervention on engineering identity development.

Thus, this work presents on efforts to enhance these student-student connections both within class cohorts and between upper and lower division students. Students who identify with another person who is succeeding in school may believe such a goal is attainable (Fox et al., 2015). Fox et al. (2015) linked first year and senior year engineering design teams and showed that early academic career engineering students were able to effectively decide on whether engineering was an appropriate career path. An important aspect relative to this linkage was the need for senior design teams to assume a mentoring role (Fox et al., 2015). An additional study showed that role model exposure had positive effects on both STEM and non-STEM students' interest in STEM as well as their perceived identity compatibility between the self and STEM (Shin et al., 2016). The overall project focuses on seniors in a capstone design course and their engagement with underclassmen, initially to freshman students, then continuing to include sophomore students, through structured formal and informal interactions with the lower-division students. By interacting with senior students, the lower division students will be exposed to greater knowledge of the discipline in addition to often untaught disciplinary norms and expectations. Through these interactions, it is hypothesized that lower division students will more quickly establish an engineering identity, and this will increase retention and persistence in the engineering curriculum. In this paper, we present on the first baseline data of engineering identity from Seniors, Freshmen, and Sophomores.

Theoretical Framework: This study draws on three determinants of identity development: role acquisition theory and identity, socialization process, and peer interactions. Our theoretical framework is shown in Figure 1. Role acquisition theory postulates that individuals set goals, make decisions, form relationships, and develop their personal and professional identities through their college experiences (Kraus, 2012). This means that faculty have an opportunity to intentionally design activities that allow engineering students to engage in behaviors and interactions where they can learn new roles and reflect on how they fit into the new roles. Thornton and Nardi (1975) conceptualize role acquisition in four stages: anticipatory socialization, learning formal role expectations, learning informal role expectations, and developing personal role expectations.

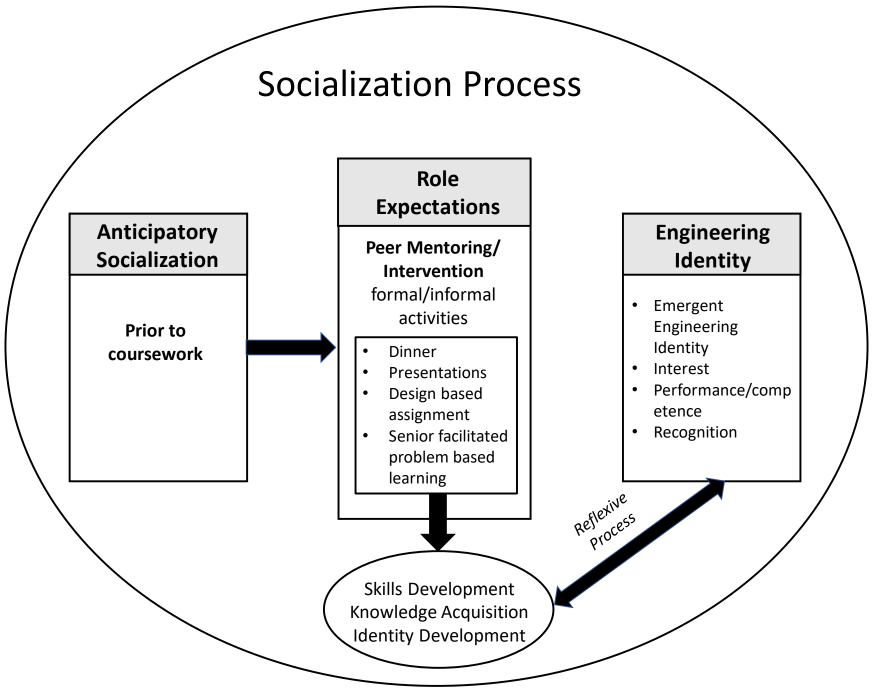

Figure 1. Imparting an engineering identity via a peer-mediated socialization process that integrates role identity/role acquisition theory and socialization theory.

