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Development of Engineering Professional Identity and Formation of a Community of Practice in a New Engineering Program

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***Abstract* – In 2016 Campbell University added a School of Engineering, offering a general engineering degree with concentrations in chemical and mechanical engineering. This paper describes efforts to intentionally support the development of engineering identity in students during their first year through the formation of a community of practice. Faculty managed and supported a variety of in-class and extracurricular activities to encourage the development of engineering identity. As part of the first-year experience, methods employed to foster community and identity development included four main avenues along with three cross-cutting themes. The four main avenues for development were the first-year engineering (FYE) design course sequence, an FYE seminar, mandatory extracurricular programming in professional development and service, and mandatory machine shop and makerspace training. The three cross-cutting themes were the core values of the School of Engineering, the need for diversity in engineering, and the availability of different career choices in engineering. Data was collected throughout the 2016-2017 academic year to understand the first year experience of the charter cohort at Campbell University. Data sources including student event participation record, facilities use records, and a modified professional identity scale were used to characterize and assess the methods. Results indicate that these efforts effectively promoted the creation of an engineering community and supported identity development for the initial cohort of students. This work may provide a template for other programs wishing to increase or systematize their efforts in identity development and community of formation.**

Index Terms - Community of Practice, Identity, New Program, Professional Development

INTRODUCTION

Campbell University is a small, Southern, rural, liberal-arts institution drawing a primarily in-state student body including a substantial proportion of nontraditional and underrepresented students. Campbell University offered engineering classes for the first time during the 2016-2017 academic year, through the new School of Engineering (SoE). Exclusively first-year coursework was available, with higher-level courses to be added as the charter cohort advances. Some previous works have reported on Campbell University's context and initial efforts, including [1]-[3]. Reference [1] reports on Campbell University's efforts to recruit a diverse cohort of students, [2] reports on the facilities prepared for and used by the incoming engineering students, and [3] discusses some elements of the origins and adaptation of the first-year engineering curriculum.

Campbell University's School of Engineering is in the unique position of developing a new engineering program within a liberal arts context. In addition to providing high-quality engineering coursework, the faculty are working together to provide consistent messaging and intentional departmental norms and practices across an integrated engineering curriculum. In the 2016 – 2017 academic year, the School of Engineering welcomed its inaugural class, providing first-year engineering programming and extracurricular opportunities to nearly one hundred students who enrolled in at least one engineering course. The School of Engineering also provided opportunities for students to interact with the broader Campbell community through student presentations at campus events. Practicing engineers interacted with students through in-class and extracurricular events while students were encouraged to act as engineering ambassadors themselves through community outreach events. The in-class practices, faculty messaging, and extracurricular events provide a basis for this pilot study regarding areas of strength and weakness in the Campbell University School of Engineering community of practice.

One foundational aim for the engineering program is promoting the formation of engineering professional identity in students. The intentional development of the community of practice within the School of Engineering was selected as the mechanism to achieve this aim. Rather than allowing a community of practice to form organically as the students, faculty, and staff act, react, and interact, the School of Engineering takes a deliberate and holistic approach to developing each student's unique engineering identity. This approach goes beyond typical engineering coursework, employing numerous interconnected methods tied to the development of the community of practice. It is expected that efficacy for individual practices and methods will vary between students. Employing multiple methods will make it more likely that each student will encounter at least one that is effective in welcoming them into the Campbell Engineering community of practice and developing their

personal engineering identity. Additionally, emphasis and repetition stretching across classes and other programming throughout the community of practice is expected to be more effective than isolated efforts.

As part of the first-year experience, methods employed to foster community and identity development included four main avenues along with three cross-cutting themes. The four main avenues for development are the first-year engineering (FYE) design course sequence, an FYE seminar, mandatory extracurricular programming in professional development and service, and mandatory machine shop and makerspace training. The three cross-cutting themes are the core values of the School of Engineering, the need for diversity in engineering, and the availability of different career choices in engineering. Results indicate that these efforts effectively supported identity development and the formation of a community of practice, and may provide a template for other programs wishing to increase or systematize their efforts in identity development and community formation.

FRAMEWORK

At Campbell University, student identity development is operationalized through a Communities of Practice (CoP) framework. A community of practice has three components: the domain, community, and practices [4]. The domain is engineering. The community is the School of Engineering at Campbell University. The practices are more difficult to define as directly and succinctly as the domain and community and are continuing to evolve as the program grows. These include engineering problem solving, ethics, and other areas as defined by ABET and common to most engineering programs. They also include the mission and values of Campbell University as well as practices intended to reduce barriers for underrepresented populations and evidence-based practices [1].

