

Re-thinking Engineering Doctoral Students' Sense of Belonging:
In Consideration of Diversity in Citizenship and Interpersonal Interactions

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved July 2020 by the
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ARIZONA STATE UNIVERSITY

August 2020

ABSTRACT

A defining feature of many United States (U.S.) doctoral engineering programs is their large proportion of international students. Despite the large student body and the significant impacts that they bring to the U.S. education and economy, a scarcity of research on engineering doctoral students has taken into consideration the existence of international students and the consequential diversity in citizenship among all students. This study was designed to bridge the research gap to improve the understanding of sense of belonging from the perspective of international engineering doctoral students.

A multi-phase mixed methods research approach was taken for this study. The qualitative strand focused on international engineering doctoral students' sense of belonging and its constructs. Semi-structured interview data were collected from eight international students enrolled at engineering doctoral programs at four different institutions. Thematic analysis and further literature review produced a conceptual structure of sense of belonging among international engineering doctoral students: *authentic-self, problem behavior, academic self-efficacy, academic belonging, sociocultural belonging, and perceived institutional support.*

The quantitative strand of this study broadened the study's population to all engineering doctoral students, including domestic students, and conducted comparative analyses between international and domestic student groups. An instrument to measure *the Engineering Doctoral Students' Quality of Interaction (EDQI instrument)* was developed while considering the multicultural nature of interactions and the discipline-specific characteristics of engineering doctoral programs. Survey data were collected from 653 engineering doctoral students (383 domestic and 270 international) at 36 R1

institutions across the U.S. Exploratory Factor Analysis results confirmed the construct validity and reliability of the data collected from the instrument and indicated the factor structures for the students' perceived quality interactions among domestic and international student groups. A set of separate regression analyses results indicated the significance of having meaningful interactions to students' sense of belonging and identified the groups of people who make significant impacts on students' sense of belonging for each subgroup. The emergent findings provide an understanding of the similarities and differences in the contributors of sense of belonging between international and domestic students, which can be used to develop tailored support structures for specific student groups.

DEDICATION

I dedicate my dissertation work to my beloved family, who have been always by my side, who have supported my life decisions including the one I made five years ago to get into this adventure on the other side of the world. You are the ones who have been my source of love and strength, I love you.

I give thanks to my beloved friends. I will always appreciate all you have done, especially Youjung for all the conversation we had despite the time difference and Heyjie for being my friend in this desert. I give special thanks to Tan for always being there for me and brightening my heart when it is dark.

Lastly, I dedicate this work to the God. Thank you for your love, guidance, strength, power and peace of mind, and for being my shelter. All of these, I offer to you.

ACKNOWLEDGMENTS

I would like to express my sincere and deep gratitude to my co-advisors, Dr. Jennifer Bekki and Dr. Adam Carberry, who were the best advisors for me and the warmest persons I have met. They have given unfailing support throughout my academic journey. I was able to complete this dissertation work thanks to their countless hours of guiding, encouraging, reading, reviewing, and discussing for my funding behind the scenes. In addition to academic support, they have listened to me, gave me sincere advice, cared me not only as a doctoral student but also as a human being, and truly wished my happiness; which helped me to overcome ‘dynamic’ challenges I have faced in my personal journeys in the U.S. I truly appreciate you, Drs. Carberry and Bekki.

I also thank my committee member, Dr. Nadia Kellam, for agreeing to serve on my committee and providing guidance on the qualitative research methods. In addition to your insight and precious time given to me for my dissertation, I have been always inspired by your passion for research. Also, I extend my gratitude to the community of Engineering Education Systems and Design (EESD) Ph.D. program, which provided me a safe place to explore, experience, and express. Special thanks to Dr. Samantha Brunhaver and Dr. Brooke Coley, not only for teaching me research skills and knowledge but also for sharing your bright smiles, warmth, and kindness.

Lastly but least importantly, I would like to thank my friends in the EESD program, who I have shared laughs, tears, and sleep deprivation. Special thanks to Rohini, Mark, and Javeed, I cannot forget the time that we worked and talked together, it was my vitamin. I will also remember the encouragement and wisdom shared by you, I truly feel blessed that I have you all.

TABLE OF CONTENTS

	Page
LIST OF TABLES	xi
LIST OF FIGURES.....	xii
CHAPTER	
1 CHAPTER I. DISSERTATION OVERVIEW	1
2 CHAPTER II. INTRODUCTION	3
3 LITERATURE REVIEW	5
3.1 Conceptual Understanding of Sense of Belonging	5
3.2 Empirical Research on Graduate Students' Sense of Belonging	6
3.3 International Students' Social Experience	7
3.4 Impact of Engineering Characteristics on Students' Sense of Belonging	8
4 RESEARCH METHODS	10
4.1 Participant Recruitment: A Purposive Participant Selection	10
4.2 Data Collection	13
4.3 Data Analysis: Coding Structure and Abstraction	13
4.4 Establishment of Reliability and Quality	14
5 LIMITATION	16
6 FINDINGS	17
6.1 A Conceptual Model of Sense of Belonging for International Doctoral Students in Engineering	17
6.2 Thick Descriptions	19
Theme 1. Academic Competency	20

CHAPTER	Page
Theme 2. Academic Support Through Interactions	21
Theme 2-1. Faculty Approachability and Research Guidance	21
Theme 2-2. Academic Peer Support	23
Theme 3. Unease Being “Friends” with Peers	24
Theme 4. Faculty Psychosocial Support	27
Theme 5. Cultural “Contact Points”	29
Theme 6. Perceived Support from Institution	30
7 DISCUSSION	33
7.1 Contextualized Concept of Sense of Belonging	33
The Emergence of the Institutional Support Component	33
Uncertainty in Sociocultural Sense of Belonging	33
7.2 How Social Norms Function in Cross-Cultural Interactions?	35
7.3 Advantages and Shortcomings of the Current Engineering Doctoral Educational Environment.....	38
8 CONCLUSION, IMPLICATION, AND FUTURE WORK	40
9 CHAPTER III. INTRODUCTION	41
9.1 Study Context: Diversity in Students’ Citizenship in Engineering Doctoral Education	41
9.2 Research on Sense of Belonging in Engineering Education	42
10 RESEARCH QUESTIONS	44
10.1 New Questions: Have we Conceptualized Sense of Belonging as a Theo- retical Constructs?	44

CHAPTER	Page
11 RESEARCH METHODS	46
12 LIMITATIONS	48
13 LITERATURE REVIEW	49
13.1 Sense of Belonging in Higher Education: Inconsistencies in Definitions and Constructs	49
13.2 Sense of Belonging: Constructs/Defining Components in Different Student Groups	55
Undergraduate Students' Sense of Belonging	55
Graduate Students' Sense of Belonging	56
Underrepresented Minority (URM) Students' Sense of Belonging	57
International Students' Sense of Belonging	59
14 DISCUSSION	61
14.1 A Conceptualization of International Engineering Doctoral Students' Sense of Belonging	61
15 IMPLICATIONS AND CONCLUSION	65
16 CHAPTER IV. INTRODUCTION	66
17 LITERATURE REVIEW	69
17.1 Belongingness Hypothesis.....	69
17.2 Doctoral Students' Sense of Belonging and Interpersonal Interactions within the Academic Unit	70
17.3 International Students' Sense of Belonging and Interaction within the Academic Unit	71

CHAPTER	Page
17.4 Impact of Engineering Cultural Characteristics on Students' Sense of Belonging	72
18 RESEARCH OVERVIEW	74
19 PART 1. INSTRUMENT DEVELOPMENT	76
19.1 Methods	76
Item Generation, Content Validity, and Face Validity.....	76
Participant Recruitment and Data Collection Procedure.....	80
Participants	81
Analysis Approach – Exploratory Facotr Analysis	84
Listwise Deletion.....	84
Exploratory Facotr Analysis	84
19.2 Limitation in Context	85
19.3 Results: EFA Factor Structures	86
Scale 1.1 Domestic Students' Interaction with a Faculty Advisor.	88
Scale 1.2 International Students' Interaction with a Faculty Advisor.....	88
Scale 2a.1 Domestic Students' Interaction with International Peers.....	90
Scale 2a.2 International Students' Interaction with Domestic Peers.....	90
Scale 2b.1 Domestic Students' Peer Interaction with Domestic Students.....	93

CHAPTER	Page
Scale 2b.2 International Students' Peer Interaction with Other International Students	93
Scale 3.1 Domestic Students' Interaction with Staff.....	95
Scale 3.2 International Students' Interaction with Staff.....	95
Sense of Belonging Scale.....	95
20 PART II. REGRESSION ANALYSIS	97
20.1 Methods	97
Participants and Data Collection.....	97
Measures and Variables	97
Sense of Belonging	98
Frequency + Quality of Interaction.....	98
Student Characteristic Variables.....	98
Analysis Approach	100
Multiple Imputation	100
Descriptive Statistics and t-test	100
Multiple Linear Regression.....	100
20.2 Descriptive Statistics and t-test Results	102
20.3 Regression Models.....	103
Bivariate Correlation	103
Multiple Linear Regression Models	106
21 DISCUSSION, IMPLICATIONS, AND FUTURE WORK	111
Part I	111

CHAPTER	Page
Part II	111
22 CHAPTER V. CONCLUSION	116
CHAPTER	Page
REFERENCES	118
APPENDICES	
A. CHAPTER II: IRB APPROVAL LETTER	130
B. CHAPTER II: RECRUITMENT LETTER	132
C. CHAPTER II: ELIGIBILITY LETTERS	136
D. CHAPTER II: SEMI-STRUCTURED INTERVIEW PROTOCOL.....	140
E. CHAPTER II: CONSENT FORM	143
F. CHAPTER IV: IRB APPROVAL LETTER.....	146
G. CHAPTER IV: EDQI AND DEMOGRAPHIC SURVEYS	148
H. CHAPTER IV: RECRUITMENT LETTER.....	156
I. CHAPTER IV: CONSENT FORM.....	159

LIST OF TABLES

Table	Page
1. Institutional Information	11
2. Participants Information	12
3. The Sense of Belonging Construct for International Engineering Doctoral Students ...	62
4. Overview of Scales within the Instrument.....	79
5. Demographic Information	83
6. Scale 1. Faculty Advisor Interaction	87
7. Scale 2a. Peer Interaction	89
8. Scale 2b. Peer Interaction.....	92
9. Scale 3. Staff Interaction	94
10. Dummy-Coded Student Characteristic Variables	99
11. Descriptive Statistics and t-test Results	103
12. Bivariate Correlation between Dependent and Independent Variables.....	105
13. Results of Sequential Linear Regression Models for Sense of Belonging	106
14. Forward Regression Models for Sense of Belonging.....	108

LIST OF FIGURES

Figure	Page
1. Dissertation Overview	1
2. A Conceptual Model of Sense of Belonging	18
3. A Summary of the Literature Review on the Belonging Constructs/Defining Components	50

CHAPTER I. INTRODUCTION

CHAPTER I. DISSERTATION OVERVIEW

The recent report ‘Graduate STEM Education for the 21st Century (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018)’ added citizenship to diversity indices along with the traditional measures of race/ethnicity, gender, etc. This has yet to translate into the engineering education literature despite those inclusion efforts that clearly indicate the relevance and significance of international doctoral students in the field of engineering. This dissertation research - *Re-thinking Engineering Doctoral Students’ Sense of Belonging: In Consideration of Diversity in Citizenship and Interpersonal Interactions* - bridges this gap using a multi-phase mixed methods research approach that: 1) contextualizes belonging from the international engineering doctoral students’ perspective, and 2) provides empirical data supporting the influence of interpersonal interactions on international and domestic students’ sense of belonging (Fig. 1).

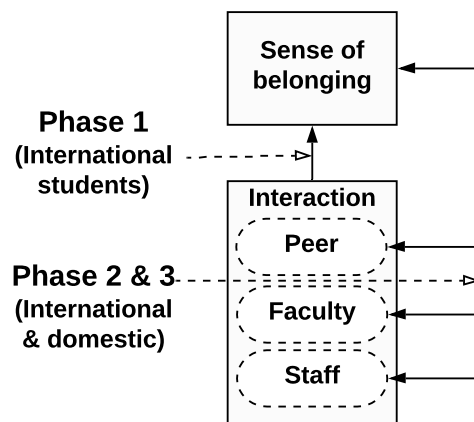


Figure 1. Dissertation Overview

Phase 1 (see Chapter II) used qualitative interviews to conceptualize international student sense of belonging through students' interpersonal bonds with peers, faculty, and staff. Findings showed theoretical constructs of sense of belonging (e.g., *academic belonging, sociocultural belonging, and perceived institutional support*) among the study sample, which are largely influenced by interpersonal interactions.

Phase 2 (see Chapter III) is a literature review on the theoretical construct or defining features of sense of belonging in education. The conceptual structure of sense of belonging developed in Phase 1 was elaborated on in light of the previous literature (e.g., *authentic-self, problem behavior, academic self-efficacy, academic belonging, sociocultural belonging, and perceived institutional support*).

Phase 3 (see Chapter IV) is a quantitative strand consisting of survey instrument development and quantitative survey research. First, a survey instrument to measure the perceived quality of interaction with a faculty advisor, international and domestic peers, and staff in different types of discourse was developed using emergent findings (e.g., *academic and non-academic, i.e., personal, social, and cultural*) from Phase 1. Second, the influence of students' perceived quality and frequency of *academic and non-academic, i.e., social, personal, and cultural* interaction with a faculty advisor, international and domestic peers, and staff, on their sense of belonging was examined among different student groups (e.g., international and domestic). A comparative analysis extracted distinct features on the factors influencing students' sense of belonging for international and domestic students, respectively. Discussions will be made by synthesizing the quantitative and qualitative findings.

CHAPTER II. UNDERSTANDING INTERNATIONAL ENGINEERING DOCTORAL STUDENTS' SENSE OF BELONGING THROUGH THEIR INTERPERSONAL INTERACTIONS IN THE ACADEMIC COMMUNITY

2. CHAPTER II. INTRODUCTION

The number of international students enrolled in full-time graduate engineering programs at US universities has increased from 24% to 58% between 1980 and 2017 (NSF, 2019). The percentage of international students varies by majors; in some majors, such as computer science engineering and electrical engineering, international students represent 88% and 93% of all students, respectively (National Foundation of American Policy [NFAP], 2017). The recent 'Graduate STEM Education for the 21st Century' report (National Academies of Science, Engineering, and Medicine [NASEM], 2018) included citizenship, for the first time, in diversity indices to represent the large international student body enrolled in STEM graduate programs (NSF, 2019). This has opened the door for researchers to use this acknowledgement of citizenship as a diversity measure to expand investigations exploring the integration and inclusion of international STEM graduate students.

