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A Mentoring Program for First Year Engineering Graduate Students

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ABSTRACT

In this paper, we describe and evaluate a graduate mentoring program named "First ChEnnections," organized by the department of chemical engineering and later expanded to all engineering departments at a large, public research institution in the Southwest U.S. The main goal of this program was to develop a community to support first-year PhD students in navigating challenges related to entering graduate school, especially those exacerbated by pandemic-related social distancing. The program aimed to develop research and engineering identities, augment sense of belonging, improve perception of institutional climate, and increase awareness of available resources for first-year doctoral students. The program evaluation is based on student reflections and pre- and post-surveys. The data analysis shows that the program helped foster research identity and sense of belonging. The program also facilitated students' adjustment to life in a new city and to graduate school in general. Participant feedback and evaluation results prompted the School of Engineering to implement similar programs in all its engineering departments during the academic year 2021-2022, with positive results reported here. The contribution of this paper is to describe multiple components of a graduate-level mentoring program and to add to the body of evidence supporting the efficacy of mentoring programs for engineering graduate students.

Key words: graduate education, sense of belonging, peer mentoring

INTRODUCTION

In this paper, we describe and evaluate a mentoring program for incoming first year graduate students, aiming to support them during their transition to graduate studies. This program was organized by the department of chemical engineering at a large, public research institution in the Southwest during the summer and fall semester of 2020. It consisted of a multilayered approach to mentoring with guidance provided through peer mentoring to facilitate social activities and interpersonal connections, and faculty involvement to alleviate the challenges that usually arise with gatekeeper courses. This paper adds to the literature of mentoring programs for graduate students, offering suggestions that could positively influence the experience of first year graduate students.

BACKGROUND

Theoretical Framework

This project was guided by the theory of social capital (Coleman 1988; Bourdieu 1986; Putnam 2000), defined as the connections among people belonging to the same social group regulated by shared norms, values, and mutual trust. In particular, Coleman (1988) defines social capital as the value of the resources available to members of a social system regardless of social and/or economic status. By promoting a community of mentors, mentees and faculty, members generate social capital through their engagement in this community and benefit from it. Social relationships provide access to helpful resources, such as career guidance, advising, professional connections and emotional support. Studies have shown how social capital can be an important element in supporting STEM students from marginalized backgrounds (Mondisa and Adams 2020; Martin, Simmons, and Yu 2013).

This framework has important implications. Considering that students come from different backgrounds, different institutions, and different work and life experiences, we are interested in evaluating the support that could be provided by the mentoring program in gaining comfort and confidence in the new city and in the new school environment. Additionally, the importance of sense of belonging, defined by Strayhorn (2012) as the feeling of being valued and a part of a community, cannot be understated. Several studies have shown that being a part of a community is an important factor in students' engagement and persistence in STEM and in alleviating some of the challenges that students face (Wilson et al. 2015; Sax et al. 2018; Rodriguez and Blaney 2021; Johnson 2012; Espinosa 2011; Estrada et al. 2011). We are interested in analyzing how the social capital generated through the mentoring program affects students' sense of belonging and overall perception of department climate. We will also measure if and how engineering and research identity are affected by the social capital created during the participation in this program.

In summary, the intent of this study is to evaluate how the social capital acquired through the mentoring program, with its various components of peer and faculty support, affected the experience of first year graduate students and their perception of being a part of an inclusive and supportive environment.

Challenges in Graduate School

Transitioning to graduate study often comes with added responsibilities and less structured guidance. The higher expectations for academic independence can be overwhelming to students. The challenges of adapting, together with the heavy course load, research, other commitments may cause burnout, making it difficult to find a healthy life-work balance (Brus 2006). Many students report that their advisors are often inaccessible, leaving them feeling unsupported (Patterson 2016). This is more grievous for students from historically excluded groups, since lack of representation may make students feel isolated and impact their ability to persist in their program (Espinosa 2011; Bancroft 2013). Social, institutional, and systemic barriers all negatively impact sense of belonging (Rainey et al. 2018; Strayhorn 2015; Apprey et al. 2014; Ridgeway et al. 2018; Johnson-Ahorlu 2013; Seanna and Tabbye 2018; Rodriguez and Blaney 2021). Related to these barriers is imposterism (Clance and Imes 1978), which is connected to self-doubt and stereotype threat and negatively correlated to self-efficacy and institutional climate (Tao and Gloria 2018). Imposterism often has a greater impact on marginalized groups (Tao and Gloria 2018; Seanna and Tabbye 2018; Canning et al. 2019; MacInnis et al. 2019). Lastly, the COVID-19 pandemic has had a negative impact on many aspects of graduate education, including declining graduate enrollment in engineering (Enyu Zhou and Janet Gao 2021), limiting students' ability to perform research, increasing feelings of isolation (Matthews, Roy, and Wilson 2020) and growth in mental health disorders (Chirikov et al. 2020). These issues continue to manifest in the experience of first year graduate students as they transition to their new role and environment.