The CoP framework allows us to operationalize levels of student engagement with the SoE community. There are four levels of participation within a CoP, the peripheral group, occasional group, active group, and core group [4]. Students begin as members of the peripheral group through legitimate peripheral participation; we operationalize this as taking engineering courses and meeting the minimum requirements set for them by the SoE and Campbell University. Students move beyond the minimum requirements in the occasional group, attending extracurricular meetings that interest them (but are not consistent members) or possibly using the facilities for a one-off project without taking additional interest or training in what is available. Members of the active group have shown consistent interest in some sort of extracurricular activity, whether gaining additional certifications in the lab facilities, working on an undergraduate research project with a faculty member, consistently attending an engineering-focused extracurricular activity, assisting with a course, or some other focus. The core group is the strongest level of participation, where students are likely to know and be known by those in the department even if they have not been in the same class, take on mentoring roles including leadership positions in engineering-focused organizations, and is able to represent the SoE to others. These designations will allow the SoE to track student progress and to understand what impact the CoP focus on developing student identity has on student retention and persistence over time. As this model incorporates cross-cohort and mentoring roles, this paper does not categorize students using this model. The model was used to inform the initiatives discussed in this paper.

Identity can be viewed and considered in multiple ways. For this paper, identity is viewed through Gee's framework [5]. In Gee's framework there are four ways to view identity, one's innate state of being, nature-identity, one's position as officially sanctioned through an authority, institution-identity, one's individual traits as recognized by others, discourse-identity, and one's chosen experiences, affinity-identity. Some identities include only one of these perspectives while other identities encompass up to four of them. For some, engineering involves three of Gee's perspectives. One may be employed as an engineer as their institution-identity, be recognized as an engineer by others in their discourse-identity, and be involved in engineering clubs and activities in their affinity-identity. One is not born an engineer - even when one is considered a "natural engineer", that is recognition of their identity by others and therefore an example of discourse-identity.

As engineering students, all in the SoE at Campbell University hold the institutional-identity of engineering. While they are marked as engineers, they may not consider themselves engineers until they are recognized by others as engineers, gaining a discourse-identity that incorporates engineering, or by adding an affinity-identity by engaging in extracurricular organizations that are focused on engineering. A strong engineering identity may require multiple perspectives on identity to be present. Using the CoP framework as a model for the Campbell University first-year engineering experience, students are drawn into a community that will recognize them as engineers and are encouraged to engage in extracurricular activities that center around engineering. Student engineering identities are expected to strengthen through this model, and strong engineering identities, particularly those that begin in the first year of an undergraduate engineering degree, are likely to lead to greater student persistence and success [6]. In particular, students with strong engineering networks and engagement in engineering activities, or students active in a community of practice, have been found to persist in engineering as compared to students who have left engineering majors [7].

The first year experience for Campbell University engineering students is designed to quickly advance students from peripheral group status to active group status. This shift from legitimate peripheral participation to active members of the SoE community is intended to develop students' identities as Campbell University engineering students and more broadly as professional engineers.

Engineering identity can be and has been operationalized in various ways [8]. For the purposes of this study, students

are directly asked if they identify as engineers rather than evaluating underlying constructs relating to identity.

METHODS AND RESULTS

In its first year Campbell Engineering employed numerous methods to promote the development of professional identity, centered on the intentional formation of a community of practice. These are not novel methods; the School of Engineering is employing a variety of evidence-based practices to understand what works best in the Campbell University context. What is novel about this approach is the intentionality and integration of these methods from the inception of the school of engineering, including faculty buy-in, support, and input on what is and is not Campbell Engineering. This paper focuses on engineering students' first-year experience using data from the charter cohort.

Four main avenues for development were pursued along with three cross-cutting themes appearing across avenues. The four main avenues for development are the first-year engineering (FYE) design course sequence, an FYE seminar, mandatory extracurricular programming in professional development and service, and mandatory machine shop and makerspace training. The three cross-cutting themes are the core values of the School of Engineering, the need for diversity in engineering, and the availability of different career choices in engineering. Given the large number of efforts pursued, each method is discussed alongside results pertaining to it, if any are available. After all listed methods are discussed, overall results from a survey of engineering identity are presented.

I. Cohort

This study examines only students who began their engineering studies at Campbell University without the need for preparatory coursework in the fall semester of 2016. These students had the same instructor for all engineering coursework in their first year of study. This allowed for consistent capture of student data. This cohort started in the fall of 2016 with 65 students (18 women and 47 men) and continued in the spring with 37 students (11 women and 26 men). It is noted that fewer than 20% of the students not continuing in the spring failed their fall engineering requirements; most of these students did not achieve the required degree of C in either a required math or chemistry class but remained engineering majors. Due to the relatively small number of students involved, results are only examined for the cohort as a whole rather than demographic subgroups.