There has been a scarcity of studies focusing on international engineering doctoral students' experiences, including as related to their sense of belonging. In this paper, we adopt the ideas put forth by Strayorn (2012, p.3) in which sense of belonging refers to the extent to which students feel "cared about, accepted, respected, valued by, and important to the group (e.g., campus community) or others on campus (e.g., faculty, peers)." Educational psychologists argue sense of belonging to be a concept developed through

individuals' interpersonal interactions and a means to understand interpersonal behavior (Baumeister & Leary, 1995), and it is a key indicator of academic integration and inclusion in higher education (Gardner & Barker, 2015; Marshall et al., 2012). Recent attention to international STEM doctoral students' sense of belonging has revealed relatively lower sense of belonging for these students compared to their domestic counterparts (Glass & Westmont, 2014; Glass et al., 2015b; Glass 2018). Furthermore, the majority of studies were conducted using quantitative research methods and do not provide the depth needed to understand 'why' this phenomenon is occurring.

The purpose of this study is to investigate international engineering doctoral student sense of belonging by gaining an understanding of their interpersonal interactions within their academic unit. A qualitative research approach using critical incidents technique (Flanagan, 1954) was employed to illuminate the dynamics by which these interactions contributed to (or hindered) the students' experiences. This study addresses the following research questions: "What contributes to international engineering doctoral students' perceptions of sense of belonging?" and "What contributes to international engineering doctoral students' perceptions of positive and negative interactions within their academic unit?"

3. LITERATURE REVIEW

3.1 Conceptual Understanding of Sense of Belonging

Sense of belonging is one of a number of ways used to refer to the fundamental human need for social bonds and connections (Baumeister & Leary, 1995; Maslow, 1954). The ‘belongingness hypothesis’ (Baumeister & Leary, 1995) has been largely used in education research to explain how student behaviors, intentions, or motivations connect with sense of belonging (Glass & Westmont, 2014; Glass et al., 2015a; Glass et al., 2015b; Ingram, 2012; Sax et al., 2018; Peter et al., 2015; Wilson et al., 2015). The hypothesis argues the significance of positive and meaningful interactions with others to satisfy the need for belonging.

The theoretical components that structure the concept of sense of belonging within higher education are divergent across different models and theories that have emerged since Spady (1970) first introduced sense of belonging as a precursor of student integration. The majority of sense of belonging research in education suggests two constructs – academic and social sense of belonging – in relation to peer and faculty interactions (Goodenow, 1993; Hoffman et al., 2002; Tinto, 1993). Later, the construct was broadened to include institutional commitment, and this added component has been shown to relate closely with students’ interactions with staff (Fisher et al., 2019; Ingram, 2012; Yao, 2015).

3.2 Empirical Research on Graduate Students' Sense of Belonging

Research exploring graduate student sense of belonging is scarce compared to the body of literature on undergraduate student sense of belonging (Curtin et al., 2013; O'meara et al., 2017; Strayhorn, 2012). The research that does exist at the doctoral level has investigated sense of belonging in relation to strengthening efforts to create an inclusive culture in graduate education and to support graduate student socialization (Curtin et al., 2013; Fisher et al., 2019; O'Meara et al., 2017; Ong et al., 2011; Pascale, 2018; Strayhorn, 2012).

Sense of belonging is a key component of diversity and inclusion efforts because of its demonstrated impact on students' academic integration, success, and completion rate across educational levels (Goodenow, 1993; Tinto, 1993; Sax et al., 2018). The majority of sense of belonging research, particularly in graduate STEM education, focuses on this impact for underrepresented student groups (Fisher et al., 2019; Okahana & Zhou, 2019) but does not focus on international students.

Recent, related research also focuses on the concept of student socialization. Graduate student socialization refers to the process of belonging as a member of the academic community through learning the knowledge, skills, and values of the academic unit (Weidman & Stein, 2003). This concept is critical to student success, persistence, and retention in the academic field (Fisher et al., 2019; Gardner & Barnes, 2007; O'Meara et al., 2017), while also influencing student sense of belonging (Weidman & Stein, 2003). The mechanisms to enact socialization include interactions with others (e.g., faculty and peers), learning of knowledge, or entrance into the actual academic community (Strayhorn, 2012; Weidman & Stein, 2003).

Recent studies have begun to consider demographic attributes and characteristics of the academic environment to better understand how graduate student sense of belonging varies in different settings (Curtin et al., 2013; Gardner et al., 2014; Twale et al., 2016). Gardner et al.'s (2014) exploration of doctoral students' sense of belonging across different disciplines indicates that engineering doctoral students reported a relatively lower sense of belonging within their academic department compared to students in other disciplines. An inference from this work is that international student status may play a role. The revised version of Weidman's graduate student socialization model (Twale et al., 2016) aligns with this assertion and argues that the diversity in citizenship and associated linguistic and cultural differences that exist within graduate education can challenge interactions between students of different nations, including domestic students. These challenges can negatively affect student's integration into an academic field or departmental culture. O'Meara et al. (2017) echoes this claim, reporting that fewer facilitators of sense of belonging exist within STEM doctoral program environments than in non-STEM programs. These studies collectively suggest the need to consider student citizenship within specific disciplines and the influence these factors play on students' interpersonal interactions during their doctoral education (Gardner, 2010)

3.3 International Students' Social Experience

Meaningful interactions play a critical role in developing students' sense of belonging (Baumeister & Leary, 1995; Glass & Westmont, 2014; Glass, 2018). The lack

of meaningful interactions between international students and domestic students has been reported as one of the commonly cited reasons for why international students demonstrate a poor sense of belonging (Brandenburg & De Wit, 2011; Campbell, 2015; Glass & Westmont, 2014; Le & Gardner, 2010; Yao, 2015). Low satisfaction or challenges with social interactions have led to an increase in students' sense of isolation from the campus community (Schweitzer et al., 2011; Williams & Johnson, 2011). These challenges go beyond peer interactions to include faculty interactions, which are one of the most influential factors affecting students' learning and adjustment (Glass et al., 2015b; Glass et al., 2017; O'Meara, Knudsen, & Jones, 2013).

In contrast, the established social connection of international students with peers from co-national, international, and host students has a positive impact on students' bond with the campus community (Kashima & Loh, 2006) and contributes to student's perception of the community as a secure environment to form relationships (Hendrickson et al., 2011). International student interactions that are mostly cross-cultural in nature provide a deeper understanding of a social context, which is required to develop meaningful interactions (Glass & Westmont, 2014).

3.4 Impact of Engineering Characteristics on Students' Sense of Belonging

Some of the characteristics of engineering doctoral education environments themselves also create specific challenges for student interpersonal interactions within their academic unit. For example, the advisor-advisee relationship in engineering is typically a supervisor-supervisee relationship where the dominant interaction is on

academic support (Primé et al., 2015). Psychological and social support from advisors that contribute to building a positive and meaningful relationship and sense of belonging are often lacking in engineering doctoral education (Bargar & Mayo-Chamberlain, 1983; Lovitts, 2004; Robbins et al., 2004). The prevalent lecture-based instructional methods in engineering also have an adverse influence on student sense of belonging. Traditional pedagogical approaches place the teacher at the center, which hinders interpersonal interactions among peers (Felder & Brent, 2005), while activities that encourage interpersonal interactions (e.g., retreats, conferences, etc.) have the opposite effect on students' sense of belonging (Wilson et al., 2008). Such activities emphasize the healthy development of belonging, psychological sense of community, and extraversion (Wilson et al., 2008).

Building on existing literature, this study investigates international engineering doctoral students' sense of belonging through an analysis of their interpersonal interactions within their academic unit, while also considering the discipline-specific characteristics of engineering doctoral programs.

4. RESEARCH METHODS

This research used a qualitative research approach based on a constructivist perspective to investigate the concept of belonging. The approach aimed to understand perspectives of students within the context in which they occurred by capturing experiences perceived to have critical impact on their conceptions (Creswell, 1998; Crotty, 1998). We conducted semi-structured to obtain an in-depth and descriptive understanding of the experiences (Strauss & Corbin, 1990). The critical incident technique (CIT) was chosen to guide the interview protocol to facilitate the discovery of significant experiences (Flanagan, 1954; Strauss & Corbin, 1990). Guided by CIT, the semi-structured interview protocol is grounded in the perspective that certain incidents are critical to understanding resulting behaviors or perceptions (Flanagan, 1954).

4.1 Participant Recruitment: A Purposive Participant Selection

A sample of eight international engineering doctoral students attending four different research-intensive institutions make up this study. International students in this study are “individuals who do not hold US citizenship or permanent residence and who pursue higher education in the US ... under a special class of nonimmigrant visa, category F-1 (NASEM, 2018).” All participants were international students pursuing a doctoral degree as their first degree in the United States. This ensured that participants had not yet culturally adjusted through a previous academic experience in the US, in turn allowing this study to capture influences of cultural differences specific to their doctoral experiences (Hyun et al., 2006; Hyun et al., 2007; Persell, 1990; Searl & Ward, 1990;

Zhou et al., 2008). Additionally, participants had at least two semesters of experience within a US educational institution. A purposive participant selection process (Polkinghorne, 2005) accommodated diverse experiences with a limited number of participants.

Institution selection considered all research-intensive institutions with a robust presence of international STEM graduate students (Nature, 2018), and previous findings on the environmental variables of international students' experiences informed the selection criteria (Migration Policy Institute, 2017; McCormack, 2007). Two large, public schools and two small, private schools were selected to provide geographic and residential (e.g., suburban or urban) variation (Table 1).

Table 1

Institutional Information

Institution	Carnegie classification	Region	Public vs. Private	Suburban vs. Urban	International population*
Institution 1	Doctoral universities: Highest research activity	Southwest	Public	Urban	13%
Institution 2		Southeast	Public	Suburban	4%
Institution 3		West	Private	Urban	9%
Institution 4		Northeast	Private	Suburban	21%

*The percentage of international student enrollment in each university (US News, 2018).

Participant recruitment involved contacting the chair of each engineering doctoral program in the selected institutions. A call for participants containing demographic and background surveys was distributed via various internal listservs during a four-week

recruiting period in October 2018. Selected for inclusion in the study were students with the most divergent form of experiences based on their background and demographic information (e.g., citizenship, gender, age, degree program, and years in the US) (Guest et al., 2006; Hyun et al., 2006; Hyun et al., 2007; Persell, 1990; Searle & Ward; 1990; Zhou et al., 2008). Thirty-five eligible students expressed interested in participation, and ultimately, two participants from each targeted institution comprised the sample.

Table 2

Participants Information

Participants (pseudonym)	Citizenship /Language	Gender	Age	Degree program	Years in the US	Marital status	Institution
Fan	China/ Chinese	Male	28	Biomedical engineering	5	Married	Institution 1
Rohit	India/ Kannada	Male	28	Electrical engineering	2	Single/ never married	
Farzad	Iran/ Kurdish	Male	30	Textile engineering	6 months	In a committed relationship	Institution 2
Jiwon	Korea/ Korean	Female	28	Chemical engineering	4	In a committed relationship	
Amber	Taiwan/ Chinese	Female	28	Materials engineering	4	Single/ never married	Institution 3
Yoshiko	Japan/ Japanese	Female	28	Chemical engineering	3	Married	
Amit	Bangladesh / Bengali	Male	25	Electrical engineering	1	Married	Institution 4
Benita	Cuba/ Spanish	Female	27	Mechanical engineering	2	Married	

The demographic information of the eight selected participants is in Table 2, including participant pseudonyms to promote confidentiality. In Table 2, the number of years in the US represents the number of years a student was enrolled in their program.

All eight participants earned their master's degree in their home country, and all except one then came directly to the US. One participant (Farzad) worked in industry for one year prior to starting his doctoral studies.

4.2 Data Collection

One-on-one interviews with each participant took place either at a convenient in-person location or through the video conferencing tool, Zoom. Critical incidents in this study are students' accounts of lived experiences that show clear consequences to their perceptions of their sense of belonging and to their perceptions of the quality of their interpersonal interactions within their academic unit. The interview protocol was developed to have three *a priori* categories – sense of belonging, interactions with faculty, and interactions with peers – aligning with our research questions. For each of the three *a priori* categories, we developed interview questions to elicit students' accounts of critical incidents. Each 60 to 90 minutes interview was audio and/or video recorded and later transcribed. The interviewer also took an analytic memo during and after each interview. Each participant received a \$10 Amazon gift card after the completion of the interview.

4.3 Data Analysis: Coding Structure and Abstraction

Data analysis followed the qualitative coding methods recommended by Saldaña (2015). We used an iterative process to fully understand the interview data and collate students' critical incidents into codes. Next, we abstracted these codes into themes of

influencers per each of the *a priori* categories and themes across categories. We used coding on two levels to implement the iterative process of abstraction.

We used structural coding for first cycle coding to identify critical incidents. Such incidents included any outcomes relating to specific interview questions or *a priori* categories (Douglas et al., 2008; Moore & Popadiuk, 2011). Every incident provided by the students' accounts were categorized under as many codes as possible during this phase of coding. The first cycle structural coding process produced codes and subordinate categories of the *a priori* categories with examples of critical incidents.

We used pattern coding for second cycle coding to find relationships between codes across categories and develop conceptual constructs for sense of belonging (Saldaña, 2015). This gradual abstraction process required significant interpretation through discussions among research team members. The process aimed to create “meta-codes” (Saldaña, 2015; pp. 209) and patterns across the data. We reviewed and iteratively adjusted, based on analytic memos written during data collection, emergent “meta-codes” and patterns to determine themes across the data. Ultimately, six themes regarding conceptual constructs of sense of belonging and quality interactions emerged.