Mentoring

Mentoring has been widely used to improve engagement and retention, provide academic and emotional support to students, create a community of learners, and promote sense of belonging and identity (Tsui 2007; Summers and Hrabowski 2006; Bhatia and Amati 2010; Estrada et al. 2019; Pfund et al. 2016). Through mentoring, African American students have been found to increase their social capital by improving their social networks and support systems and gaining a better understanding of how to navigate their academic environments (Mondisa and Adams 2020; Apprey et al. 2014; Kendricks, Nedunuri, and Arment 2013). Although African American women students rated same-race and same-gender mentors as better capable of relating to them (Patton 2009), the

responsibility for mentoring students of color should not fall disproportionately on women faculty of color (DeCuir-Gunby, Grant, and Gregory 2013). Studies have shown that shared values and beliefs are also important in establishing impactful mentoring relationships (Blake–Beard et al. 2011; Hernandez et al. 2017). In a study of undergraduate researchers, Haeger and Fresquez (2016) found that "socioemotional and culturally relevant" mentoring strongly supported identity development. It is also important that all STEM faculty receive training and develop competence in multicultural mentoring, identity development and historical power dynamics (Dahlvig 2010).

Several studies have shown a strong connection between mentoring and professional identity development (Estrada et al. 2019; Tsui 2007; Summers and Hrabowski 2006), which is an important predictor of students' motivation to persist in STEM (Estrada et al. 2011). Ahmed, Muldoon, and Elsaadany (2021) found that peer and faculty mentoring combined with advising led to a significant increase in self-confidence and sense of belonging of first-generation undergraduate biomedical engineering students. McCallum (2018) found that a successful mentoring program can improve students' satisfaction for racially marginalized students, students with disabilities and those identifying as LGBTQIA+.

Peer mentoring has been widely used to support students transitioning to higher education. Several studies have demonstrated the value of peer mentoring in building self-confidence, receiving guidance and support, expanding social networks and increasing awareness and self-confidence toward graduate studies (Bhatia and Amati 2010; Winterer et al. 2020; Luna and Prieto 2009). Fávero, Moran, and Eniola-Adefeso (2018) showed that peer mentoring in graduate school is an effective tool to promote inclusivity and academic success among graduate students. Similarly, Bhatti et al. (2020) reported that mentoring programs for graduate students increase academic success and ability to navigate graduate school activities, and provide additional social and emotional support to students. Establishing mentoring relationships with faculty members is another important source of social capital. Undergraduates' interactions with faculty are a factor in their higher education retention and persistence (Pascarella and Terenzini 2005), intentions to apply to graduate school (Eagan et al. 2013; Houser, Lemmons, and Cahill 2013) and development of scientific identity (Carlone and Johnson 2007).

PROGRAM GOALS

This study intends to evaluate the following questions:

1. Did the mentoring program support the development of students' engineering and research identities, sense of belonging and positive perception of institutional climate?

2. Did the mentoring program help improve students' awareness regarding the resources available in their department, i.e., their social capital?
3. When the program is expanded to multiple departments, what are the gains in these measures for students from historically excluded groups?

METHODS

Positionality Statement

The authors are two faculty members and one PhD graduate with degrees in engineering. The second author designed and administered the initial offering of the mentoring program and served as Program Director, while the first and third authors conducted the evaluation. The evaluators are unaffiliated with the chemical engineering department. The evaluation was designed to better understand what can be done to improve the experience of students transitioning to engineering graduate study, at a time when graduate education is changing rapidly.

Protection of Vulnerable Populations

The philosophy of the mentoring program is rooted in an anti-deficit approach to changing the culture of higher education by inviting all students to participate in developing an inclusive and supportive community in which students lift each other up. We obtained approval from the human subjects research (IRB) review body. The online survey sent to all participants began with informed consent. Participants were given the option to skip any item. Demographic questions included the options "Prefer not to answer" and "Other." A separate consent form was sent to participants to obtain permission to use reflections. In internal reports and in this paper, we presented aggregate results to protect the privacy and confidentiality of participants.