The anticipatory socialization occurs before an individual is an actual member of a group. The student anticipates what it will be like to be a member of the group based on their prior exposure and other perceptions of that group. In the formal role expectation, students are exposed to the norms, expectations, and values of the group (i.e. engineering). These norms and values can be communicated to students through classroom experiences, freshman orientations, and other formal means of communication. During this formal orientation to the discipline, students are learning about the general expectations of the discipline and may conform to these expectations without personal insights. Learning the informal role expectations is when students begin to initiate and seek out informal opportunities to engage in role performance. Students may have to navigate tension between their experiences in the formal and informal activities and learn how to effectively perform in the new role. The ability of the students to understand the new role and develop knowledge, skills, and attitudes that enable them to be successful in the new role results in a stronger role identity. There is a socialization process that occurs as a freshman student navigates the formal and informal activities associated with the new discipline.

Role identity is a reflexive process in which individuals develop through the roles they assume, ascribe meaning to those roles, and engage in interactions as part of a member of a group (Burke & Reitzes, 1991). A person's professional and personal identities are integral to the socialization process. As students enter into the educational context, they bring with them their expectations of performance. Through the reflexive process of socialization, students' existing identities interact with their new roles and expectations, such as peer and advisor relationships, and may influence how students perceive the socialization process. Positive interactions between students and their peers may further influence the socialization experience. Socialization theory as it applies to education posits that students need to be socialized to understand the expectations, roles, and responsibilities of their discipline (Austin, 2002). Several factors including peers, employers, professional associations, and faculty may impact students' socialization to their disciplines and professions (Merton, 1957). Peer mentors have been shown to play an important role in providing support systems that are integral to retaining students in STEM. Particularly, it is the newer students who often "learn the ropes" of their program from more advanced students (Weidman, et al., 2001). It has been shown that socialization processes are facilitated by faculty and student mentors that offer guidance and support for developing the "scholarly potential of students as well as for perpetuating the traditional norms and values of academic life and intellectual inquiry." (Girves & Wemmerus, 1988). Scholars believe that the socialization of students should be thought of as a mentoring process of mutual exchange rather than something done to students and that it should highlight the importance of collaborative experiences that will foster paths to successful degree completion and career advancement (Golde, 2000).

Project Approach and Survey Instrument: For this 2-year project, the engineering identity of several cohorts of students will be measured over time using an instrument developed by Godwin (2016). A baseline was collected at the beginning of the fall semester in year 1 (departmental baseline) for freshman, sophomore, and senior engineering students, and this will be done again at the beginning of the following semester. This process will be repeated at the start and end of each subsequent semester for the courses outlined in Figure 2. Persistence in the major, defined as enrolling in the next course in our curriculum, and engineering identity will be tracked after each of the four semesters. Over the course of the 2-year study, students will have varying levels of and exposure to the student interaction (see Figure 2 for the course progression). We hypothesize that those students with more direct peer-mentoring exposure (type, quality, and quantity) will have higher levels of engineering identity development over time and will be more likely to persist.

Intervention Description: For senior and first year students in the first iteration, the mentoring role was semi-structured and occurred via in-class presentations by the senior students to the freshman and participation in "design dinners" with small groups of freshman students in ECHM 100. During one capstone design lecture (50-minute class), the authors briefly presented on mentoring in the engineering profession, the benefits of peer-peer mentoring, and gave an outline of the objectives of the dinners with freshman students. Prior to this lecture, the seniors completed an assignment in which they were asked to reflect on their experiences as a freshman student, list questions they had at that time, and recall things that they anticipated (both positive and negative).

This approach is based on a mentor training described by Neubert et al. (2013) wherein peer mentors were used to deliver engineering content in calculus courses. The authors also provided the senior students with guidelines for the initial 'talking points' to be covered during the dinner and a short reflective assignment they completed after the dinner to provide accountability. Class concluded with time for senior students, within their design teams playing the role of mentor and mentee, having their own facilitated conversations as if they were interacting with the first-year students. One half of the students in the senior class gave presentations to the freshman class twice during the semester. The presentations were followed by small group dinners consisting of freshman and these senior design students wherein the students were given time for informal and unstructured interactions. One half of the senior class was not used in the role of a mentor and served as a negative control for senior cohort in this study. In year two of this project, the interventions will focus on the sophomore students. Year two's freshman class will not participate in an intervention and serve as a negative control.