4.4 Establishment of Reliability and Quality

Following Kellam and Cirell (2018), several steps were undertaken throughout the research process to establish the reliability and improve the quality of this study. First, researchers' subjectivity was managed by continuous documentation of analytic memos. The first author, who took the role of interviewer for all the participants, is an

international engineering doctoral student from South Korea. Although her experience of sharing the same status with participants was viewed as an advantage in understanding the participants' experiences and capturing the subtle, but important nuances of being an international student, the research team also acknowledged potential biases introduced from this status. The process of continuously discussing her own subjectivity not only using analytic memos but also in research meetings enabled her to engage in "a formal, systematic monitoring of self" (Peshkin, 1988; p.20). Second, the data was approached from more than one perspective to assess the trustworthiness and credibility of the analysis. A single researcher coded each interview followed by subsequent reviews by three other researchers who read the interview transcriptions and discussed the initial identified codes and themes. Iterative discussions were undertaken until the four researchers came to a consensus agreement on a list of final themes. The inclusion of positive and negative experiences for each category provided opportunities to identify patterns in the data through a compare-and-contrast approach. Lastly, the current research utilized the 'sense of belonging hypothesis' (Baumeister & Leary, 1995) as a theoretical map that helps to explain the potential reasons why international reported lower sense of belonging (i.e., why it happens) by understanding what is happening in their interpersonal interactions (i.e., what is happening). The consistent integration of the theory throughout the different steps (e.g., to frame the research, develop the interview protocol, and analyze the data), in turn, served a role to frame connections between pieces of data (Kellam & Cirell, 2018), helping researchers to highlight as much data as possible.

5. LIMITATION

We describe here some limitations to help frame the findings of this study. First, the first author who conducted the interviews and analyzed the data is an international doctoral student. The possible biases were understood and efforts, such as team discussions with faculty members from the US, were made to reduce the potential impact. Second, we made an effort to capture diverse voices of international engineering doctoral students by using a strategic participant selection process. However, our results and discussion do not represent the entire international student population in engineering doctoral education, which is quite complex with disproportionately higher populations of students from certain cultures. Finally, data used in this study comes solely from the perspective of international students and provides no insights from domestic students or US faculty. Additional data from domestic students and US faculty would provide a fuller picture of the entire landscape of engineering doctoral students' sense of belonging.

6. FINDINGS

We present the findings as both a conceptual model of sense of belonging and supporting thick descriptions. Presenting the results using these two different levels of abstraction provides complementary views of the finding and combats the limitations of each approach. Presented findings focus solely on international student perspectives, and the analysis process attempts to highlight the incidents regarded to be critical to those students. This includes variables specific to the international student population (e.g., language, culture, religion, etc.) as well as those universal to all doctoral students.

6.1 A Conceptual Model of Sense of Belonging for International Doctoral Students in Engineering

We created a conceptual model to provide a theoretical understanding of the components that contribute to international engineering doctoral students perceived sense of belonging (Fig. 2). The derived model identifies theoretical constructs of sense of belonging (*academic sense of belonging*, *sociocultural sense of belonging*, and *perceived institutional support*) and how students' perception of each component interacts with their social relationship with the people in their academic unit, i.e., *faculty interactions*, *peer interactions*, and *staff interactions*. This model addresses the first research question by providing a theoretical understanding about the components contributing to international engineering doctoral students' perceived sense of belonging.

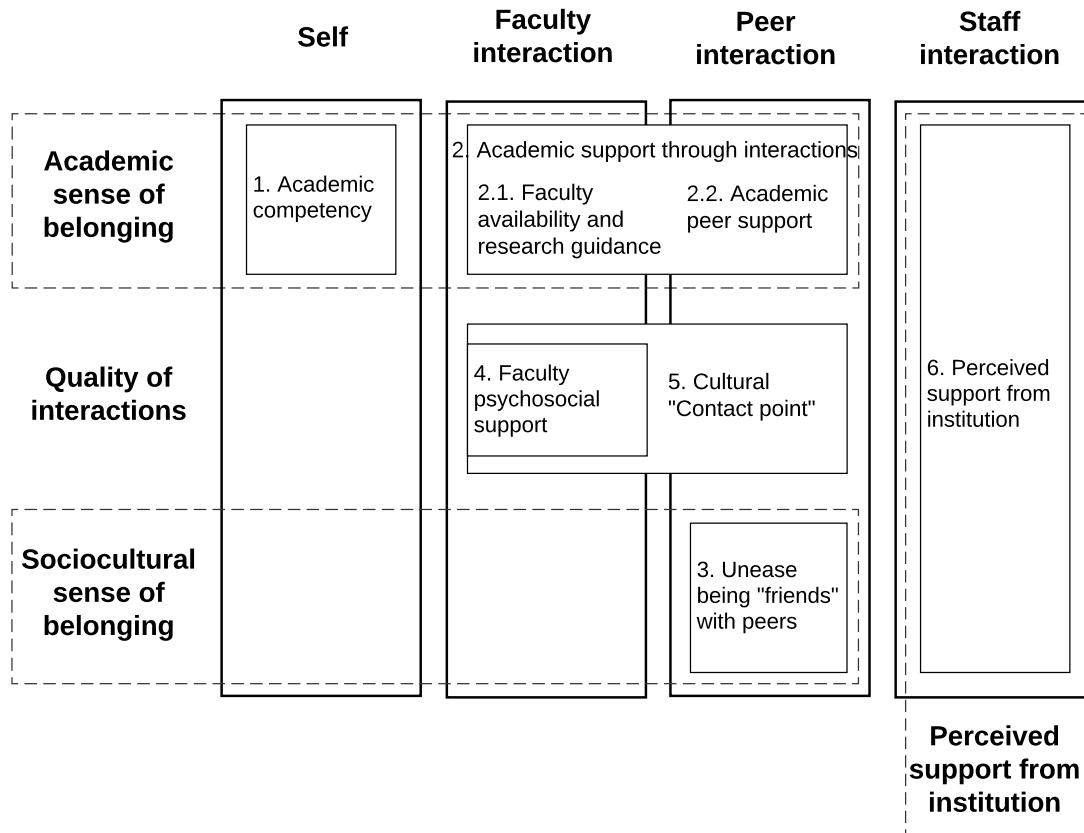


Figure 2. A Conceptual Model of Sense of Belonging

Academic sense of belonging involves academic interactions with faculty and peers (see *Themes 1. Academic competency & 2. Academic support through interactions* in the thick descriptions of the findings section). Such interactions influenced connectedness to the academic unit in a professional way and influenced participants' perceived academic competency. Most incidents connected with *academic sense of belonging* were positive and had a positive impact. *Sociocultural sense of belonging* was only described when participants discussed interactions with peers. Most incidents coded within this category were about challenges faced during social interactions with peers, and these incidents negatively influenced *sociocultural sense of belonging*. Notably, two

emerging themes that describe positive social interactions with faculty and peers (e.g., *Theme 4. Faculty psychosocial support & 5. Cultural “contact points”*) included critical incidents that did not have an impact on the sociocultural facet of student belonging. Finally, *perceived institutional support* (see *Theme 6. Perceived institutional support*) captures additional interactions with staff members at different administration offices within the institution, i.e., staff interactions, which introduces a new set of potentially impactful interactions on sense of belonging.

This conceptual model unpacks the relationship between interpersonal interactions and sense of belonging, underscoring how sense of belonging develops through the formation of close and safe emotional bonds driven by interpersonal interactions (Baumeister & Leary, 1995; Skinner et al., 2008; Peter et al., 2015). The previously noted disconnect between the positively perceived social interactions with faculty and peers (e.g., *Theme 3. Unease being “friends” with peers & 4. Faculty psychosocial support*), and *sociocultural sense of belonging* can be explained using this model. The potential lack of emotional intimacy and the associated interactions with different groups of people help to identify which aspects of interpersonal interactions in students’ graduate school experience influence each facet of sense of belonging.

6.2 Thick Description

Thick descriptions add contextual richness to the conceptual model; with them, we provide detailed descriptions of each theme or subtheme with excerpts from the

participant interviews to add information that highlights the complexity of sense of belonging within the sample of international doctoral students in engineering.

Theme 1. Academic Competency. The majority of participants stated that feeling confident or capable as a graduate student working in a professional setting with engineering content contributed to their academic sense of belonging. Incidents within this theme included academic work (e.g., coursework or research) or academically related tasks (e.g., teaching assistantships). These interactions require direct interactions with domestic students or faculty using English (e.g., instruction, office hours, informal communication, etc.). This theme is closely related to the academic support through interactions theme (Theme 2) because students' perception of their own academic competencies were frequently influenced by positive feedback received by others (e.g., peers, instructors, principle investigators, advisors, and undergraduate students).

Amber, a female fourth-year materials engineering student from Taiwan, described her teaching assistantship (TA) experience as:

I guess it shows me that in a professional setting, I can do just as well, if not better than, my American peers and or just, you know like I can do [it]. Okay, so I guess it kind of ease[s] my anxiety about if I stay in America, and I have to work here. Like... will I be capable of doing this? So, I guess a positive interaction makes me feel like I can do it professionally in an academic setting. It's, it's work and I can [do it]. It's a job. It's work and I can do it.

This implies the potential influence of such experiences on the intention to stay or leave after graduation. Contrarily, Jiwon, a fourth-year chemical engineering student

from Korea, and the only participant whose childhood included high English proficiency, described her TA experiences as not having a positive impact on her sense of belonging. Jiwon said that it “didn't make me feel like I belong to the department. It was just like a job. It was a job that needs to be done.”

Theme 2. Academic Support Through Interactions. This theme describes incidents relating to academic support received by students through interactions with people in their academic unit. The examples depict different types of academic support needed for addressing different types of academic challenges. This theme consists of two sub-themes based on the people with whom the students interacted (e.g., faculty and peers).

Theme 2-1. Faculty Approachability and Research Guidance. This sub-theme includes incidents describing instructors providing extra support outside of the classroom (e.g., holding office hours, providing digital versions of class materials, and suggesting supplementary resources) and displaying a patient attitude towards the participants' English proficiency. Benita, a female second-year mechanical engineering student from Cuba reported related incidents as examples of positive and memorable faculty interactions:

I remember this professor that we were being TA for, he was really nice. And he was like, “I know I'm not like your professor [advisor]. But if you find my help you guys.” I mean, I'm saying ‘guys’ because we were, it was a huge class. And we were like 8 TAs, and he was always like “If you have [anything that you need

help]”, and then he was like, “I know that sometimes international students feel like it's hard for them to reach out [to] professors or to ask for help.” so that somehow makes you feel support[ed], you know, because you know that you have someone that you can go to if you need it.

Incidents coded within this subtheme also include positively perceived interactions with dissertation advisors. Examples of positive interactions include advisors' being available, providing useful feedback, advocating on students' behalf, and providing instrumental support in the form of professional development financial support opportunities. The incidents coded in this sub-theme emphasize the potential influence of the advising relationship on students' perceived sense of belonging and overall student success (Mainhard et al., 2009).

Participants also expressed uneasiness in reaching out to advisors because of cultural differences based on country of origin. For example, Yoshiko, a female third-year chemical engineering student from Japan, commented:

In the first year, I didn't know what to do... After like several months, then I think [my American born advisor was] expecting the students to come to him if we need him. But like, especially when I grew up in Japan, it's always the teacher that comes to students. But here I need to be more independent.

Amber also described:

Well, so... for me, I'm very scared of high authorities so that means pretty much all the professors. So, it just, it makes myself uncomfortable to talk to them or chat with them and always stressful for me.

A number of participants in this study expressed similar discomfort or hesitation in asking for help from advisors and instructors. In each case, the incident began due to a lack of student awareness about the educational environment in the US, including general cultures, norms, and student-teacher relationships.

Theme 2-2. Academic Peer Support. This sub-theme describes incidents relating to participants' interactions with peers regarding academic issue. One of the most significant aspects of this sub-theme was that the majority of participants described academic peer support as coming from fellow nationals or other international students, but not from their domestic student peers. Most participants also expressed a level of comfort in interacting with domestic peers in the context of discussing academic (vs. social) topics. The incidents included participants expressing positive feelings involved with having peers to work with, sharing common academic concerns or research ideas, feeling comfort in asking questions, and sharing physical workspaces in either formal (e.g., regular group studies, weekly lab meetings, academic conferences, etc.) or informal (e.g., study groups, daily conversations with lab mates, etc.) occasions.

The emergent critical incidents regarding academic peer support varied depending on whether the participant had joined a research lab. A high number of incidents described by participants already assigned to a lab revealed lab-based experiences with their lab mates. Some incidents imply that a lab culture of sharing and helping positively influenced the perceived academic peer support of students. For example, Rohit, a male second-year electrical engineering student from India, mentioned:

That [a lab culture of helping] is really helpful because usually in research it happens that you get stuck in problems and you don't know what to do. Yeah. But when you get opinions from different people, you will find a way to solve [them]. Yeah.

Incidents provided by participants who had not yet joined a research lab were predominantly focused on first-year study groups set up by the participants and typically with fellow nationals or other internationals. Collectively, the incidents coded with this subtheme included expressions of relationships evolving into friendships. However, not all participants shared this positive experience. Amber shared her experiences of facing challenges in finding a study group in her first year:

So America students, I think they have their own study groups. And international students... the funny thing is that I think we also have like a really high percentage of Chinese students from China. Yeah, and they, I think they also have their own study group.

Notably, participants were also able to articulate the difference in terms of sense of belonging in having relationships within and outside of their academic unit. Benita, for example, described, "I can have friends anywhere, but hanging out with the friends outside of [the] program doesn't influence my feeling of belonging in the program."

Theme 3. Unease Being “Friends” with Peers. Many participants discussed difficulties faced when socializing outside of academic contexts. These incidents mainly included interactions with participants’ domestic peers. The most frequently mentioned example was participants feeling unable to join a conversation with groups of peers at

large graduate student social events typically held at the institution and hosted by the program, department, graduate school, etc. Cultural differences, including language, norms in verbal interactions, and an empty set of common interests outside of research were the source of the difficulty. Benita, for example, mentioned, “There are some jokes [in the conversation] and sometimes you are like ‘what?’ because you don’t get it, you know. You somehow feel excluded because you don’t understand everything said.” Participants’ unfamiliarity with the cultural norms of socialization in the US also emerged. Amber shared, "I feel like comparing to my experiences in Taiwan, people here talk to strangers who are considered as acquaintances in Taiwan." Amber continued by saying, "You know, you sat there quietly and felt really uncomfortable. Then it really shows that you do not belong, as opposed to you're having lunch with them and you totally are their friends." These examples represent aspects of feeling excluded and isolated from group conversations.