II. Engineering Identity Survey

A survey on engineering identity based on an adaptation of the *Are College Students Adults?* instrument developed by Arnett [9] and modified by Meyers and colleagues [6] was prepared. Additional modifications were made. The instrument developed by Myers et al. asked students to "Indicate whether you feel each of the following is necessary to be considered an engineer" in Yes / No format. The instrument used in this study added a second question to each prompt, which was "Then, mark whether you can do each thing at the current time" also in Yes / No format. This addition permitted inspection of correspondence between items students believed to be important and items students believed themselves capable of. Eleven new Likert-scale prompts were also added, focusing on the efficacy of methods of supporting professional identity development used by Campbell University and the strength of the community of practice. The engineering identity survey was administered at the end of the second semester to all 37 students of the second-semester first-year engineering design course. The survey was administered during the final class session on paper, alongside standard course evaluations. 35 of the 37 students returned complete surveys for a response rate of 95%. Some results from this survey are reported adjacent to discussions of specific methods, below, and more general overall results appear at the end of this section.

III. FYE Design Course Sequence

A signature piece of Campbell University's efforts to promote professional identity formation is the two-semester FYE course sequence. These courses meet four hours a week in classes no larger than 24 students. More information on this course sequence can be found in [3]. The first-year engineering design sequence supports the formation of professional identity development through a community of practice in three main ways. First, collaborative, student-centered learning is regularly practiced, where student groups and teams must solve meaningful challenges while working together. For example, students discover Kirchoff's Laws inductively in groups using a breadboard and multi-meter, then compare results and represent their findings mathematically. When individual work is performed, students who solve in-class problems before others are required to help other students, such that it is typical for the entire class to complete each problem before moving on as a group. Students are engaging with the norms and practices of the Campbell Engineering community as they interact in the classroom. Second, the FYE course sequence regularly requires students to solve practical problems and produce working code, systems, or prototypes, which is anticipated to help students build confidence in their engineering capabilities, supporting the development of engineering identity through authentic engineering practice. Finally, the FYE course sequence regularly encounters and discusses elements of the cross-cutting themes, discussed later in this section.

As part of the larger year-end outcomes survey previously mentioned, students responded to the prompt "After completing ENGR120 I felt more like I was an engineer" on a Likert scale. Of the 35 respondents, 14 strongly agreed (40%), 15 agreed (43%), 5 disagreed (14%), and 1 strongly disagreed (3%). For the second course in the sequence with a similar prompt, 17 strongly agreed (49%), 15 agreed (43%), 2 disagreed (6%), and 1 strongly disagreed (3%). It can be seen that a large majority of students found that the first-year engineering course sequence made them

feel more like engineers, with the more advanced second course in the sequence having a more pronounced effect. While it is not possible with this data to attribute gains to specific methods employed in the class, the overall effects of the methods in tandem can be observed.

IV. FYE Seminar

A first-year engineering seminar that focused on the profession of engineering, with a secondary emphasis on student success, was mandatory for all engineering students. This seminar was grounded in the CoP domain, engineering, while also allowing students to engage with their community and develop practices like talking about engineering and their place in engineering. A strong norm for Campbell University that stood out in this class is that engineering is a hard major, and it is okay to feel overwhelmed and to reach out to others for help if needed. This seminar typically introduced one aspect of the profession of engineering each week (such as professional ethics requirements), fostered in-class discussion of key points, and required students to reflect on their response and personal connection to the given topic. This seminar also supported the cross-cutting themes as discussed below. Overall, this seminar was intended to help students dispel misconceptions of engineering and make engineering as a profession more concrete, personal, and interesting for students. Students also consistently reported in person and in written reflections that the class helped them feel more like members of a community due to the in-class discussions.

As part of the larger year-end outcomes survey, students responded to the prompt "After completing ENGR100 I felt more like I was an engineer" on a Likert scale. Of the 35 respondents, 8 strongly agreed (23%), 15 agreed (37%), 9 were neutral (26%), 3 disagreed (9%), and 2 strongly disagreed (6%). For the prompt "ENGR100 helped me understand what engineering is", 14 strongly agreed (40%), 14 agreed (40%), 3 were neutral (9%), 2 disagreed (6%), and 2 strongly disagreed (6%). It can be seen that a large majority of students found that the first year engineering course sequence helped them understand what engineering is, and that a plurality of students felt more like engineers after completing the seminar. These results show the efficacy of this seminar in supporting professional identity development.