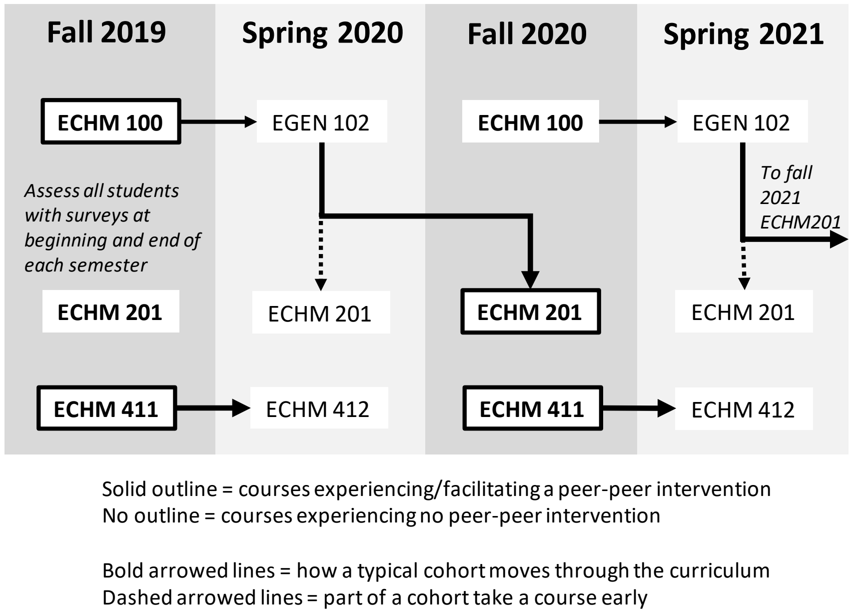

Figure 2: Proposed implementation scheme for interventions. This scheme provides for students who do not receive an intervention of any kind and will serve as a control. Other pathways through the curriculum yield cohorts with exposure from one to two cumulative interventions. Note: EGEN 102 is not part of this proposed work and is included to show the

In the second year of the project, the seniors will facilitate two sets of recitation sessions attended by sophomores in ECHM 201. Recitation sections enroll approximately 20-25 students and are 50 minutes in length. In each session, the senior students will be tasked with helping students as they work on a multi-unit material and energy balance problem using Excel. At this point in the semester, the sophomore students will have just learned the basics of material and energy balances while the seniors will have applied a larger system-wide material and energy balance as a part of their design projects. The seniors will possess knowledge of the contextual relevance of this exercise, having recently completed one of their own based on their design project, while the sophomore students will be expanding on their newly acquired skills and applying them to a larger problem for the first time. A similar reflective assignment will be given to the seniors prior to facilitating their first recitation section based on that described in Neubert et al. (2013). As the recitation sessions occur throughout the semester, a class period on this training will be less beneficial. Instead, the instructors will also provide senior students with a 'tip sheet' about best practices in running the recitation, focusing on how to engage and support the students in the recitation.

Survey Design: The survey instrument employed to measure student outcomes (engineering identity) was developed by Dr. Allison Godwin (2016). Her tool focuses on engineering identity via quantitative measurement. The three key constructs include recognition, interest, and performance/competence. There are 11 questions total within the three constructs, including "My instructors see me as an engineering"; "I find fulfillment in doing engineering"; and "I understand concepts I have studied in engineering." These are assessed on a six-point scale (strongly disagree to strongly agree). Role identity is identified as a theoretical framework. Her initial pilot study included over 300 students and the subsequent study had over 2500 student responses. As she concludes in her 2016 paper "The items developed to measure engineering identity are the first of their kind to quantitatively measure students engineering identity self-beliefs. I offer these items as a way to quickly assess and broadly understand students' engineering identity development." Thus, we feel this validated instrument is a strong fit for our ongoing study. In addition to Godwin's identity instrument, the students were asked a series of questions in key theme areas, including the decision to enter engineering, prior mentoring experiences and educational experiences. Topics queried are as follows:

1. To what extent did the following factors influence your decision to major in engineering: Parent(s), Sibling, Other relative, Friends, Guidance counselor, Extra-curricular activities, Career interests, Teachers, Potential future earnings, Other. In this case the responses were on a 5-point Likert scale from "Very important" = 1 to "Not at all important" = 5.
2. To what extent have you been mentored in your development as an engineer: Outside the University, Within engineering (faculty, TAs, advisor, etc.), Tutors, Elsewhere at [Institution name]. In this case respondents were given the following choices: 1 – "A great deal," 2 – "Often," 3 – "Occasionally," 4 – "Seldom" and 5 – "Never."
3. Godwin (2016) was administered and respondents were given the following choices responding to each statement on a Likert scale ranging from 1 = "Agree strongly" to 6 = "Disagree Strongly."