Program Description

"First ChEnnections" was a mentoring program for incoming PhD students organized by the department of chemical engineering at a large, public institution in the Southwest during the summer and fall of 2020. This program was inspired by the mentoring program developed by Fávero, Moran, and Eniola-Adefeso (2018) for first-year chemical engineering doctoral students at the University of Michigan. In 2020, at the height of social distancing and online instruction, First ChEnnections was completely virtual and ran from July to December. Its approach to mentoring included both peer mentoring and faculty involvement. The program aimed to create a community of peers through small, personalized environments; provide faculty the opportunity to learn about students and their

individual needs; and mitigate the challenges related to entering graduate school (like many chemical engineering departments, this department does not admit master's students). Additionally, due to the COVID-19 pandemic, it was crucial to support incoming PhD students who may have suffered from isolation and stress.

Although this program welcomed students from all backgrounds, its design was guided by the needs of those who are not the majority. The intention of the organizer was to address inclusivity in terms of exposing everyone to a multitude of cultural competences — emphasizing that all have value — to improve respect and sensitivity in a supportive community. The philosophy behind this design is that everyone benefits and builds social capital from an inclusive community and welcoming institutional climate. By participating in this program, students would begin to develop cultural competencies that could improve the climate in their graduate program and their later workplaces. Participation in this program was completely voluntary and did not confer course credit.

The feedback received from participants and the results of this evaluation prompted the School of Engineering to implement similar programs throughout all its departments. The model was implemented in each department with different names and varying degrees of fidelity to the original program. A brief report of the evaluation results of this expanded mentoring program is included.

Incoming-Students To-Do List

Prior to the kick-off meeting, incoming PhD students received a training packet containing links to two short webinars regarding how to prepare for the first meeting and how to establish proactive communication within their mentoring group. In addition, students were asked to write a short reflection to answer the following questions:

- What are some of the feelings that you are experiencing?
- What do you think that you, as a first-year student, need to understand further?
- What do you want to get out of this program?

The Program Director collected reflections prior to the kick-off meeting. In preparation for fall courses, students were asked to share with faculty detailed syllabi from their undergraduate courses in thermodynamics, transport/fluid mechanics, and kinetics. In collaboration with the first-year course instructors, the Program Director reviewed these materials to recommend placement (i.e., whether to recommended starting with undergraduate courses).

Peer mentoring

Each incoming PhD student was assigned to a group led by trained mentors, who were established chemical engineering doctoral students. To intentionally match mentors and protégés, "connection cards" were created for each student and mentor including a photo, school that they

attended for undergraduate studies, research interest, country/geographic area of origin, gender identity, and hobbies. The protégés' information was shared with the mentors, and they identified 1-3 people whose interests resonated with their own. The Program Director used these rankings to pair them.

Positionality, diversity of backgrounds, and their relationship to mentoring were explicitly addressed during a two-part, three-hour mentor training. Each mentoring group met weekly or biweekly. The peer mentoring component was created to promote socialization, openly discuss issues related to graduate school and the department and facilitate incoming students' adjustment to the new city. In addition, peer mentors organized a series of social gatherings outside of the regular meetings to facilitate interpersonal relationships and promote friendships outside of the university.

Faculty involvement

Faculty involvement refers to two different components: weekly faculty sessions led by the Program Director and content knowledge assessment.

Weekly faculty sessions were scheduled to facilitate a connection between incoming students and first-year instructors, teaching assistants, and department staff. Topics included succeeding in first year courses, advisor selection, publishing and giving talks in graduate school, work-life balance, working in a research team, maintaining resilience, tracking and owning progress, and overcoming imposterism. Additional topics include forming beneficial professional relationships, cultural competency (interacting with diverse researchers), effective communication, and ethics. Before each meeting, students were asked to reflect on that week's topic.

The other component of faculty involvement included a set of assignments named "homework zero" to assess students' content knowledge related to the first-year courses of thermodynamics, transport/fluid mechanics, and kinetics. The personalized recommendations that followed homework zero included adjusting the syllabi of the first-year courses to better align with students' knowledge and advising students to start with an undergraduate class if necessary. This personalized approach intended to alleviate the stress of a heavy course load and destigmatize the possible need to start with an undergraduate class by making it a natural part of the process.

An example of the mentoring schedule for the 2020 cohort is reported in Table 1.

Recruitment and Participants

Mentors were trained volunteers, recruited through a listserv of established PhD students of the chemical engineering department. Twenty-six students volunteered to participate as mentors.

Table 1. First "ChENNECTIONS" mentoring schedule, 2020.