V. Professional Development and Service Requirements

Professionalism and service are two core values of the School of Engineering. Students were required to attend and participate in events outside of class centering on professional development as engineers and service to the community. Attendance at events with other engineering students continued to form community beyond classroom interactions and the foci of professional development and service reinforced the values, practices and norms of the SoE community of practice. Students learned broader engineering norms and practices through development activities including meeting with practicing engineers, preparing resumes, and acquiring networking and interviewing skills. Professional development and service requirements also helped students to recognize available resources and introduced them to opportunities to participate in professional organizations.

These requirements were enforced through a pass/fail mechanism with substantial grade penalties in the FYE design sequence for failure to complete the required number of hours. Separate hours requirements were applied to both professional development (15 hours per semester) and service (10 hours per semester). A wide variety of events programming, both internal to the School of Engineering and including some public events, was made available to students - ranging from tours of industrial facilities and panels of practicing engineers, to resume development, to fixing hurricane-damaged local infrastructure. To receive credit, students had to both attend an event and submit a reflection about their learning from it. Overall, engineering students logged more than 3,000 hours of professional development and service credit in the 2016-2017 academic year from 87 separate events. Given the large number of events and the wide variety, not all events had a strong engineering focus, but a majority of events did.

As part of the large year-end outcomes survey, students responded to the prompt "Professional Development events made me feel more like an engineer" on a Likert scale. Of the 35 respondents, 6 strongly agreed (17%), 15 agreed (43%), 7 were neutral (20%), 4 disagreed (11%), and 3 strongly disagreed (9%). While a plurality of students report identity development due to Professional Development events, the results are not as strong as those from the FYE design courses and the FYE seminar. This may be due to mismatches between student interests and specific events, or the subset of events attended by some student being relatively weak (no students attended all events).

For a similar prompt on Service events, of the 35 respondents, 3 strongly agreed (9%), 7 agreed (20%), 9 were neutral (26%), 12 disagreed (34%), and 4 strongly disagreed (11%). These results indicate that change is needed in either the presentation or content of service events to derive more value from them. Students reported that some service events lacked engineering content or focus and did not give them the feeling of participating in service as an engineer might. This area will be considered for improvement going forward.

VI. Machine Shop Training

Certification on the available tools was mandatory for all first-year students. This enabled them to pursue personal, creative engineering projects outside of class. Additionally, this training was also intended to support the development of engineering identity through the domain knowledge of the tools and materials, meeting with others and reinforcing or enhancing their network during training or while working, and learning the expected practices including safety requirements and the desire for all students to be comfortable using the available machinery. Prior studies of Makerspaces have found that students who engage with the facilities feel that their GPA and professional development in engineering are enhanced by the Makerspace [10]. To this end, a student-

friendly machine shop and Makerspace were priority facilities for the Campbell University School of Engineering [2].

Some basic training and experience in these facilities was provided in-class in the first-year engineering design course sequence, but to enable students to make safe use of the machine shop and Makerspace facility for personal projects, additional training was required. Therefore, general training was made mandatory as a pass/fail assignment worth a letter grade in the first-year engineering design sequence, resulting in very high compliance with training processes. In the fall semester students completed the basic training and by the end of spring were expected to have completed the second level of training with more dangerous equipment. Requiring all students to be trained was intended to lessen the potential for intimidation to occur in students with fewer prior shop experiences and to increase use of the facilities for personal engineering projects, fostering identity development. Student use of the Makerspace (but not the machine shop) was logged, and it was found that 57 different engineering students made 482 separate visits to the Makerspace during the 2016-2017 academic year. It can be seen that students made use of the Makerspace.

As part of the large year-end outcomes survey, students responded to the prompt "Working on personal projects in the Makerspace or Fab made me feel more like an engineer" on a Likert scale. Of the 35 respondents, 14 strongly agreed (40%), 17 agreed (46%), 3 disagreed (9%), and 1 strongly disagreed (3%). These results support the idea that student use of the Makerspace and machine shop support the development of engineering professional identity.

VII. Cross-Cutting Theme: Core Values

The Campbell University School of Engineering identified eight core values to be expressed through the engineering program as a whole and adopted by our students. The values are community, ethics, excellence, ownership, professionalism, relevance, resilience, and service. It is intended that these values form a nucleus around which the professional identity of the engineering students may form, and are a foundational component of the intended community of practice. These values were emphasized in recruiting efforts, during orientations, referred to in coursework or professional development programming when applicable, formed the basis of a class session and reflection in the first-year seminar, and were emblazoned on a twelve-foot-tall banner in the center of the engineering building.