Participants reported some exceptions to this when they received a private invitation from domestic peers or when relationships with domestic peers developed naturally through academic socialization such as study group activities. Farzad, a male first-year textile engineering student from Iran described it as, “I felt like ‘okay. I'm invited.’ So, I had a good positive [experience] that they invited me ... Yeah, that was the part that I felt like again, I'm a member of that society.” His account reflects that such invitations feel linked to social acceptance in a host country as "a member of that society." Amber confirmed this:

Maybe one day I will be truly belonged, like when people invite me to their house. I mean, that part. If it's just a big party, then if you get an invitation, that's,

that's no big deal. Like, people like [are at a] big party and they don't care who you are. But if I feel like they invite me because they want me there, then this is really a good thing, showing that they're seeing me as me, not just... you know, an international student in my program or like an Asian or whatever. They want me.

Her account also highlights her perceptions of the difference between large and private social events and underscores a desire to be valued as an individual.

Another group of incidents negatively associated with sense of belonging within this theme relate students observing or experiencing segregation. Such segregation was noted as occurring both between students from different countries and between international and domestic students. Farzad describes the complexity of these peer interactions:

International students here [are] like to hang out with their own country's classmates like Iranians hang out together, Indians hang out together, like Koreans are getting together, like that. I like to hang out to everybody as the whole package.

Participants also experienced incidents relating to racism, stereotype and tokenisms. The consequence of such negative experiences included deciding to avoid further interactions with a particular group of students based on the origin of the original action (e.g., students from a certain country, etc.) as described by Amber:

He was the TA of one of the class[es] I took. And when I took the class, I didn't really feel like he's, you know, racist. I mean, it's not like [an] outright racist then you know [that he is a racist when] he told me [discriminatory remarks]. And I was like, okay, so maybe even people you don't think they're racist could be

racist, then It just started [to] let me kind of mess with my mind. And made me think that maybe a lot of people who are actually racist and they just, you know, don't show that, but they will never become friends with you. And I guess that made me put my wall up because I don't want to try to be friends with someone and it turns out they're actually racist...

Overall, most incidents described by participants relating to students' social interactions with peers negatively attributed to their sense of belonging. A significant underlying aspect across these incidents was students' previous or current willingness to become close friends with domestic students as well as their willingness and effort to join social events (e.g., practicing English, trying to speak up in public, or watching TV to learn the culture). This was reflected in Amber's account:

Academic, like I say, academically I know I belong in, belong with. Yeah, but like, do I ever, will [I ever] belong to this culture? I will not say belong to this culture but like just 'blend in' with this culture. And when I talk, they will, you know, immediately like "oh, where do you come from?" Just like an outsider. Even though people here are like, trying to be polite in anything. But, politeness is not enough to become friends or want to become friends.

Theme 4. Faculty Psychological Support. The incidents coded in this theme included faculty-initiated conversations about personal (vs. academic) issues. These topics could be in reference to something personal for the student or the faculty member. Such incidents were perceived as meaningful and classified as quality faculty-interactions. Examples included advisor inquiries about a student's status as an

international student (e.g., visa status, visits home during breaks, cultural background or current issues in their home country) or an advisor sharing a personal story (e.g., family, graduate school life, pets, etc.). Those conversations mostly took place on informal occasions (e.g., holiday dinner at the advisor's home, research group lunch, conference travel, or conversations at the end of a one-on-one research meetings). A significant aspect of such incidents was the students' feeling of having a person-to-person relationship, which also played a role in helping students feeling understood as an international student. Jiwon stated:

Two years ago, I had a big car accident. And then I was devastated. Like I hurt my neck. I missed my family and I was all alone [here]. Like I didn't have any family to be with me at that time of trauma. So I have... I was traumatized. But then my advisor, Dr. [advisor's name] and the both of my [co-]advisors, Dr. [co-advisor's name]. They would actually call me. Call me whenever I [Jiwon] need help. And then just check on me. Just to make sure that I'm doing fine.

Knowing and understanding more about the advisor personally was also described as meaningful. Amit, a male first-year electrical engineering student from Bangladesh recalled his trip from a conference site to another with his advisor's family by the advisor's invitation to join:

Frankly, so... I believe that it was almost their [the advisor's] family trip. But he had actually allowed me to ... be with his families and children in the same car, a personal experience. And also, in general, he was like... when you're at that time, you don't talk about research. So you talk about maybe personal stuff and things

like that. You also had quite some personal interactions. I believe that they are the reasons [why the trip was a meaningful incident to me].

In spite of the meaningfulness of such personal interactions in the students' perceived psychosocial support as an international student, they were not necessary regarded by participants as contributing to their sense of belonging. Participants frequently described feeling anxiety or pressure associated with initiating personal conversation with their advisor, as illustrated by Amber:

Well, for right now, about most of my interaction with my advisor, even though in lunch conversations, it's still stressing me out. Like, I feel uncomfortable... Just, I've never felt comfortable in the interactions with people having power over me.

This statement implies the effect of a perceived hierarchical culture (Hofstede, 1986; Yoo, 2014) framing interactions with her advisor. It also highlights how diverse cultural aspects, such as societal structure and language, can play a role within student-faculty interactions. Similar interaction patterns emerged during student-faculty interactions regardless of whether the interaction was academic or psychosocial.

Theme 5. Cultural “Contact Points”. Positive incidents grouped in this theme described moments when peers or faculty showed an interest in a student's culture, cross-cultural friendships existed, or experiences relating to the students' cultural backgrounds were shared. Fan, a Chinese biomedical engineering student, recalled such a relationship with a domestic peer:

We had a postdoc who is also American. He was a very, very funny guy. Yeah, he also liked to, to learn our [my] language. Yeah. So... he's the guy that asked

questions about our [my] language. ... It was pretty interesting. Yeah, I loved that postdoc.

Amber also explained that her advisor asked questions about her home country of Taiwan, which helped her engage in the conversation as “there isn't much in my life [more] than research [in the US].” Students found these cultural “contact points” to be things they could build conversations around, and cultural topics brought up by faculty members or peers contributed to a relief of nervousness for some participants. These cultural contact points were not regarded by participants as having an impact on their sense of belonging, although they were pointed out as positive and meaningful incidents.

Theme 6. Perceived Support from Institution. The final theme describes a group of incidents relating to both the academic and sociocultural supports that participants received from their institutions (e.g., offices for graduate students, international students, or housing). Most of the incidents coded within this theme occurred by way of formal programming provided by the institutions during the participants’ transition to the US. The described academic supports included specific resources (e.g., office space or initial faculty advisor assignment) and assistance mediating academic issues (e.g., academic counseling or coursework-TA workload adjustment) that enabled the participants to cope with the unknowns and issues associated with their transition into doctoral education or the US educational system. Examples of sociocultural supports included information for settling down in the US and opportunities for interpersonal socialization among international students (e.g., international student orientation, assistance with administrative work such as Visas, SSN, housing, etc.).

Participants also attributed those incidents to feelings supported in dealing with all the requirements needed during a life transition, as Benita noted: “[we] don’t know how things work at all because we are not used to liv[ing] here.”

A different understanding of institutional support from the academic unit emerged in cases where the participants did not go through such transitional challenges. For example, Jiwon, who was familiar with the American educational system and English proficiency prior to coming to the US, did not mention institutional support as critical to her sense of belonging. This gives some evidence that this theme is influenced by international student characteristics (e.g., language barrier, struggling with new academic environment, cultural dissonance, etc.) (Aydinol, 2013; Glass, 2018).

Many of the reported incidents related to institutional support occurred through interactions with advising staff and/or faculty (e.g., graduate coordinators, academic support staff, faculty advisors, etc.). The participants generally viewed their staff interactions very positively, which is one of the significant aspects that differentiate the participants’ attitudes towards staff interactions from those with peers and faculty. The positive perception of staff members was reflected in the participants' described feelings, which include students being relieved by having people [staff] who, as Farzad noted, “really want to help you” and, as Yoshiko stated, “you can always go and ask questions.”

In interactions with staff, participants frequently commented on aspects of the American culture such as a flat societal structure or friendliness to strangers. Fan compared his experiences with staff from the US and his home country of China when he stated, “Feels like the staff working here is like... We're like friends. We are human. But the Chinese, like the staff, they are higher than you. They're not very friendly...” Jiwon,

who didn't regard the provided academic and sociocultural support to have an impact on her sense of belonging did express the positive influence of the 'American friendliness:'

Well, our department is a very [a] friendly environment... We just come by giving you 'hi' and 'how are you doing?' 'How is your research going?' So they really care about you, like individual people. It's not just me. Like everyone in our department. We don't really consider ourselves as what works like a professor-student relationship more like a family. It's a very friendly environment. I love it. Her description represents how the everyday conversation and routine behavior of staff that is rooted in the individualistic US culture were interpreted by international students as feeling cared for and valued as an individual person, which positively affects their sense of belonging.

Some institutional differences emerged between the incidents collected from the participants at private and public universities. Differences included the perceived approachability of advising staff and faculty and a noted closer relationship with more frequent interactions for students at small private institutions. Benita explained, "Here in my university, a lot of people just go and ask questions in person because it's a small university...many people are in two or three doors away." This aligns with other findings showing the perceived sense of belonging among students with similar resources depend on the institution and program size (McCormack, 2007).

7. DISCUSSION

7.1 Contextualized Concept of Sense of Belonging

The Emergence of the Institutional Support Component. The findings of this study identified components that contribute to sense of belonging and the contributing interpersonal interactions among international engineering doctoral students. Research on the conceptual structure of sense of belonging for the majority of students suggests components of academic and social integrations (Goodenow, 1993; Hoffman et al., 2002; Tinto, 1993). Our findings add the component of *perceived institutional support*, which is related to international students' perception of the individual level support provided by institutions regarding the academic and sociocultural issues. This institutional support component aligns with the institutional commitment aspect of sense of belonging that is discussed in recent studies literature focusing on the sense of belonging of underrepresented students (Fisher et al., 2019; Yao, 2015), but in those studies, the concept focused on students' perception towards the institutional (vs. individual) level support regarding such aspects as campus racial climate (Fisher et al., 2019). This difference supports the need to further investigate the sense of belonging of graduate students whose perceived support may differ from those of the more heavily studied undergraduate students.

Uncertainty in Sociocultural Sense of Belonging. Our findings also suggest an alternative perspective to what is already published in the literature related to international graduate students prioritizing academic vs. social interactions (Baek, 2013;

George et al., 2018; Sato & Hodge, 2009). Participants involved in this study strongly expressed their confidence in academic sense of belonging compared to uncertainty in regard to their sociocultural sense of belonging. This same finding has been observed in other studies (Baek, 2013; George et al., 2018), but the explanation about the underlying reasons for the prioritization is lacking. Most studies suggest that international graduate students' place higher expectations on academic achievement compared to interpersonal socialization. Participants in our study reported the decision to give up social lives after experiencing repeated failures in their attempts to be connected with domestic social communities. Simultaneously, they often described a past or current desire to be accepted into social groups, posing an alternative explanation to the existing interpretation in literature. According to Walton and Cohen (2007), individuals from a socially marginalized group with a risk for belonging uncertainty could have "disproportionately large impacts (p.86)" from subtle events that confirm their lack of social sense of belonging. This concept of 'belonging uncertainty' may help interpret this finding by explaining how a small number of negative interactions can result in segregation among students.

Our data also suggest that student feelings of academic sense of belonging were largely influenced by their interactions with faculty, primarily their advisors, which aligns with existing sense of belonging literature (Campbell, 2015; Glass et al., 2017; Ingram, 2012). Other aspects of the faculty – student interaction and its impact on student sense of belonging that are found include, the role of faculty as a 'bridge' to international students' social integration (Glass et al., 2017; p. 906) or as a protective buffer against

social adversity for marginalized students (Dayton et al., 2004; Hurtado & Carter, 1997). Neither of these ideas were revealed by data in our study.

7.2 How Social Norms Function in Cross-cultural Interactions?

The complex nature of students' interpersonal interactions within the context of engineering doctoral education requires perspectives that account for peers and faculty members coming from different cultures to coexist. The results of this study shed light on the question of what aspects of diversity in citizenship, language, and culture impact students' peer and faculty interactions, all of which are emphasized by graduate student socialization literature (Gardner, 2010; Twale, 2016; Weidman et al., 2014). According to our findings, the challenges that participants encountered in their peer and faculty relationships involved confronting unfamiliar social norms or holding conflicting social norms. In sociology, social norms are defined as the informal rules governing behavior in society, as "a kind of grammar of social interactions (Bicchieri et al., 2011)." This means that it was a natural consequence to feel uneasiness, distressed, or discomfort when participants were exposed to social interactions in the United States without being informed about the "grammar."

Participants frequently mentioned that they were confronted with unfamiliar social norms in their peer relationships. The resulting preferences to be friends with culturally similar peers and challenges associated particularly with domestic peers, aligns with the literature on international student adjustment (Geary, 2016; Glass et al., 2015a; Trice, 2003; Trice, 2007). According to a 'developmental model of Intercultural maturity'

(King & Baxter-Magolda, 2005), this lack of awareness of social norms and intergroup differences corresponds to the features shown in the initial level of maturity in cross-cultural interactions. Other features in the model (King & Baxter-Magolda, 2005), such as dependent relations with similar others or perspectives of different others viewed as wrong, were also found in our study (e.g., international students' self-segregation) (Trice, 2003, p. 24). Our study also revealed a strong focus among our participants on negative experiences with peers, which may imply a lack of appropriate social support related to social norms, rules, and etiquette of interactions in the US.

Our findings examining faculty interactions echo the literature on doctoral academic advising in STEM examining advisees from foreign countries or their faculty advisors (Joy et al., 2015; Kim, 2007; Trice, 2003). Participants' critical incidents describing their faculty interactions sometimes conflicted with the social norms from their home countries terms of attitudes and expectations within a teacher-student or help-seeking relationship. Of course, not all international students are the same and that students from different cultural backgrounds may encounter varied challenges in their interactions with faculty. Such conflicts in student-faculty interactions caused by culturally rooted differences in our data were primarily reported among participants from Northeast Asian countries that share a hierarchical culture. According to Hofstede (1986), the US represents a culture with small power distance and a student-centered education system that values the students' initiative. Northeast Asian countries represent a large power distance culture with a teacher-centered education system that emphasizes the teachers' order.

Some participant reports of uneasiness to initiate conversations with faculty reflect the norms in a culture with large power distance, where students place the responsibility of establishing a relationship on the teacher. Other norms, such as expecting the teacher to outline paths to follow or only speaking when invited to do so by the teacher, help our interpretation of the observed passive attitude of help-seeking in our findings. The misinterpretation of student actions or conflicts that result from the discrepancy in expectations regarding student-faculty interactions were also addressed by previous literature investigating faculty perceptions toward international doctoral students (Joy et al., 2015; Kim, 2007; Trice, 2003). Faculty play a significant role in helping international doctoral students' adjust academically (Glass et al., 2017). Our results provide insights into how the societal or educational culture of students' home countries influences their current interactions with faculty in the US and support the need to consider students' cultural backgrounds.