Thurs 7/16	Program kickoff meeting
Week 7/20	Peer-mentor meeting
Thurs July 23rd	Topic #1: Graduate school as a training program and career stepping stone. What is graduate school and what can I do after?
Week 7/27	Peer-mentor meeting
Thurs Aug 6th	Topic #2: Navigating graduate school expectations: courses, research, teaching/building a network of mentors. How do I make it through graduate school? Are research advisors and mentors the same?
Week 8/3	Peer-mentor meeting
Thurs Aug 13th	Topic #3: Planning for effective meetings and effective communication. How do I set effective meetings through the advisor selection process and beyond?
Week 8/10 &17	Peer-mentor meetings
Week 8/19	Orientation
Week 8/24	First week of classes (8/26)
Thurs Aug 27th	Topic #4: Setting early career goals and being proactive in graduate school. How do I make the most out of my graduate school experience?
Week 9/13	Peer-mentor meeting
Thurs Sept 10th	Topic #5: Imposterism; remaining confident and positive throughout graduate school. How can I overcome this fear of not being capable enough?
Week 9/14	Schedule mentee meeting
Thurs Sept 24th	Topic #6: Operating successfully in a diverse environment: respect and sensitivity as a community member. How can I make sure I build others around me?
Week 9/28	Peer-mentor meeting
Thurs Oct 8th	Topic #7: Getting engaged in group meetings and contributing towards inclusivity in scientific discussions. How do I become a contributing member to my research team?
Week 10/12	Peer-mentor meeting
Thurs Oct 22nd	Topic #8: Time management and work life balance. Can I still have a life outside of lab?
Week 10/26	Peer-mentor meeting
Thurs Nov 5th	Topic #9: Engaging as a future scholar (Part I): planning purposeful research, publishing, and getting acquainted with the research field. How do I better position myself as a productive researcher and how do I show that?
Thurs Nov 19th	Topic #10: Engaging as a future scholar (Part II): reading scientific research papers and archiving them. What am I supposed to get out of the literature and how do I organize all this information?
Week 12/1	Last formal peer-mentor meeting
Thurs Dec 3rd	Topic #11: Scientific networking: customizing a research pitch and maintaining connections. How do I take most advantage of short scientific encounters?
Fri 12/11	End of Program Celebration

Among them, 11 identified as women, 15 as men. Eighteen identified as White/Caucasian, two as Hispanic, three as Asian, three as Black/African American, including international students. The department's graduate population was 41% international students in 2020. International students who completed their bachelor's degrees in the U.S. and abroad participated in the mentoring program.

Incoming PhD students were contacted through a listserv of admitted PhD students encouraging them to participate in this optional mentoring program. Nineteen students agreed to participate. Among them, five identified as White/Caucasian, two as Hispanic, five as Asian, five as Black/African American, one as Caucasian and Asian, and one preferred not to answer. Ten identified as women, and nine identified as men.

Data Collection

Data collected to evaluate this mentoring program include:

- Pre- and post-surveys administered through Qualtrics™ before the start of the program, in August, and at the end of the program, in December.
- Students' reflections.

The questions were kept consistent between pre- and post-surveys. Constructs such as students' research and engineering interests, research performance/competence, sense of belonging, and institutional climate were included in the surveys and measured using published scales comprising multiple items. Questions related to research and engineering interests were adapted from Choe and Borrego (2020) and research performance/competence questions from Choe et al. (2017). Questions related to sense of belonging (Valued and Belonging) and institutional climate (Thriving and Growth) were adapted from a University of Michigan (2017) diversity, equity and inclusion climate survey. Additional topics in the surveys included single items concerning confidence and competence adapting to the new city and the new institution, knowledge of what to expect during the first year of graduate school, knowledge of students who had successfully completed the first year of the program, and suggestions on how to improve institutional climate. These items were designed specifically for the program evaluation. Students' reflections ranged from 1 paragraph to more 2 pages. Twelve participants consented to using their reflections for program evaluation.

Data Analysis

Survey respondents were asked to rate the extent of their agreement/competence toward a series of statements on a 5-point Likert-type scale ranging from 1=Strongly Disagree/Not at All Competent to 5=Strongly Agree/Very Competent. To answer research questions 1 and 2, the first author compared the means of pre- and post-survey responses using a nonparametric unpaired t-test, the Mann-Whitney test, using Stata. We report effect sizes (Yatani 2018; Fritz, Morris, and Richler 2012; Cohen 1992) and statistical significance.