The survey was distributed via email to students and responses will be tracked longitudinally over time.

Results and Discussion

Freshman, sophomore and senior chemical engineering students were surveyed in the fourth week of classes. Numbers of students responding to the survey are as follows: 35 freshman, 25 sophomores and 43 seniors. Factors that influenced respondent's choice of chemical engineering as a major are shown in figure 3. Students rated each factor from 1 – not at all important to 5 – extremely important. In terms of factors that influenced choice of chemical engineering as major, all cohorts of students rated career interests as the most important factor followed by potential future earnings as the second most influential factor. Freshman students more strongly agreed as a cohort to both career interest governing their selection of major than did the sophomores and seniors. Seniors' responses indicated that they

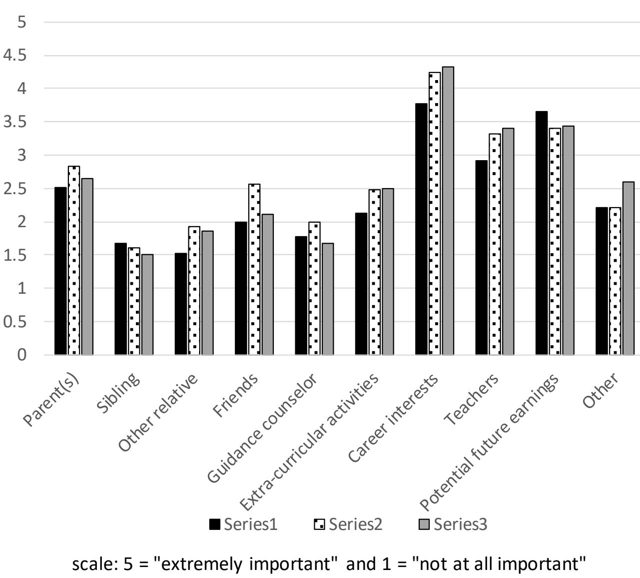

Figure 3: Student responses to factors influencing their choice of major. Higher scores indicate greater influence/ importance.

weighted career interests and potential future earnings more evenly than did the freshman and sophomore cohorts.

The results of the identity survey developed by Godwin are shown in figures 4, 5 and 6. These are broken into constructs relating to recognition as an engineer, personal interest in studying engineering (figure 5) and student's reported academic self-efficacy (figure 6) related to understanding of engineering problems, ability to perform well on exams and overcome setbacks.

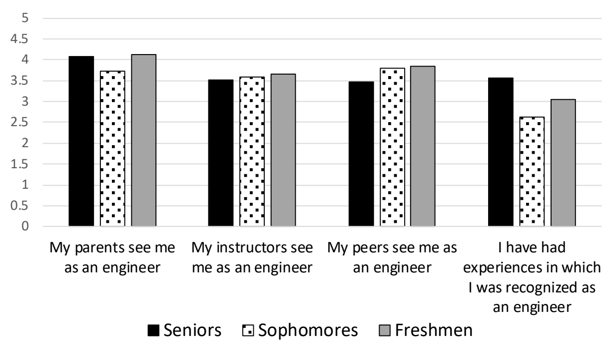

Figure 4. Student responses to statements from the engineering identity assessment regarding being recognized as an engineer by peers, faculty and family members. Higher scores indicate higher agreement.

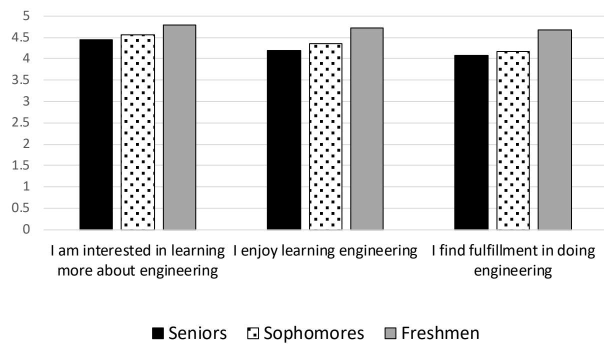

Figure 5. Student responses to statements from the engineering identity assessment regarding their interest and fulfillment in studying engineering. Higher scores indicate higher agreement.