A final significant aspect of both peer and faculty relationships was participants' desire to be seen and related to as an individual instead of as a token international student (Deci & Ryan, 1991; Ryan, 1993). This finding aligns with Baumeister's and Leary's (1995) seminal article in which the need for sense of belonging was defined as more than superficial social contacts and required establishing desired relationships with ongoing and stable features. Overall, our findings revealed aspects of interpersonal socialization that hinder smooth interactions with peers and faculty, in turn contributing to emphasizing that further social supports are needed to improve sense of belonging among international graduate students in engineering.

7.3 Advantages and Shortcomings of the Current Engineering Doctoral Education Environment

This study primarily focuses on students' sense of belonging in relation to their interpersonal interactions, but also revealed the influence of the engineering doctoral education environment on students' interactions. First, some findings support the critical impact of the supervisor-supervisee advising relationship in doctoral engineering education. The majority of participants shared an ambivalent perspective towards the advisors' psychosocial supports, regarded personal interactions with faculty members as meaningful and positive experiences, but not necessarily as the advisors' responsibilities. This reflects the student perception of the advising relationship and supports the significant influence of interpersonal interactions as an informal way of socializing (Twale et al., 2016; Weidman, 2014).

Another group of incidents revealed the positive influence on sense of belonging of collaborative work integrated into coursework. Such experiences were described as promoting interactions among students and aligns with the literature on the adverse effects of traditional, lecture-based instructional methods in engineering on students' sense of belonging (Felder & Brent, 2005). Our findings suggest using collaborative approaches in engineering classrooms as a promising first step to developing peer relationships, as such opportunities were perceived by participants to be relatively low-pressure opportunities to academically interact with other students.

Finally, our findings also revealed advantages of existing features of engineering doctoral education to participant sense of belonging. Students' working in a common lab space was found to be a positive influence on participants' sense of belonging. A clear

difference was seen in the data between those who had a physical lab space and lab mates compared to those who did not, supporting the role of lab-working culture in naturally generating regular peer interactions (e.g., weekly research meeting, lab retreat, etc.). The existence of such physical settings as a support structure was not as important as the impact of advisors or as having peers from the same country outside of a lab, which aligns with the literature (Gardner, 2010) and implies the underutilization of labs as a source of support in engineering doctoral student socialization.

8. CONCLUSION, IMPLICATIONS, AND FUTURE WORK

This study explored the concept of a 'sense of belonging' from the perspective of international engineering doctoral students. Emergent critical incidents distilled from the participants' lived experiences enabled an in-depth understanding about the sense of belonging and the dynamics of interactions among different groups of people with different cultural backgrounds. These findings serve as an important first step toward better understanding the multifaceted concept of 'sense of belonging' in the context of doctoral engineering education. The identified incidents with detailed examples help identify where additional supports are needed for students' academic and social integration, and the implications of this work are in promoting the development of academic environments that focus on inclusion of international students rather than their diversity based on citizenship status.

Future studies will investigate how students' academic and socio-personal interactions with different groups of people in their academic unit (e.g., faculty, peers, and staff) relate to their perceived sense of belonging. This will be achieved through the development and deployment of a survey instrument to a large-scale sample of engineering doctoral students including both international and domestic students. The comparative analysis will uncover similarities and differences in how aspects of students' interactions with others contribute to the development of belonging and will identify unique aspects of this phenomenon for international students.

CHAPTER III. CONCEPTUALIZATION AND SITUATING OF SENSE OF
BELONGING AMONG INTERNATIONAL ENGINEERING DOCTORAL
STUDENTS: IN LIGHT OF THE PREVIOUS LITERATURE

9. CHAPTER III. INTRODUCTION

9.1 Study Context: Diversity in Students' Citizenship in Engineering Doctoral Education

According to the recent report 'Science & Engineering Indicators' (NSB, 2018), the US positions itself as the destination for the largest number of international students worldwide in the fields of science and engineering. International students who possess citizenships from 225 countries earned more than half of doctoral degrees in engineering in 2017, underscoring the diversity in citizenship among the student population (NSB, 2018).

Recently published national reports also support the existence of diversity in citizenship in STEM graduate education. For example, citizenship was included in diversity indices along with the traditional measures in the recent report 'Graduate STEM Education for the 21st Century' (NASEM, 2018). This paper answers the call to study this population in an effort to ensure that our engineering programs are inclusive of this important and understudied population (Gardner, 2010).

9.2 Research on Sense of Belonging in Engineering Education

Belongingness, the fundamental human need for social connection, is a construct that has garnered interest in studies of inclusion (Baumeister & Leary, 1995; Maslow, 1954). Sense of belonging was introduced to education as a precursor of students' integration within their academic unit (Spady, 1970; Tinto, 1993) and serves as a measure of the perceived degree of inclusion within that unit. The concept is still evolving because of its transitory characteristics that can change according to the specific context. This means that the sense of belonging for an individual student changes based on their current context, and thus a student with a high sense of belonging in a certain educational context can have a low sense of belonging if they move into a different educational context. This has resulted in a call to view the concept of belonging as complex, multi-faceted, and as impacted by extra-institutional factors (Ingram, 2012). Moreover, additional researchers have begun to take account of disciplinary-specific characteristics, such as student demographic characteristics and departmental culture (Curtin et al., 2013; Gardner et al., 2014; Trale et al., 2016).

Most research investigating belongingness in engineering education has focused on undergraduate students with demographic characteristics limited to gender and race/ethnicity. Aspects of student interactions with peers and faculty derived from the diversity in students' citizenship and the subsequent differences in language and culture (Beak, 2013; George et al., 2018; Lee et al., 2019; O'Meara et al., 2017) are absent from this work. Among the sparse research that does include students' citizenship as a variable, differences in sense of belonging were also reported between domestic and international STEM doctoral students (Curtin, 2013; O'Meara et al., 2017) in turn

underscoring the need for increased understanding sense of belonging from the international student perspective, particularly in the context of engineering doctoral education.

Our earlier work (Lee et al., 2019) related to understanding international doctoral students' sense of belonging is a first step in responding to this identified need. We investigated students' perception of their interpersonal interactions with peers and faculty and the associated relationships on their sense of belonging. The findings include a conceptual model that demonstrates the different constructs of belongingness, (e.g., engineering self-efficacy, academic sense of belonging, sociocultural sense of belonging, authentic-self, problem behavior, and perceived institutional support) and the influence of students' interpersonal interactions with different groups of people (e.g., faculty, peers, and staff) on those constructs (Lee et al., 2019).

10. RESEARCH QUESTIONS

10.1 New Questions: Have we Conceptualized Sense of Belonging as a Theoretical Construct?

New questions have arisen while situating our research in the broader literature related to sense of belonging. Definitions and conceptual structures of sense of belonging are sporadic and inconsistent across the belongingness literature in engineering education. The questions (i.e., have we conceptualized sense of belonging as a theoretical construct?) were supported by a cumulative argument in higher education that has claimed the lack of sense of belonging research that specified it as an independent construct (Davis et al., 2018; Hausmann et al., 2009; Johnson et al., 2007). This is surprising considering arguments made by research in both higher and engineering education regarding the significance of the concept on students' academic outcomes and perceived inclusiveness. The disparities in researchers' understandings on the conceptual constructs and the potential confusion driven by inconsistent definition use and terminology among researchers have led to recent concerns in higher education (Allen et al., 2018; Slaten et al., 2017).

We proceeded to review the sense of belonging literature in higher and engineering education not only for conceptualizing and situating of our own previous research (Lee et al., 2019), but also for diagnosing current understanding on the conceptual structure of sense of belonging within the engineering education research community. Correspondingly, this paper has three primary goals:

1. Examine the varied characteristics of sense of belonging as a theoretical concept (e.g., definitions, constructs/or defining components, and measures)

in different contexts (e.g., K-12 education, undergraduate education, graduate education, and community) among different study populations (e.g., adolescents, undergraduate students, underrepresented students, and adults) by reviewing literature in higher education.

2. Synthesize unique features of belongingness constructs/defining components across the higher and engineering education literature depending on the demographic characteristics of the study's sample (e.g., undergraduate, graduate, underrepresented (URM), international students).
3. Conceptualize and situate the constructs of international engineering doctoral students' sense of belonging based on a literature review.

11. RESEARCH METHODS

The approach to the literature review is broken up into two parts: 1) inconsistencies in definitions and constructs/defining components, and 2) constructs/defining components in different student groups. Part 1 provides a brief review of the sense of belonging literature in education and psychology, and part 2 reviews the constructs or defining components of belongingness in different groups of students (e.g., undergraduate students, domestic graduate students, other underrepresented students, and international students).

A non-systemic, general thematic review was conducted for this study. First, literature that studied sense of belonging as a theoretical construct or developed a measure of belonging while providing conceptual structures or constructs/defining components were identified using literature from education (e.g., undergraduate and graduate) and psychology. Searches were conducted within existing databases (e.g., Google Scholar and Web of Science) using keywords in the Boolean function (e.g., (“sense of belonging” or “belongingness”) AND (“constructs” or “dimensions” or “conceptual structure”) AND (“higher education” or “college” or “graduate” or “international students”)). The majority of the search results were not relevant to this study because the conceptual structure or constructs they investigated were about other concepts (vs. sense of belonging), which were studied or measured together with sense of belonging. Consequently, the search yielded a small but relevant literature base for this study, including both theoretical/conceptual work and empirical research.

Second, each identified publication was reviewed using a lens that focused on reported constructs or defining components of the work. This action established several

themes that indicated the characteristic of constructs/defining components – *academic*, *social*, *general*, and *institutional* – by using analytic memos on their names and features. The constructs/defining components reported in each piece of literature were then categorized into the identified groups.

Third, the constructs/defining components of belongingness were reviewed within different groups of students (e.g., undergraduate students, domestic graduate students, other underrepresented students, and international students) using the literature from higher education. In particular, constructs/defining components that were unique to different student groups were reviewed and synthesized using analytic memos.

Finally, findings from the literature review were used to conceptualize and situate constructs of international engineering doctoral students' sense of belonging. The working definitions of the constructs and future research plan will be provided.

12. LIMITATIONS

Although this work provides a basic understanding of the belongingness constructs, the reviewed literature in the current work is limited to the selected seminal papers for the purpose of conceptualizing and situating our previous work (Lee et al., 2019). To gain a clear and in-depth understanding of the conceptual structure of a sense of belonging, far more literature should be reviewed with a systematic process with specific search, inclusion, and exclusion criteria.

13. LITERATURE REVIEW

13.1 Sense of Belonging in Higher Education: Inconsistencies in Definitions and Constructs

Sense of belonging is one of a number of ways to refer to the fundamental human need for social connection in psychology (Baumeister & Leary, 1995; Maslow, 1954). The concept of belongingness has been extensively researched at the K-12 education level and its theoretical constructs and importance on students' academic and psychological outcomes have been demonstrated by a vast amount of research (Allen et al., 2018; Slaten, 2017). Figure 3 presents a summary of the literature review and includes the constructs or defining components of sense of belonging in different contexts – *K-12, undergraduate, graduate, and community* – among different groups – *non-URM/URM students, international students, and adult*). Hagerty et al. (1995) (Fig. 2, left), which developed a widely used instrument in mental health (the Sense of belonging Instrument/ SOBI), is included in Fig. 2 as an example of a broader scale to measure a sense of belonging to the general community among adults. Our previous study (Lee et al., 2019) is also included in Fig. 2 to enhance the understanding of how we conceptualized and situated the international engineering doctoral students' belongingness in line with the sense of belonging literature.

	ADULT (Community)	K-12 (Classroom)	UNDERGRADUATE (Institution)				GRADUATE (Academic unit)
GENERAL	Individual's perception on fit (person-environment)	Students' general feeling about school as a whole	Perceived classroom comfort Perceived isolation	Self-worth Problem behaviors	Authentic-self Problem behaviors		
SOCIAL	Valued involvement or the experience of being valued	School based relationships and experiences (with peer)	Extracurricular activities Peer interactions (formal & informal)	Peer support Social acceptance	Socio-cultural sense of belonging (Faculty & peer)	Socio-cultural sense of belonging (Faculty & peer)	
ACADEMIC		Student - teacher relationships	Faculty interactions (formal & informal) Academic achievement	Empathetic understanding Faculty support Scholastic competence	Intra-personal Meaningful personal relationship	Academic sense of belonging (Faculty & peer) Engineering self-efficacy	
INSTITUTIONAL				Perceived institutional support Environmental factors	Perceived institutional support Environmental factors	Perceived institutional support	
	Hagerty & Patusky (1995)	Allen et al. (2018)	Tinto (1975)	Hoffman (2002) Pittman & Richmond (2007)	Ingram (2012) URM	Slaten (2017)	Lee et al. (2018) INTERNATIONAL ENGINEERING

Figure 3. A Summary of the Literature Review on the Belonging Constructs/Defining Components

In spite of the emergent inconsistencies in conceptual structures across the literature, some common features exist in the belonging constructs among students in education. First, *academic* and/or *institutional* groups of constructs/defining components emerged in the sense of belonging literature across levels of education. Compared to Hagerty et al. (1995), which weighed mostly on the individuals' perception of *person-environment fit* and *value* through their interactions with an environment, *academic* and *institutional* facets have been shown in the sense of belonging literature among students (Fig. 2). Second, reference groups are varied depending on the level of education (e.g., *classroom, institution, academic unit, etc.*). These features imply the more dynamic and multifaceted characteristics of belonging in education where not only the individuals' perception on the environment but also the diverse external referents in the educational environments play roles as determinants of belongingness. The following section will provide a literature review of the belongingness constructs/defining components at a different level of education.

Allen et al. (2018) conducted a meta-analysis of the sense of belonging literature in K-12 education. Their analysis regarding the definition, constructs, factors related to, and outcomes of the students' perceived belonging revealed three constructs across the literature, 1) *student-teacher relationships*, 2) *school-based relationships and experiences (with peers)*, and 3) *students' general feeling about school as a whole* (Fig. 2). The definition from Goodenow (1993), "the extent to which students feel personally accepted, respected, included, and supported by others in the school social environment (p.80)" was reported as most consistently used (Allen et al., 2018).