To evaluate question 2, the first author also analyzed students' reflections. We compared the mean of pre- and post-survey responses and contrasted these results with the analysis of the reflections to evaluate in what ways, if any, the mentoring program responded to students' needs.

RESULTS

Q1: Did the mentoring program support the development of students' engineering and research identities, sense of belonging and positive perception of institutional climate?

To evaluate question 1, we compared the mean of pre- and post-survey responses. The results are reported in Table 2 (complete list of survey items in Appendix). Cronbach's alphas ranged from 0.74 to 0.91, above the minimally acceptable range (DeVellis and Thorpe 2021).

Table 2 shows an overall increase of all measures, with "Research Interest" ($p \leq 0.05$) showing a statistically significant improvement. This finding is surprising for two reasons related to pandemic social distancing. First, the incoming PhD students had less research experience than previous cohorts. Second, it was not possible that year to offer a research experience component to incoming PhD students. The statistically significant improvement of this measure suggests that, despite the lack of a dedicated research component, the knowledge acquired through peer and faculty conversations related to research nonetheless increased interest and perhaps alleviated apprehension about research.

"Valued and Belonging" ($p \leq 0.05$) also shows a statistically significant increase. This finding aligns with one of the primary goals of this mentoring program. Sense of belonging is a key indicator of retention and persistence in STEM (Wilson et al. 2015), and it is linked to institutional climate (Hurtado and Carter 1997; Ong et al. 2011). Thriving and Growth did not show a statistically significant change, but the positive trend of this measure together with the significant increase in belonging suggest an improved perception of departmental climate.

Table 2. Engineering and Research Interests; Sense of Belonging; Research Self-Efficacy; Institutional Climate.

Factors (1=Strongly Disagree/Not at All Competent; 5=Strongly Agree/Very Competent)	Pre (19)	Post (12)	Effect Size	Alpha
Research Interest	4.50	4.78*	0.40	0.88
Research Performance/Competence	3.70	3.88	0.11	0.81
Engineering Interest	4.56	4.61	0.05	0.91
Valued and Belonging	3.97	4.29*	0.38	0.81
Thriving & Growth	3.61	4.19	0.31	0.74

* $p \leq 0.05$
**$p \leq 0.01$
Effect size: .1 to .29 small, .3 to .49 medium, and > .5 large

Q2: Did the mentoring program help improve students' awareness of resources available in their department, i.e., their social capital?

To evaluate question 2, we compared the survey results with the reflections to determine in what ways, if any, student needs expressed in their reflections were met. In their reflections, many students expressed hope about receiving guidance on (1) how to be successful in graduate school, (2) career planning, (3) how to stay organized, and (4) maintaining a healthy life/work balance. Additionally, students requested support on how to be a better researcher, how to establish good relationships with advisors, and an "honest assessment of the good and bad aspects of graduate school." Students also reported that they were looking forward to social and interpersonal relationships with other first-year students and with more advanced students. They hoped to improve their communication skills, ease anxiety regarding the first semester core classes, minimize imposterism and adjust to a new city. Both the connections with others and access to advice and information contribute to social capital.

Analysis of additional survey responses is reported in Table 3 and 4. Table 3 reports items related to students' readiness regarding their first year of graduate school. The data show an improvement in all measures with some statistically significant changes: "I am well-informed about the advisor search process" ($p \leq 0.01$), "I know where to focus my effort during my first year in graduate school" ($p \leq 0.01$) and "I know what to expect for my first year in graduate school" ($p \leq 0.01$). These increases address concerns raised in reflections regarding advisor relationships and priorities and expectations during the first year of graduate school. "I know ChE graduate students who have successfully completed their first year of graduate school" ($p \leq 0.01$) also shows a statistically significant improvement, as expected. As designed, the program connected incoming PhD students with established students who had successfully completed their first year of graduate school, who could serve as role models and provide encouragement during their first year.

Table 3. Readiness regarding first year of graduate school.

To what extent do you disagree or agree with the following statements (1=Strongly Disagree; 5=Strongly Agree)	Pre (19)	Post (12)	Effect Size
I am well-informed about the advisor search process	2.84	4.75**	0.80
I know where to focus my effort during my first year in graduate school	2.68	4.42**	0.62
I know what to expect for my first year in graduate school	2.68	4.50**	0.65
I know ChE graduate students who have successfully completed their first year of graduate school	3.53	4.83**	0.62
I am excited about the research I will do at UT Austin	4.74	4.83	0.11
I received high-quality peer mentoring this summer (post only)	N/A	4.25	N/A
I received high-quality faculty mentoring this summer (post only)	N/A	4.50	N/A

*$p \leq 0.05$
** $p \leq 0.01$
Effect size: .1 to .29 small, .3 to .49 medium, and larger than .5 large

Table 4. Competence regarding first year of graduate school.