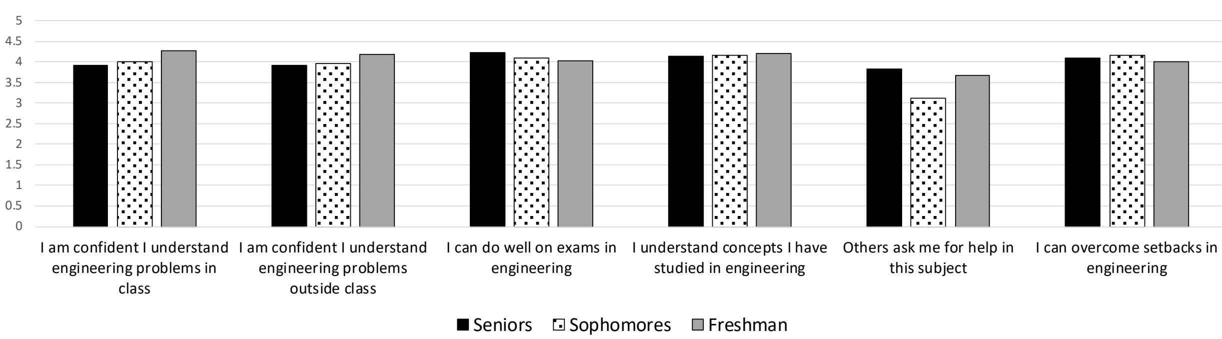

Figure 6. Student responses to statements from the engineering identity assessment regarding their perceived performance/competence as an engineer. Higher scores indicate higher agreement with each statement.

In terms of an overall composite response to the identity instrument, the freshman cohort were more likely to agree with the statements and display a greater engineering identity (4.1, s.d. = 1.1, N = 33) than either the sophomore (3.8, s.d. =1.1, N=25) and senior student cohorts (4.0, s.d. = 1.2, N = 43). This may be due to the freshman providing more anticipatory responses and imparting optimistic or positive projections to the questions "I am interested in learning more about engineering" and "I find fulfillment in doing engineering," rather than responses rooted in personal experience. At this point in the semester, the freshman students are new to college and have not had many actual engineering experiences. The freshman students also displayed more self-efficacy relating to their abilities in responding to the statement "I am confident that I can understand engineering outside of class" with more positive responses than either the sophomores or seniors. Again, due to the timing of collecting the baseline data, very few of the freshman cohort had experienced an exam at the college level yet. Student responses indicated minimal agreement to disagreement with the statement "I have had experiences in which I was recognized as an engineer" by all three cohorts of students.

Because this study involves studying the influence of peer mentors within the chemical engineering major as a variable in the development of an engineering identity, we sought to establish the level of mentoring that students received from other sources. This will be important in follow up work wherein the authors seek to ascertain the effectiveness of the current and future interventions on the development of engineering identity. Students in all cohorts were queried on the extent to which they received mentoring from sources within and outside the university. Freshman reported receiving more mentoring outside the university than did sophomores and seniors. Seniors reported having received more mentoring within the university than did sophomores or freshman. This is not surprising because the freshman students, at the point this survey was administered, have had little time at the university and were less likely to have accessed university resources. Students were also asked if they view themselves as mentors to other students. The senior cohort agreed to seeing themselves as a mentor slightly, with an average score of 3.1 while the sophomore and freshman student cohorts disagreed slightly, with an average score of 2.7 for both sophomores and freshmen.