Sense of belonging was introduced to higher education as a precursor of students' social and academic integration by Spady (1970) and Tinto (1993), but the concept has been understudied as an independent, theoretical concept (Allen et al., 2018; Davis et al., 2018; Hoffman et al., 2003; Hausmann et al., 2009; Hurtado & Carter, 1997; Johnson et al., 2007; Slaten et al., 2017). Consequently, definitions and theoretical constructs in the context of higher education have been unclear or lacking in the higher education sense of belonging literature. Some research has conceptualized sense of belonging in higher education, but most were informed by theories in psychology or sociology pertaining to the person-environment fit rather than empirical data from students' experience (Johnson et al., 2007; Slaten et al., 2017). The conception of belonging in the majority of research in higher education is grounded by Spady and/or Tinto's models of social and academic integration (Spady, 1970; Tinto, 1993). These models explain the concept of belongingness as a component of social integration impacting student persistence and retention, while having mutual influences on academic integration. Sense of belonging in higher education is consequentially "often implied as the result of social and academic integration, rather than specified and measured as an independent construct (Hausmann et al., 2009; p.806)". The majority of engineering education research on sense of belonging has been informed by the literature in higher education which explains the inconsistencies in definitions and constructs.

Hoffman (2003) empirically studied sense of belonging as a theoretical concept by exploring first-year college students' experiences regarding their belongingness. The study used a focus group and developed a measure of belongingness. Exploratory factor analysis (EFA) results suggested the addition of a construct regarding students' general

sense of belonging to the classroom and institution, i.e., *perceived classroom comfort* and *perceived isolation*. The remaining constructs included *faculty support*, *empathetic faculty understanding*, and *peer support*, which are relevant to the peer and faculty interaction components in Tinto's model (1993). The study is significantly meaningful in its investigation of the theoretical constructs of belongingness, but failed to provide validity evidence beyond EFA. However, the follow-up study (Tovar et al., 2010) providing additional validity evidence using confirmatory factor analysis (CFA) revealed an entirely different factor structure, which brings into question the original study's results on the belonging constructs.

Pittman & Richmond (2008) conducted a theory-based study suggesting a construct relating to the individual student's perceived academic competency, i.e., *scholastic competence*, among undergraduate students. They developed an instrument called the 'Psychological Sense of School Membership Scale (PSSM)', which adopted items for the student belonging construct from Goodenow's (1993) measure developed for middle school students. A belonging measure for underrepresented undergraduate students was also developed by Ingram (2012) based on a theory-based conceptualization of inclusion. A construct regarding the students' perceived institutional effort towards diversity and inclusion, i.e., *perceived institutional support*, was suggested to be included and remained after CFA.

Inconsistencies in conceptual structure exist across the studies of undergraduate students presented in Figure 3 (Hurtado & Carter, 1997; Ingram, 2012; Johnson et al., 2007; Tovar et al., 2010) despite all being informed by Tinto's model (1993). The constructs were selectively chosen according to the needs of the authors resulting in none

of the conceptual structures or measures encompassing all variables. Confusion in the interpretation of results using varied instruments creates a consistency problem when considering the prevalent use of these instruments with different constructs in the current belongingness literature. Similar claims have arisen in higher education (Meeuwisse et al., 2010; Slaten et al., 2017) bringing about questions on the appropriateness of these measures due to inconsistent results.

These claims accompanied arguments made about the underlying assumptions that led researchers to use or adopt scales developed in K-12 education, or develop ad-hoc scales without concern for the conceptual structure. Assumptions varied in whether emergent belongingness constructs in K-12 research were identical in undergraduate contexts. The previous research also provides insights on the belongingness constructs in the context of higher education, but note that “It is possible that the concept of sense of belonging is more complex than we assumed (Meeuwisse et al., 2010; p. 543)”. Slaten’s conceptual constructs also support the increasing complexities in the structure of belongingness relative to the advance in educational level (Fig. 2) and argues the needs for developing a conceptual model based on empirical data that takes account of the context-specific variables. This paper argues that researchers should acknowledge that sense of belonging can have different meanings when studied with different groups of students and that the meaning should be identified or considered as a theoretical concept in advance of measurement selection or analysis of the results.

13.2 Sense of belonging: Constructs/defining components in different student groups

The constructs or defining components varied within the engineering discipline based on educational level, student group, and students' citizenship. Characteristics of each student group's belongingness constructs will be synthesized and categorized into the identified facets of belonging - *academic*, *social*, *general*, and *institutional* (Fig. 2). The meaning of some terminologies used in different contexts will be clarified in each context.

Undergraduate Students' Sense of Belonging. The majority of research in student belonging in both higher education and engineering education has focused on undergraduate students in connection with diversity and inclusion efforts (Ong et al., 2011; Sax et al., 2018). Most of the literature has identified the entire campus community or institutions as reference groups, but peer groups and classrooms have also been identified as reference groups depending on the literature. Such shift in reference groups from classrooms in K-12 to the entire institution in higher education explains the addition of constructs/defining components on the students' connectedness to the institution to the *social* facet of belonging. The examples include *Extracurricular activities* (Tinto, 1993) and *valued group membership* (Slaten et al., 2017) in Figure 3, which describe the students' engagement through a student organization or a residential environment. Regarding the *academic* facet of belonging, the emergence of intrapersonal components such as *Academic achievement* (Tinto, 1993) and *Scholastic competence* (Pittman & Richmond, 2008) was shown in the literature (Fig. 2).

Graduate Students' Sense of Belonging. Sense of belonging research in graduate education is scarce but is currently growing (Lee et al., 2019). Graduate students' sense of belonging is regarded to be developed through their involvement in their academic units, such as a specific graduate program or department. Such changes in the students' reference groups of belonging are likely associated with the primary goals of graduate education where professional development within the area of academic specialty has greater importance (Twale et al., 2016). Accordingly, the defining components relevant to the institutional engagement activities in the *social* facet of belongingness among undergraduate students are replaced by the students' academic and professional engagement in their field of academic specialty (e.g., academic conference, research meeting, etc.) (Lee et al., 2019).

Regarding the *academic* facet of sense of belonging, student belongingness research is closely related to graduate student socialization in graduate education (Garner, 2010; O'Meara et al., 2017). Socialization in graduate education refers to the process of becoming a member of the academic community through learning the knowledge, skills, and values of the academic unit (Weidman, 2003). It has been regarded to be important in graduate education literature due to its impact on student persistence and retention in the academic field after graduation (Fisher et al., 2019; O'Meara et al., 2017). The recent attention toward students' sense of belonging in graduate education has derived from the mutual influence between student belongingness and socialization. According to Weidman's graduate socialization model, the mechanisms of socialization were explained as the interplay among interactions with others (e.g., faculty and peers), sense of integration or belonging, and learning of knowledge. The model indicates the significance

of belonging for student socialization. On the other hand, Stayhorn (Stayhorn, 2012) interpreted the socialization process as the passage of individuals to belong to the academic community and argued the impact of socialization experienced on the individuals' connectedness to academia.

Underrepresented Minority (URM) Students' Sense of Belonging. The sense of belonging research in engineering education has shown inseparable relationships with URM students in engineering who are marginalized in gender, race, and ethnicity. Students from stigmatized groups have been known to have higher uncertainty about their belonging and potential than majority students (Walton & Cohen, 2011). An emphasis on understanding the URM students' belongingness is a natural consequence of inclusion efforts to embrace the diversified student population in engineering.

One of the defining features of URM students regardless of educational level is the emergence of *institutional* facet of sense of belonging, such as *Perceived institutional support* and *Environmental factors* in Fig. 2 (Fisher et al., 2019; Hurtado & Carter, 1997; Ingram, 2012; Lee et al., Yao, 2015). Distinctive features have been found in the literature in terms of the characteristics of the institutional support components between undergraduate and graduate students. Among undergraduate students, institutional support components focus on their perceptions toward the institutional level support or commitment (e.g., the campus racial climate, positive institutional climate for diversity, etc.) (e.g., *Perceived institutional support* (Ingram, 2012) and *Environment factors* (Slaten et al., 2017) in Fig. 2). On the contrary, among graduate students, *Perceived institutional support* (Lee et al., 2019) focuses more on the individual level support

provided by institutions or people from the institution regarding the students' academic and social issues (e.g., structured PhD program, institutional support, etc.) (Fisher et al., 2019; Lee et al., 2019). Considering the overall paucity of research on the graduate students' sense of belonging, such divergent perceptions of support suggest the need for further investigation of graduate student belongingness within the URM student population.

Regarding students' interactions with peers and faculty that are integrated within the *social* and *academic* facets of sense of belonging, differences have appeared in the belonging literature among URM students. Figure 3 shows belongingness constructs pertaining to the interpersonal interactions or relationships, such as *Peer interaction (informal & formal)*, *Faculty interaction (informal & formal)* (Tinto, 1993), *Peer support*, *Empathetic understanding*, *Faculty support* (Hoffman et al., 2003), *Social acceptance* (Pittman & Richmond, 2008), *Social sense of belonging*, *Academic sense of belonging* (Ingram, 2012), *Meaningful personal relationship* (Slaten et al., 2017), and *Socio-cultural sense of belonging (Faculty & Peer)*, and *Academic sense of belonging (Faculty and Peer)* (Lee et al., 2019). Although these components are also known as determinants of belonging regardless of a group presentation, students' relationships with faculty have been highlighted as salient features connected to student belonging and engineering identity, particularly among URM students (Campbell, 2015; Dayton et al., 2004; Glass et al., 2017; Ingram, 2012). Relationships with peers from underrepresented backgrounds have also been reported to contribute to URM students' ability to find a deeper sense of belonging through the community by creating opportunities to share their experiences and barriers (Davis et al., 2018; Griffin et al., 2018).

International Students' Sense of Belonging. Although the majority of research on URM students' belongingness in engineering education has focused on women, racial and ethnic URM students who have been traditionally known as marginalized groups of students, recent attention has been paid to international students, particularly at the level of doctoral education (Glass et al., 2017; Lee et al., 2019; O'Meara et al., 2017) Some aspects of URM students' belongingness have also emerged for international students, such as the importance of faculty in student belonging, lending support to consider international students in engineering doctoral education as being marginalized based on citizenship, even though their number quantitatively outpaces their US counterparts. In addition to such commonalities, some distinct features also have emerged for the international student population.

One noticeable feature among international students is the emergence of cultural aspects across all the identified facets of belongingness (i.e., *general*, *social*, *academic*, and *institutional* in Fig 2.). Regarding the *general* facet of belonging, the differences in the students' cultural background and/or language associated with the diversity in the students' citizenships have emerged as influencers of students' perceived acceptance, isolation, or discrimination (e.g., *Authentic self* and *Problem behaviors* constructs (Lee et al., 2019) in Fig. 2). Similarly, the *institutional* facet of belonging among international students include the support from the academic unit of the institution during the students' academic, social, cultural, and life transitions (e.g., assistance with administrative work such as Visas, SSN, housing).

Regarding *social* and *academic* facets, international students have reported different patterns in peer and faculty interaction and the cultural differences have been

frequently reported as the biggest reason. For example, lower interactions with both faculty and peers have been reported among international students compared to other groups (e.g., majority and the racial/ethnic URM students) in spite of the significant role faculty interactions play in the URM student perceived belongingness (Jeoung et al., 2019; Joy et al., 2015; Kim, 2007; Trice, 2003; Trice, 2007). International students' perceived frequency of social and personal interactions with faculty was significantly lower than others (e.g., majority and the racial/ethnic URM students) although all the groups reported the similar frequency of academic interactions (Jeoung et al., 2019). Also, racial/ethnic URM status did not show a significant association with the frequency of interaction with peers and faculty (Jeoung et al., 2019). This synthesis implies the greater impact of international student status and the associated differences in cultures and social norms on the peer and faculty interaction patterns compared to other marginalized statuses (Jeoung et al., 2019; Johan & Rienties, 2016; Meeuwisse et al., 2010; Rienties & Nolan, 2014).

14. DISCUSSION

14.1 A Conceptualization of International Engineering Doctoral Students' Sense of Belonging

This section will provide a conceptualization of sense of belonging among international engineering doctoral students based on our previous work (Lee et al., 2019) and the literature review on the constructs/defining components of belonging in education. Our previous work (Lee et al., 2019) explored students' lived experiences on belongingness in connection with their interpersonal interactions with people in their academic units. The results include a conceptual model of sense of belonging among international doctoral students with three constructs - *Perceived institutional support construct*, *Academic sense of belonging*, and *Sociocultural sense of belonging*. In this section, the initial conceptual model was informed by the findings of the literature review and revised. Table 3 presents the six constructs of the revised version of conceptual model among international engineering doctoral students' belongingness, with their names and definitions. The constructs are also categorized into the four identified groups of constructs/defining components that resulted from the literature review - *academic*, *social*, *general*, and *institutional* (Fig. 2).

Table 3

The Sense of Belonging Constructs among International Engineering Doctoral Students

Name	Definition	Groups
Authentic self	The extent to which students perceive that they are viewed and accepted as their authentic self regardless of their personal background (e.g., citizenship, culture, language, etc.)	<i>General</i>
Problem behavior	The extent to which students experience problem behaviors (e.g., discrimination, oppression, disadvantage, etc.) relating to and/or caused by their personal background	
Engineering self-efficacy	Students' belief about their capabilities to perform tasks (e.g., coursework, research) needed to successfully complete their doctoral degrees in the US as international students	<i>Academic</i>
Academic sense of belonging	The extent to which students feel that they are academically and professionally included in their academic units through their academic interactions (or socialization) with faculty and peers	
Sociocultural sense of belonging	The extent to which students feel that they are socially included in and culturally accepted by the group of faculty and peers in their academic units through personal interactions (or socialization) with them	<i>Social</i>
Perceived institutional support	The extent to which students feel that they are supported from their academic units regarding their academic, social, and cultural issues, through staff interactions	<i>Institutional</i>

The initial conceptual structure in our previous work (*Academic sense of belonging, Sociocultural sense of belonging, and Perceived institutional support*) (Lee et al., 2019) were mostly informed by the empirical results but also guided by the prevailing notion of the belongingness that are mostly grounded on Tinto and Spady's models (Spady, 1970; Tinto, 1993) Although the findings of our previous work (Lee et al., 2019) included the analyzed themes relevant to the newly added constructs in this paper (*Authentic-self, Problem behavior, and Engineering self-efficacy*), they were included as a part of the former three constructs to make consistency with the previous literature.