How competent are you… (1=Not at All Competent; 5=Very Competent)	Pre (19)	Post (12)	Effect Size
Understanding what is expected of me in graduate school	3.47	4.50**	0.59
Finding a stimulating research group	3.32	4.75**	0.77
Performing well in graduate-level courses	3.53	4.25*	0.44
Finding resources for living in Austin	3.63	4.42*	0.39
Making friends or finding community in Austin, beyond the university	2.84	3.58*	0.36
Doing good research at UT Austin	3.26	3.67	0.14
Settling into life in a new city	3.58	4.25	0.32
Finding help if struggling academically	3.63	3.92	0.11
Finding help if struggling with stress, mental health, or wellbeing	3.58	4.08	0.19

*$p \leq 0.05$
** $p \leq 0.01$
Effect size: .1 to .29 small, .3 to .49 medium, and larger than .5 large

The post-only items "I received high-quality peer mentoring this summer" and "I received high-quality faculty mentoring this summer" show means ranging between agree and strongly agree. This result could be interpreted as evidence of the strong commitment of faculty and mentors to support students during this transition and/or the quality of the mentor training.

Table 4 reports students' confidence regarding their first year in graduate school. The results indicate an overall positive change of all measures, some statistically significant. The statistically significant improvement in "Understanding what is expected of me in graduate school" ($p \leq 0.01$) suggests that students' expectations were met regarding a better understanding of what the first year of graduate school entails. "Finding a stimulating research group" ($p \leq 0.01$) aligns with expectations related to improving as a researcher and hoping to find challenging research topics. The increase in "Performing well in graduate-level courses" ($p \leq 0.05$) suggests that the mentoring program may have helped alleviate the anxiety toward first semester core courses. Faculty involvement in the assessment of students' content knowledge through adjusting the syllabi and personalized advising may have eased students' anxiety toward first year classes and improved their confidence in their ability to meet their course requirements.

"Finding resources for living in Austin" ($p \leq 0.05$) and "Making friends or finding community in Austin, beyond the university" ($p \leq 0.05$) also increased statistically significantly, suggesting that the opportunity to connect with other students may have helped incoming PhD students to develop a support system. These two measures directly address reflection concerns regarding relocating and establishing a social network, especially in a time of isolation and social distancing. Although surveys did not include questions about COVID-19, isolation and difficulty establishing social connections were

concerns expressed in the reflections. We speculate that the community created through the program may have mitigated feelings of isolation and helped first year students build a support system.

Q3: When the program is expanded to multiple departments, what are the gains in these measures for students from historically excluded groups?

In 2021-22, the mentoring program was expanded to all seven engineering departments, including some master's programs, and the pre-post surveys were repeated. Larger sample sizes allow for comparisons between identity groups. To avoid removing any individuals from the data set, we combined groups for analysis.

Gains by Race/Ethnicity

Among students who identified as coming from historically excluded racial/ethnic backgrounds (i.e., not white nor Asian), we observed statistically significant increases in five areas:

- Research Interest (pre mean = 4.30, post mean = 4.50; $p \leq 0.05$)
- Engineering Interest (pre 4.47, post 4.61; $p \leq 0.05$)
- I know where to focus my effort during my first year in graduate school (pre 2.94, post 3.90; $p \leq 0.05$)
- Finding a stimulating research group (pre 3.06, post 4.20; $p \leq 0.01$)
- I know engineering graduate students who have successfully completed their first year of graduate school (pre 3.65, post 4.50; $p \leq 0.01$)

Gains by Gender Identity

Among students whose gender identities are historically marginalized in engineering (women and gender divergent individuals), we observed statistically significant increases in four areas:

- Research Competence (pre mean 3.92, post 4.36; $p \leq 0.05$)
- Feeling Valued and Belonging (pre 3.87, post 4.37; $p \leq 0.05$)
- Finding a stimulating research group (pre 3.63, post 4.29; $p \leq 0.05$)
- I know engineering graduate students who have successfully completed their first year of graduate school (pre 3.95, post 4.57; $p \leq 0.05$)

For women and gender divergent participants, we also observed a statistically significant decrease in engineering interest (pre mean 4.74, post 4.60; $p \leq 0.05$).