Conclusion and Future Work

Overall, it was found that the freshman students demonstrated a more positive overall response to the statements posed in Godwin's engineering identity instrument prior to intervention than did the senior students and sophomore students. All three cohorts of students rated the factors of "career interests" and "possible future earnings" as important in their choice of chemical engineering as a major and overall, we found that the students had little mentoring experiences (both as mentor or mentee). While the seniors slightly agreed that they were viewed as mentors, the freshman and sophomores slightly disagreed to the statement that other students viewed them as mentors. Ongoing work this year involves administering follow-up surveys containing the engineering identity instrument in spring 2020 semester and conducting small focus groups with senior students to gather qualitative information regarding their experiences as mentors. In the coming year, an intervention is planned which will include sophomore students and will again utilize the senior students as mentors. In this next iteration, however, the context will be more structured and related to a project assignment the sophomore students are completing for a course.

Acknowledgements

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References

Austin A. E. (2002). Preparation of the next generation of faculty; Graduate school as socialization to the academic career. *Journal of Higher Education, 73,* 94-122.

Blimling, G. *The Resident Assistant*: *Applications and Strategies for Working with College Students in Residence Halls*. 7th Edition, Kendall Hunt Publishing

Burke P.J. and Reitzes, D.C. (1991) An identity theory approach to commitment. *Social Psychology Quarterly*. *54(3),* 239-251.

Chen, X. (2013) STEM Attrition: College students' paths into and out of STEM fields (NCES 2014-001) National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington DC.

Fox, G.A., Weckler, P., and Thomas, D. (2015) Linking first year and senior engineering design teams: Engaging early academic students in engineering design. ASEE: Advances in Engineering Education. Winter 2015, 1-14

Girves J. E., & Wemmerus, V. (1988). Developing models of graduate student progress. *Journal of Higher Education, 59,* 163-189.

Godwin, A. (2016). The development of a measure of engineering identity, ASEEs 123rd Annual Conference and Exposition, New Orleans, LA.

Golde C. M. T (2005). The role of the department and discipline in doctoral student attrition: Lessons from four departments. *Journal of Higher Education, 76,* 669-700.

Kraus, A. (2012). Engaging theories and models to inform practice. *New Directions for Teaching and Learning, 138,* 13-27.

Krause, S.J., Middleton, J.A., Judson, E., and Chen, Y-C. (2015). Factors impacting retention and success of undergraduate engineering students. ASEE Annual Conference and Exposition, Seattle, WA.

Merton R. K. (1957). *Social Theory and Social Strucutre*. Glencoe, IL: The Free Press.

Morelock, J.R. (2017) A systematic literature review of engineering identity: definitions, factors and interventions affecting development, and means of measurement. *European Journal of Engineering Education, 42(6)* 1240-1262.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2007). Rising above the gathering storm: energizing and employing America for a brighter economic future (Washington, DC: The National Academies Press, 2007), pp. 1–591

Neubert, J.J., Worley, D., Kaabouch, N., Khavanin, M. (2013). CCLI: Evaluation of a mentoring program for delivering engineering content to calculus students. Paper #7208. Presented at the 120th ASEE Annual Conference and Exposition, Atlanta GA.

Ohland, M.W., Brawmer C.E., Camacho, M.C., Layton, R. A., Long, R.A., Lord, S.M., Washburn, M.H. (2011) Race, gender, and measures of success in engineering education. Journal of Engineering Education 100(2), 225–252.

Ohland, M.W., Sheppard, S.D., Lichtenstein, G., Eris, O., Chachra, D. Layton, R.A. (2008) Persistence, engagement, and migration in engineering programs. Journal of Engineering Education. 97(3) 259-278.

President's Council of Advisors on Science and Technology (PCAST). (2012). Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics. Retrieved February 15, 2018 from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Shin, J.E.L., Levy, S.R., London, B. Effects of role model exposure on STEM and non-STEM student engagement. Journal of Applied Social Psychology 2016 46, 410-427.

Thornton, R., and Nardi, P. (1975). The Dynamics of Role Acquisition. *The American Journal of Sociology*, *80*(4), 870–885.

Tinto, V. (1994) Leaving college: Rethinking the causes and cures of student attrition. Chicago; London: University of Chicago Press.

Tonso, K. (2006). Teams that work: Campus culture, engineer identity, and social interactions. *Journal of Engineering Education, 95*(1), 25-37.

Weidman, J. C., Twale, D. J., & Stein, E. L. (2001). Socialization of graduate and professional students in higher education: A perilous passage? ASHE-ERIC Higher Education Report.