However, the broadened understanding on the conceptual structure of sense of belonging obtained from the literature review convinced the research team to reconsider the conceptualization. The lesson learned from the literature review include the prevalently conceived constructs of belongingness in higher and engineering education may not be applicable to every context. Instead, there is a need for conceptualizing sense of belonging depending on the educational level and/or group of students, and there has been a recent claim to develop a conceptual model grounded on the empirical data with the students' lived experience relevant to sense of belonging. The revised conceptual model will be presented in the following sections with the reasons behind the decisions.

First, *Authentic self* and *Problem behavior* were added as individual constructs after being separated from *Sociocultural sense of belonging*. They were previously regarded as themes included in *Sociocultural sense of belonging* (Lee et al., 2019) due to the relatively smaller amount of students' experiences pertinent to each construct and the inconsistency with the belongingness constructs in the belonging literature among URM students. However, the greater impact of directly feeling accepted or rejected as 'who I am' on the students' belongingness, compared to other indirect ways of feeling belonged, was considered as important. Reviewing a broader range of the sense of belonging literature and its findings, which include the constructs on the *general* facet of belonging (Fig. 3) also supported our decision.

Second, the former *Academic sense of belonging* construct in our previous work (Lee et al., 2019) was broken down into two constructs, *Engineering self-efficacy* and *Academic sense of belonging*. What supported this decision was the significant amount of students' experiences relevant to the construct in our original data and the uniqueness of

the construct among international students. The constructs on the students' academic capacity have been shown in the literature among undergraduate students (*Academic achievement* and *Scholastic competence* in Fig. 3). However, *Engineering self-efficacy* was differentiated by encompassing the students' feeling of confidence in studying in the US by speaking English that was attributed by the international student status.

Consequently, the rest of the constructs - *Academic sense of belonging*, *Sociocultural sense of belonging*, and *Perceived institutional support* - resulted in focusing on the students' feeling of belonging in different aspects, particularly through interpersonal interactions with peers, faculty, and staff. The updated conceptual structure is comprised of intrapersonal constructs (*Authentic-self*, *Problem behavior*, and *Engineering self-efficacy*) that are influenced by interpersonal constructs (*Academic sense of belonging*, *Sociocultural sense of belonging*, and *Perceived institutional support*).

15. IMPLICATIONS AND CONCLUSION

This work will be useful for practitioners, including faculty, administrators, and researchers in the engineering education community. The developed conceptualization will provide faculty members and administrators the information needed to develop appropriate, and thus, effective support that can enhance the international engineering doctoral students' perceived belongingness. The literature review on the conceptual structure of belongingness will advance the current knowledge about a sense of belonging in engineering education, and the findings of the review indicate the need for understanding sense of belonging as an independent and theoretical concept.

CHAPTER IV. COMPARATIVE ANALYSIS ON THE PREDICTORS OF SENSE OF
BELONGING BETWEEN INTERNATIONAL AND DOMESTIC ENGINEERING
DOCTORAL STUDENTS: THE INTERPLAY OF INTERPERSONAL INTERACTION
WITH FACULTY, PEERS, AND STAFF

16. CHAPTER IV. INTRODUCTION

According to the recent National Science Board report ‘Science & Engineering Indicators’ (NSB, 2018), the United States (US) hosts the largest number of international students worldwide in the fields of science and engineering. In 2017, international students with citizenships from 225 countries earned more than half of doctoral degrees in engineering in the US, (NSB, 2018), which creates a potentially rich and rewarding, multicultural setting for domestic and international graduate students alike. Strong diversity in STEM graduate education citizenship is also supported by a recently published National Academies of Science, Engineering, and Medicine report ‘Graduate STEM Education for the 21st Century’ (NASEM, 2018). The report includes citizenship among traditional measures of diversity, such as gender and race/ethnicity. These reports highlight clear importance of the international student population to the STEM graduate culture within the US, yet very little attention has been given to how the international students’ experiences within their academic program contribute to their sense of belonging or perception of program inclusiveness.

Sense of belonging is the fundamental human need for social connection. The construct was introduced to educational researchers as a precursor of students’ integration within their academic unit (Spady, 1970; Tinto, 1993) and serves as a measure of the

perceived degree of inclusion within that unit. The construct has most widely been used to support understandings of the undergraduate student experience. Recent research has included investigations of graduate students' sense of belonging as it relates to creating an inclusive culture in graduate education and supporting graduate student socialization, which is the process of becoming a member of the academic community through learning the knowledge, skills, and values of the academic unit (Curtin et al., 2013; Fisher et al., 2019; Stayhorn, 2012; O'Meara et al., 2012; Ong et al., 2011; Pascale, 2018; Weidman, 2003). Interpersonal interactions with others have been shown to be a key mechanism for developing both sense of belonging (Baumeister & Leary, 1995) and socialization (Twale et al., 2016; Weidman, 2003).

Recent studies have also begun to consider demographic attributes and characteristics of the academic environment to better understand resulting differences in sense of belonging (Curtin et al., 2013; Gardner et al., 2014; Twale et al., 2016). Gardner et al.'s (2014) exploration of doctoral students' sense of belonging across different disciplines indicates that engineering doctoral students reported a relatively lower sense of belonging within their academic department compared to students in other disciplines. O'Meara et al. (2017) echoes this claim, reporting that fewer facilitators of sense of belonging exist within STEM doctoral program environments than in non-STEM programs. The same findings are supported by Twale et al., 2016, who argue that there is a negative effect of diversity in citizenship and associated linguistic and cultural differences to students' integration into an academic field or departmental culture because they challenge interactions between students with different cultural backgrounds. This work collectively suggests the need to consider in more detail the impact of

interpersonal interactions within the academic unit on the sense of belonging among engineering doctoral students. The following study explores this focus separately for international and doctoral students, while also considering the multicultural nature of interaction and the discipline-specific characteristics of engineering doctoral programs.

17. LITERATURE REVIEW

17.1 Belongingness Hypothesis

Research on the fundamental human need for social bonds and connections has a long history in psychology. Sense of belonging is one of a number of ways to explore this fundamental human need (Baumeister & Leary, 1995; Maslow, 1954) and has been defined in a variety of diverse ways. This study adopts the definition and conceptual understanding of sense of belonging from the '*Belongingness hypothesis* (Baumeister and Leary's, 1995)'. This hypothesis articulated the need for belonging in relation to interpersonal relationships, while suggesting that "human beings have a pervasive drive to form and maintain at least a minimum quantity of lasting, positive, and significant interpersonal relationships" (Baumeister & Leary, 1995, p. 497). Baumeister and Leary argue the significance of the positive and meaningful interaction with others to satisfy the need for belonging and they described the resulting interpersonal bonds as having "stability, affective concern, and continuation into the foreseeable future" (Baumeister & Leary, 1995, p. 500). The hypothesis has been employed in education research to explain student behaviors, intentions, or motivation in connection with belongingness (Glass & Westmont, 2014; Glass et al., 2015a; Glass et al., 2015b; Ingram, 2012; Sax et al., 2018; Peter et al., 2015; Wilson et al., 2015).

17.2 Doctoral Students' Sense of Belonging and Interpersonal Interactions within the Academic Unit

Graduate students' sense of belonging is developed through their involvement in their academic units, such as a specific graduate program or department (Lee et al., 2020). This contrasts with literature on undergraduate student sense of belonging, which focuses on the students' connectedness to the entire campus community or institutions (Hoffman et al., 2003; Slaten et al., 2018). The focus on the academic unit for graduate students is driven by the primary goals of graduate education in which professional development within the area of academic specialty has greater importance (Twale et al., 2016).

The literature on doctoral students' sense of belonging and socialization suggests that faculty and peer interactions in both formal and informal settings have the greatest impact (Gardner, 2010; Fisher et al., 2019; Jeoung et al., 2019; O'Meara et al., 2017; Weidman & Stein, 2003). These groups have a significant impact on student outcomes, including sense of belonging. Four types of student interactions with faculty were suggested by Weidman & Stein (2003): academic (field-related), intellectual (non-field related), social, and personal.

A body of literature underscoring the importance of the doctoral student – faculty advisor relationship exists, but there remains little study of the role of peers or peer relationships on doctoral student sense of belonging within their academic program. Some researchers explain this oversight within the research community by the fact that many view doctoral education as a traditional cognitive apprenticeship in which the driving factor of development is the faculty-to-student mentorship (Jeoung et al., 2019). This viewpoint neglects the role of peers as intellectual stimulators, which is emphasized in Weidman's

model (Weideman & Stein, 2003). Golde et al. (2009) has shown that doctoral students' peer relationships serve as co-mentoring relationships through which they exchange knowledge and provide feedback to one another. Interactions involving emotional support and the sharing of academic and personal concerns have also been brought forth as important types of peer interaction among doctoral students (Ulku-Steiner et al., 2000).

17.3 International Students' Sense of Belonging and Interaction within the Academic Unit

Recent literature on international students' shed light on some of the factors that promote or detract from their sense of belonging. Support from the academic unit and institution, including staff member interactions, during students' academic, social, cultural, and life transitions (e.g., assistance with administrative work such as visas and housing) has been shown to promote sense of belonging (Lee et al., 2019). Students' cultural background and/or language have also emerged as influencers of students' perceived acceptance, isolation, marginalization, or discrimination, which influence their sense of belonging (Arnold, et al., 2020; Lee et al., 2019). International students have also described cultural differences leading to differential (compared to their domestic peers) patterns in peer and faculty interaction, which shed light on the importance of international student status relative to peer and faculty interaction patterns (Jeoung et al., 2019; Johan & Rienties 2016; Meeuwisse et al., 2010; Rienties & Nolan, 2014). Fewer interactions with both faculty and peers have been reported by international students (Glass et al., 2015b; Glass et al., 2017; Jeoung et al., 2019; Joy et al., 2015; Kim, 2007; O'Meara, Knudsen, & Jones, 2013; Trice, 2003; Trice, 2007). The lack of meaningful interaction with domestic

students has been frequently reported as detrimental to sense of belonging (Brandenburg & De Wit, 2011; Campbell, 2015; Glass & Westmont, 2014; Glass et al., 2015b; Le & Gardner, 2010; Yao, 2015), while meaningful peer interactions with co-national, international, and host students have been reported to positively impact students' belonging with the campus community (Hendrickson et al., 2011).

17.4 Impact of Engineering Cultural Characteristics on Students' Sense of Belonging

The cultural characteristics of engineering can have a crucial impact on a student's sense of belonging. The advisor – advisee relationship is particularly salient. Elements of interpersonal interactions with a faculty advisor that have been shown to contribute to a student's sense of belonging include interactions around academic advising, career development, and personal (non-academic) topics (e.g., multicultural issues, personal life challenges, or concerns related to the advisee's interaction with other faculty or peers in the program) (Barnes & Austin, 2009; Gardner, 2010; Ladany et al., 1996; Mainhard et al., 2009; Zhao et al., 2008). Student progress and funding are often closely tied to the advisor's research (Wilkins et al., 2015), which can also impact interactions.

The advising relationship in engineering has been characterized as a supervisor-supervisee relationship where the dominant interaction is focused on academic support (Primé et al., 2015). Psychological and social supports, which play essential roles in building a positive and meaningful relationship between advisors and students, have a major impact on student sense of belonging. Such relationships are often lacking in engineering doctoral education (Bargar & Mayo-Chamberlain, 1983; Lovitts, 2004; Robbins et al., 2004).

Another salient cultural characteristic are experiences that occur within engineering lab settings. Collaborative laboratory spaces are where many engineering doctoral students develop their expertise. Peer interactions among doctoral students within lab-based disciplines were pointed out as a vital aspect of doctoral training by researchers in doctoral education (Golde et al., 2009; Jeoung et al., 2019) The results suggest a significant influence of lab-based settings on students' interpersonal interactions with their peers. This connects to the claim made in Weidman's model (Weidman & Stein, 2003) that graduate students' have more frequent interactions with their peers than they do with faculty. This is especially true for doctoral students in lab-based engineering or science disciplines.

18. RESEARCH OVERVIEW

This study investigates engineering doctoral students' sense of belonging through their interpersonal interactions with people in their academic unit. The research is designed to test the theoretical hypothesis that significant positive and meaningful interactions with others satisfies the need for belonging. An examination is undertaken to understand the relationship between sense of belonging, student demographic characteristics, and the quality and frequency of interactions with faculty advisors, peers, and staff. These relationships were considered separately for domestic and international students. Interpersonal interactions were characterized as being with one of three groups of people – faculty advisor, peers, staff – and around one of two possible types – academic or non-academic. The groups of people with whom doctoral students reported interactions and the types of associated interactions were defined as follows:

- Faculty advisor: faculty member who is most closely associated with the student's doctoral dissertation
- Peers: classmates, lab mates, and other peers in the student's academic program
- Staff: any university employee that provides student support (e.g., academic advising, graduate college, international student offices, housing, health center, etc.) who is not a faculty member
- Academic interaction: interactions regarding academic issues such as research, coursework, academic/professional development, etc.
- Non-academic, i.e., personal, social, or cultural interaction: interactions related to personal, social, or cultural topics, regardless of physical space (in/outside of the school) where the interactions occurred

This study is reported in two parts. Part 1 focuses on the development of an instrument to measure the quality and frequency of engineering doctoral student interactions with faculty, peers, and staff. Part 2 uses research participant responses to the instrument developed in Part 1 as the basis for conducting a regression analysis to formally investigate the relationships between student characteristics, the quality and frequency of interactions, and sense of belonging.

19. PART 1. INSTRUMENT DEVELOPMENT

The Engineering Doctoral Student Quality of Interaction (EDQI) instrument was created to measure engineering doctoral students' perceived quality of interaction with faculty advisors, international and domestic peers, and staff. Considerations were made to account for the multicultural nature of interaction and the discipline-specific characteristics of engineering doctoral programs. The instrument development process will be presented in the following subsections, which provide details regarding the methods, limitations, and results.

19.1 Methods

Item Generation, Content Validity, and Face Validity

Several steps were undertaken to develop the instrument following guidelines on psychosocial measurement and scale development (Netemeyer, Bearden, & Sharma, 2003). First, the research team reviewed the literature and existing instruments on doctoral students' sense of belonging, socialization, and interpersonal interaction or relationships with a faculty advisor, peers, or staff (Ladany et al., 1996; Mainhard et al., 2009; Minor et al., 2013; Museus et al., 2017; Ulku-Steiner et al., 2000; Weidman & Stein, 2003). This literature provided an idea of how doctoral students perceive quality interactions with faculty advisor, peers, and staff in their programs, but fell short in reflecting the international students' perspective.