SUMMARY AND DISCUSSION

In this paper, we described in detail the different components of a mentoring program created to support first year engineering doctoral students at a large, public research institution in the Southwest

U.S. We examined how the relationship with peer and faculty mentors may have supported students toward their academic success by alleviating the challenges faced during the transition to graduate study. Understanding students' expectations and how they were addressed during this mentoring program can inform future mentoring interventions.

Adaptation and Expansion

The results of the expansion to the different departments of the School of Engineering corroborate the idea that this mentoring program could still be successful if adapted for department size and culture. Adaptations may be made for programs with large cohorts, both master's and PhD students, and without common core courses. In expanding the mentoring program, all our engineering departments preserved the structure of peer mentoring (some in groups instead of pairs) and regular, topical meetings with a faculty leader. Most engineering departments began their mentoring programs at the start of the fall semester (so did not conduct assessments for placement in coursework), and some included master's students. Based on the size of the department, varying proportions of the incoming graduate cohort could participate and be assigned mentors. Regardless of the size of the incoming cohort, most department-level mentoring programs were run by a faculty member collaborating with a staff graduate coordinator or postdoc. The major time commitments include recruiting, selecting and matching mentors and mentees; offering 1-2 hours of mentor training; preparing content or inviting speakers and attending group sessions; and processing payments if stipends or meals are funded. Additionally, graduate peer mentoring programs are not possible without "leveraging the desire of students to help their peers" ((Bhatti et al. 2020), p.10). Table 5 presents a timeline and checklist for others seeking to offer such a mentoring program.

Table 5. Timeline for Planning, Evaluating and Offering Graduate Peer Mentoring.

Program activity	Dates
Announce program and solicit applications	As early as April 15, through spring term
Select participants and match mentors with mentees	June
Mentor orientation/Training session	July for summer start, one week before classes for fall start
Program kickoff, assessment pre-survey, pre-program reflections	July for summer start, One week before or one week after first class day for fall start
Homework 0 pretest of content knowledge, if offering course placement advising	At least 1 week before course registration
Course advising and placement meetings, if offering	Before and during course registration
Weekly or bi-weekly content sessions and mentor-mentee meetings	From program kickoff through fall term
End of program celebration, post-survey, post-program reflections	Early December
Reflection and planning for next cohort	January through May

Summary of Gains

Pre- and post-survey analysis revealed First ChEnnections participants' statistically significant increases in Research Interest, one component of research identity (Choe et al. 2017), connected to improvements in academic performance, retention, and persistence in STEM (Merolla and Serpe 2013; Syed, Azmitia, and Cooper 2011; Carlone and Johnson 2007; Chang et al. 2011). Recent studies on professional identity development among graduate students report that, in the transition to graduate school, students develop their professional identity and reconcile their perception of self and the requirement of their profession through the validation of the interpersonal relations and feedback received by insiders to the profession (Gelles and Villanueva 2020; Perkins et al. 2017). Considering the research focus of graduate school and of faculty and advisers, it seems plausible that research identity among graduate students is strongly supported in graduate school, while it is possible that opportunities for engineering identity development are less available. Perkins et al. (2017) found engineering graduate students to struggle with their complex and emergent engineering identities in relation to scientist identities, and that engineering identity varies by graduate discipline (Bahnson et al. 2021). Moreover, Gelles and Villanueva (2020) found that engineering graduate students redefine their engineering identities through their research experiences.

The students also saw gains in feeling valued and belonging. Recent studies (Stachl and Baranger 2020) focused on sense of belonging within the graduate community (graduate students, postdoctoral researchers and faculty) have shown that graduate students experience difficulties in maintaining a positive self-perception regarding their capabilities as researchers and scholars in particular in respect to other's view of themselves. The gain in feeling valued and belonging after participation in this mentoring program aligns with prior studies showing that mentoring programs, in which trusted relationships are developed, have a positive influence on students' sense of belonging and ability to feel supported in their community (McCallum et al. 2018; Apprey et al. 2014; Patton 2009; Kendricks, Nedunuri, and Arment 2013). According to Bhatti et al. (2020),

> Teaching students that their worries about belonging are normal and, more importantly, that they are not unique to them as a member of a particular URG [underrepresented group] increases academic success. Similarly, when students feel connected with one another, and they begin to see that their academic struggles are not unique to them, improvements in learning, performance, and general academic success follow. (p. 10)

Students participating in this program also increased their knowledge of expectations for graduate study, where to focus their effort, and the advisor search process. By design, they met more students who successfully completed their first year of graduate study. Participants also increased

their confidence in performing well in their courses, understanding expectations, finding a research group, making friends, and navigating life in their new city. We acknowledge that some of these gains might have occurred without the mentoring program, and that data from a comparison group would have helped to separate the effect of the mentoring program. However, literature regarding the positive effects of peer mentoring corroborates our findings. The fact that these gains were observed at the height of pandemic-related social distancing suggests that in-person mentoring programs may see additional benefits.