VIII. Cross-Cutting Theme: Diversity in Engineering

The Campbell University School of Engineering emphasizes the need for engineers from diverse backgrounds for innovation and business success. Diversity in engineering is full-day topic in the first-year seminar and was accompanied by a written reflection assignment. Professional development programming such as panels of practicing engineers and workshops on teaming also reflected these ideas, and often featured majority-minority composition. Deliberate efforts were made to show representations of engineers from all demographic groups on posters in the engineering building and in other media presented to students. It is also noted that six of the seven current faculty in the School of Engineering are women. These methods are intended to ensure that as many students as possible encounter practicing engineers or images of engineers sharing their background or other demographic characteristics. This is expected to both normalize and value the contributions of engineers who do not fit stereotypical imagery and help students who do not fit a stereotypical engineering image view practicing engineers like themselves and therefore, to more easily view themselves as engineers.

IX. Cross-Cutting Theme: Pathways and Careers in Engineering

The Campbell University School of Engineering consistently emphasizes the variety of career paths available to engineers. The intention is to communicate that while it is normal for a given student to find some aspects of engineering less inviting, meaningful paths forward that they can personally connect with are available. This is expected to permit students to see themselves as engineers, fostering professional identity development. Engineering careers were a full-day topic in the first-year seminar and were accompanied by a written reflection assignment, and many professional development presentations were made by engineers with widely varying career paths and job roles.

X. Engineering Identity Survey General Results

The modified engineering identity survey contains several prompts not specific to Campbell University's methods or efforts. Students were directly asked "Do you consider yourself to be an engineer?" and 8 (22%) responded yes, 24 (67%) responded 'in some ways yes and some ways no' and 4 (11%) responded no. These results are strikingly lower than those reported by Meyer and colleagues [6]. This would seem to argue against other results of this study showing efficacy for the methods supporting development of identity, but may be a function of the populations sampled. Another possibility is that Campbell University students may more readily recognize the gap between their current capabilities and the expectations of a practicing engineer. It is plausible that the extended efforts to introduce Campbell University students to engineering identity provide them with a more nuanced understanding than those in the sample taken by Meyer and colleagues [6].

Students were also asked "Do you plan to work, conduct research, continue study, or teach engineering for at least three years after graduation?" and 24 (69%) responded yes, 11 (31%) responded 'not sure' and 1 (3%) responded 'no'. In contrast with the previous result, these findings are broadly similar to those reported by Meyer and colleagues [6]. These results show that a large percentage of the student population is committed to engineering as a career after one year of study, and almost all of the remainder remains uncommitted rather than rejecting engineering as a career choice. Given

Campbell University's high percentage of non-traditional students and relatively diverse engineering population, this result is positive.

Neither of the two general results discussed here offers clear evidence that the methods employed at Campbell University to foster the development of engineering identity are superior to those at another institution, but differences in population and student experiences in the first year make direct comparisons questionable. These general results are offered for illustrative rather than comparative purposes.

Research Limitations and Next Steps

The primary limitation of this study is that the sampled cohort only reflects students who were retained in engineering and remained on-schedule for engineering coursework - students who were not able to progress in engineering, who left engineering, or who left the university are not represented in most results. This may inflate the perceived efficacy of the methods employed. To address this limitation, efforts to obtain exit interviews or other data from all departing students are anticipated. This would yield a more complete picture of engineering identity development at Campbell University in the 2017-2018 academic year.

Additionally, the data gathered for this study typically reflect single points in time and cannot be used to examine the growth of professional identity over time. More data collection points, especially from the beginning of the first year of study, would allow for investigation of growth in professional identity over time. Additional data collection is likely to be implemented in fall 2017. Finally, future cohorts are anticipated to be larger, which may allow for insight into the efficacy of identity formation efforts on population subgroups.

Conclusions

In its inaugural year, the School of Engineering at Campbell University deployed a wide range of methods to support the development of engineering professional identity in first-year students. These efforts centered around the formation of a strong and distinctive community of practice within the School of Engineering. Several sources of data were used to assess the effects of different methods in supporting this development.

Overall, the suite of methods discussed in this paper appear to be effective at promoting engineering professional identity development through the formation of a community of practice that is unique to Campbell University. Coursework and personal student engineering projects were found to be most effective for a majority of students, while extracurricular professional development activities occupied a middle ground and community service supported identity development in a minority of students. The long-term efficacy of these efforts is unknown, but a strong engineering identity is likely to enhance long-term student success. These methods may provide a sound basis for other engineering programs to target the development of professional identity through a community of practice in the first year of engineering study.

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