When the mentoring program was expanded and adapted to seven engineering departments and courses returned to in-person meetings, similar gains were observed. Students from historically excluded racial/ethnic groups increased their Research and Engineering Interests and knowledge of where to focus their effort. Women and gender divergent individuals increased their Research Competence and sense of belonging. Both groups increased their confidence in finding a stimulating research group and met more students who had successfully completed their first year. These are important aspects of hidden curriculum (Sellers and Villanueva 2021) not necessarily gained by majority participants.

Future Work

First ChEnnections was designed to initiate critical conversations regarding the challenges that marginalized students face by engaging students from all backgrounds to be exposed to topics and activities outside of their personal experience and interests. Responding to the need for culturally relevant initiatives (Apprey et al. 2014; Haeger and Fresquez 2016), several weekly meetings were dedicated to inclusivity, sensitivity, respect, proper communication in a diverse community, cultural competence, and cultural humility. In the pre-survey and in the reflection, some students suggested including open conversations related to race and racial biases, social justice, and systemic racism. The need for these conversations has been cited by Dahlvig (2010) as an important step to create deep mentoring connections, improve biases and historical power dynamics and mitigate skepticism caused by historical systemic racism. These are very important suggestions to be considered in future offerings.

CONCLUSION AND LIMITATIONS

The strength of this mentoring program lies in its multilayered approach, consisting of peer mentoring and faculty involvement. The goal was to provide an inclusive and supportive community to first year engineering PhD students and alleviate some of the challenges of transitioning to graduate

school. The evaluation revealed gains in students' research identity and sense of belonging, crucial factors in engagement and retention. The program also supported students' adjustment to life in a new city and to graduate school in general. Expansion to seven different engineering departments further demonstrates some clear benefits to implementing such mentoring programs for first-year graduate students. Even without strong fidelity to the original model, such a peer mentoring program administered by a faculty member could benefit incoming graduate students historically excluded from engineering education and help to broaden participation in engineering.

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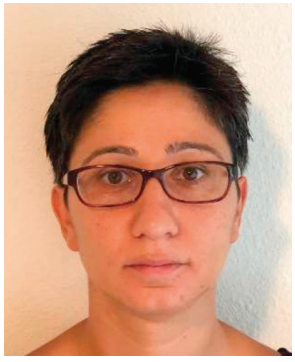

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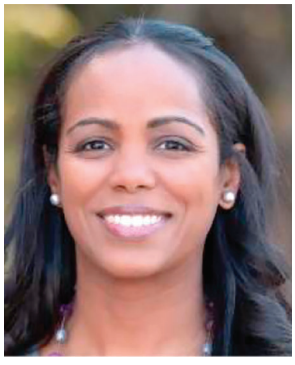

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APPENDIX

Table A1. Engineering and Research Interests; Sense of Belonging; Research Self-Efficacy; Institutional Climate.

Factors	Survey Items
Research Interest (To what extent do you disagree or agree with the following statements?)	I am interested in my research topic I am interested in learning more about research I enjoy research activities as part of my work week In general, I find working on research interesting I like doing research
Research Performance/Competence (How competent are you…)	Understanding and applying scientific and mathematical relationships based on the conditions Applying math and science concepts to make new systems/models Using calculations and equations to evaluate things Understanding derivations and equations in journal papers Understanding current research findings by using sufficient math, science or engineering knowledge
Engineering Interest (To what extent do you disagree or agree with the following statements)	I think engineering is fun I think engineering is interesting I like to figure out how things work I feel good when I am doing engineering I am interested in learning more about engineering I enjoy engineering activities as part of my work week I like doing engineering
Valued and Belonging (To what extent do you disagree or agree with the following statements)	I feel valued as an individual I feel I belong I have considered leaving because I felt isolated or unwelcome† I am treated with respect I feel others don't value my opinions† I have found one or more communities or groups where I feel I belong
Thriving & Growth (To what extent do you disagree or agree with the following statements)	My department is a place where I am able to perform up to my full potential I have opportunities for academic success that are similar to those of my peers I have to work harder than others to be valued equally† My experience has had a positive influence on my academic growth