A second subsequent step was undertaken to integrate the perspectives of international students. An existing dataset of qualitative, semi-structured interview

responses obtained previously by the same research team was used as a resource to describe the cultural domain of interaction that plays a significant role in international students' perceived quality of interaction. The international student interview data focused on experiences with interpersonal interaction and sense of belonging in the context of engineering doctoral education (Lee et al., 2019). A critical incident technique was used to collect data through a set of interview questions designed to explore instances in which participants perceived that they had positive or meaningful interactions with a faculty advisor, peers, and staff, and sense of belong to their academic unit. The current study used the part of the dataset relevant to interpersonal interactions. The research team transformed the critical incidents into "single-concept statements (Lee, 2015; Lee & Lutz, 2016; Lee et al., 2019)" that resembled survey items. This additional step helped to avoid construct underrepresentation (Messick, 1993).

Table 1 provides an overview of the scales within the instrument, including the initial number of items, the primary inspiration for the items, and example items. All the items in the instrument were positively worded for consistency and clarification. Response options for all scales were arrayed on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). In sum, a total of 66 preliminary items for three scales: *Faculty advisor interaction*, *Peer interaction*, and *Staff interaction*, were generated to measure the students' perceived quality of interaction.

Evidence of content and face validity for the instrument was collected once preliminary items were developed. Content validity was evaluated by a faculty member external to the research team with expertise in both interpersonal support in STEM and the experiences of students from diverse racial/ethnic backgrounds. Open-ended feedback on

the preliminary set of items was provided by the expert, which helped diagnose items that were unclear, inappropriate, or inconsistent with the rest of the scale. Face validity was assessed by two international engineering doctoral students and two domestic engineering doctoral students. The collective, open-ended feedback from the international students helped revise phrases or words for some items that were not easy to understand by international participants whose native language is not English. Feedback from the domestic students helped provide evidence to support the relevance of items to domestic students. Table 4 details each of the three resulting scales.

Table 4

Overview of Scales within the Instrument

Potential dimensions (Number of items)	Primary Inspiration for Items	Example Items
Scale 1. Faculty advisor interaction		
Academic interaction (20)	Doctoral students' socialization and interpersonal interaction with faculty (Ladany et al., 1996; Mainhard et al., 2009; Weidman & Stein, 2003)	<ul style="list-style-type: none"> • My faculty advisor makes me feel like I can succeed in my program • My faculty advisor demonstrates patience with me as I develop research skills
Non-academic, i.e., personal, social, or cultural interaction (10)		<ul style="list-style-type: none"> • My faculty advisor is generally friendly to me • My faculty advisor is willing to listen to me talk about non-academic topics (e.g., personal, social, or cultural) • My faculty advisor has showed me an interest in my cultural background(s)
Scale 2. Peer interaction		
Academic interaction (10)	Doctoral students' socialization and peer support (Minor et al., 2013; Ulku-Steiner et al., 2000; Weidman & Stein, 2003)	<ul style="list-style-type: none"> • At least one of my peers is someone I feel comfortable talking to about academic topics (e.g., research or coursework) • At least one of my peers would be willing to study with me
Non-academic, i.e., personal, social, or cultural interaction (13)		<ul style="list-style-type: none"> • At least one of my peers is someone I consider to be a friend • I feel comfortable talking to at least one of my peers about non-academic concerns (e.g., personal, social, or cultural) • None of my peers have expressed negative stereotypes regarding my cultural background(s)
Scale 3. Staff interaction		
Academic, personal, social, or cultural interaction (13)	Doctoral students' socialization and supportive campus environment (Weidman & Stein, 2003)	<ul style="list-style-type: none"> • At least one staff member at my institution is a person I have sufficient access to when I need academic support (e.g., course selection, advisor selection) • Staff members at my institution generally listen to me empathetically • Staff members at my institution are familiar with academic resources relevant to my citizenship (e.g., US citizen or F1 visa holders)

Participant Recruitment and Data Collection Procedure

Data were collected from international and domestic engineering doctoral students in 361 programs at 36 research intensive (R1) universities (26 public and ten private institutions) across the US. Recruitment emails to participate in the online survey were sent to students by their program chair and/or academic advisor during spring 2020. Participants completed the newly designed EDQI along with an existing measure of sense of belonging (Bollen & Hoyle, 1990) and a demographic survey.

The sense of belonging scale was included because Part II of this study investigates the influence of the students' quality and frequency of interactions with a faculty advisor, international and domestic students, and staff measured by the EDQI on their perceived sense of belonging. The scale consists of three items and all the items were modified for contextualization as the original scale was developed for undergraduate students. Changes considered the differences in reference groups of belonging at depending on the level of education. For example, "I feel a sense of belonging to the campus community" was revised to "I feel a sense of belonging to my academic unit." The instruction for this scale is "Please indicate your level of agreement with each of the following statements about how you feel about the community of your academic unit." Participants responded using a 5-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Demographics included the participants' gender, age, race and ethnicity, and their academic backgrounds (e.g., institution type, years in the program, previous foreign education, membership in a research lab, etc.). Participants completed the survey packet completed online through Qualtrics. The order in which items were shown on each scale

was randomized. Participants were asked to respond to the peer interaction scale twice to separately assess interactions with international and domestic peer groups.

Participants

The data collected through the recruitment efforts yielded a total sample of 653 responses from the selected institutions. Institution selection considered all R1 universities with a robust presence of international STEM graduate students (Nature, 2018; Indiana University Center for Postsecondary Research, n.d.) considering that the study population of this study includes both international and domestic engineering doctoral students. Various sources of data informed the selection criteria, including the number of doctoral degrees awarded to foreign nationals (American Association for Engineering Education [ASEE], 2019), the number of doctoral degrees awarded (ASEE, 2019), the total number of international student enrollment, and other environmental variables of doctoral students and international students' experiences (e.g., institution type, residential, and geographic variations) (Migration Policy Institute, 2017; McCormack, 2007). The 36 R1 universities with the highest number of doctoral degrees awarded to foreign nationals were selected in consideration of the relatively lower survey participation rate of international students. The selected institutions provided institutional (e.g., public vs. private), residential (e.g., urban vs. suburban), and geographic, i.e., different regions in the US, variation within the dataset. The percentage of international student enrollment ranged from 2% to 22% (The Carnegie Classification of Institutions of Higher Education, n.d.; US News, 2018).

The total number of responses used for the EFA analysis (Part I), Regression analysis, and t-test analysis (Part II) varied to ensure maximum number of responses for

each analysis. Reported here is the demographic information for the full sample (Table 5). For both subgroups, female students are overrepresented among survey respondents, which is a tendency typically observed in survey response data (Smith, 2008).

Table 5

Demographic Information

Category	Domestic students Number (%)	International students Number (%)
<i>Gender</i>		
Male	159 (49.53%)	64 (30.48%)
Female	162 (50.47%)	146 (69.52%)
<i>Age</i>		
24 years or less	93 (28.97%)	33 (15.71%)
25 – 30 years	194 (60.44%)	141 (67.14%)
More than 31 years	34 (10.59%)	36 (17.15%)
<i>Race / Ethnicity</i>		
American Indian or Alaska native	0 (0.00%)	0 (0.00%)
Asian	43 (13.40%)	135 (64.29%)
Black or African American	8 (3.81%)	3 (1.43%)
Hispanic or LatinX	18 (5.61%)	8 (3.81%)
Native Hawaiian or Other Pacific Islander	0 (0.00%)	0 (0.00%)
White	222 (69.16%)	39 (18.57%)
Multiracial & Others	30 (9.55%)	25 (11.90%)
<i>Institution</i>		
Public	210 (65.4%)	152 (72.38%)
Private	111 (34.6%)	58 (27.62%)
<i>Years in program</i>		
6 months of less	7 (2.18%)	15 (7.1%)
7 months - 4 years	195 (60.75%)	136 (64.76%)
More than 5 years	119 (37.07%)	59 (28.10%)
<i>Research lab</i>		
Joined the research lab	313 (97.51%)	200 (95.24%)
Have a physical workspace	295 (91.90%)	192 (91.43%)
Have labmates	302 (94.08%)	193 (91.90%)
<i>Faculty advisor nationality</i>		
	137 (42.68%)	131 (62.38%)
<i>Previous foreign edu.</i>		
	46 (14.33%)	93 (44.29%)
<i>Years in the US</i>		
1 years of less		37 (17.62%)
2 - 4 years	N/A	102 (48.57%)
More than 5 years		71 (33.81%)

Note: 18.6% of participants did not provide complete demographic data. Faculty advisor nationality = having an international faculty advisor. Previous foreign edu. = previous educational experience in foreign countries. Years in the US = International students' years in the US (only for international students).

Analysis Approach – Exploratory Factor Analysis

Listwise Deletion. A total of 653 responses from 383 domestic students and 270 international students who provided complete response to at least one scale within the instrument were used for the EFA analysis. Missing data was handled using Little's test (Little, 1988), by scale, with the assumption that missing data for each of the three scales were missing completely at random (MCAR). Missing data were handled using listwise deletion after all missing data were determined to be MCAR (Little, 1988). The final sample size ranged between 341 (for the staff interaction scale) and 383 (for the faculty interaction scale) for domestic students, and between 221 (for the peer interaction scale) and 270 (for the faculty interaction scale) for international students. These sample sizes met the minimum criterion of at least five to ten respondents per item (McCoach et al., 2013) considering EFA analysis was run on each scale separately (item range between 13 and 30 per scale).

Exploratory Factor Analysis. First, the suitability for factoring of each scale was tested by conducting the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity. The KMO test result with scores above 0.8 and a significant test result ($p < 0.05$) on Bartlett's test of sphericity both support the use of factor analysis. The number of factors to extract for each scale was determined once factorability of the data was ensured using literature, theory, and three methods: parallel analysis, Kaiser method, and scree plot (McCoach et al., 2013). If the number of factors suggested by each method was inconsistent, the research team chose the number determined by parallel analysis – the current gold standard - considering the accuracy of parallel analysis to estimate the appropriate number

of factors to retain (Fabrigar et al., 1999). Factor extraction was then executed in IBM SPSS® 24 statistical software package using principal axis factoring (PAF), with a promax rotation technique (with kappa equal to 4) to account for possible correlations among factors in multi-factor scales (McCoach et al., 2013).

The EFA factor structure for each scale was revised until all items with loadings less than 0.6 and cross-loadings greater than 0.4 on multiple factors were removed from the structure (Hong et al., 2011).

Lastly, the internal consistency for each factor was evaluated using Cronbach's coefficient alpha, which indicates whether a set of items can be expected to load onto the same factor consistently (Cronbach, 1951). Cronbach's alpha values of 0.70 or higher are generally accepted in social science research, although alpha values of 0.80 and above are considered desirable (McCoach et al., 2013).

19.2 Limitation in Context

Two limitations associated with this study are described here to help understand the findings of this study. First, the data collection for this study was conducted during the COVID-19 pandemic in spring 2020. The survey aims to measure the quality and frequency of interpersonal interactions, which were physically absent for most engineering doctoral students at the point of survey distribution due to social distancing and further restrictions (e.g., campus closings and transitions to online educational settings). This potential for distortion in data due to the unique environment at the time of data collection was acknowledged by the research team as possibly impacting the study's findings. Efforts were made to reduce the potential impact on the data using the following strategies: 1)

instruction was provided that guided participants to assess their experiences prior to the COVID-19, and 2) participants were presented with an open-ended question at the end of the survey to describe how the COVID-19 pandemic has influenced their perceived quality of interactions and sense of belonging. The open-ended question in particular played a role as both an emotional outlet for students and another source of data to gauge students' perceived gaps in the quality or frequency of interactions or sense of belonging. This data was also used to assess the validity of the responses.

Second, the research team acknowledges the complexity and diversity that exists within each international and domestic student subgroup represented by the engineering doctoral student data. The results and discussion on 'international students' or 'domestic students' do not represent an individual international or domestic engineering doctoral student. Further investigations would need to be conducted to fully understand each group of students and the potential group-specific factors relating to interpersonal interaction and sense of belonging (e.g., cultural variations among international students or the underrepresented student status for domestic students) to obtain a fuller picture on this research topic.

19.3 Results: EFA Factor Structures

Overall, strong evidence of validity and reliability emerged from the EFA and internal consistency reliability analyses for each scale in the instrument. The results for both domestic and international student groups are summarized below, by scale. Tables 3 - 6 provide the final items and associated loadings, as well as the Cronbach's alpha of each scale for both international and domestic subgroups.

Table 6

Scale 1. Faculty Advisor Interaction

	Item	Factor loading
Domestic students (n = 383)		
<i>Academic interaction (Cronbach's alpha = 0.928)</i>		
1	My faculty advisor makes me feel like I can succeed in my program*	0.911
2	My faculty advisor demonstrates patience with me as I develop research skills*	0.796
3	My faculty advisor has praised my work*	0.769
4	My faculty advisor demonstrated patience with me as I transitioned into my doctoral program*	0.755
5	My faculty advisor encourages me to develop as an independent researcher*	0.706
6	My faculty advisor is generally friendly to me*	0.702
7	My faculty advisor is someone I feel comfortable talking to about academic topics (e.g., research or coursework)	0.701
8	My faculty advisor supports my professional development*	0.641
9	My faculty advisor speaks highly of my research to others*	0.627
<i>Non-academic, i.e., personal, social, or cultural interaction (Cronbach's alpha = 0.886)</i>		
10	My faculty advisor and I talk about non-academic topics (e.g., personal, social, or cultural)	0.897
11	My faculty advisor and I have often talked about our families	0.803
12	My faculty advisor is willing to listen to me talk about non-academic topics (e.g., personal, social, or cultural)	0.782
13	My faculty advisor regularly asks me how I am doing with my life*	0.681
14	My faculty advisor has showed me an interest in my cultural background(s)	0.663
15	My faculty advisor provides me with emotional support when I am experiencing stress*	0.653
<i>Faculty advisor's availability (Cronbach's alpha = 0.812)</i>		
16	My faculty advisor generally sets aside time to have individual research meetings with me	0.826
17	My faculty advisor is generally available to answer my questions regarding academic topics (e.g., research or coursework)	0.778
18	My faculty advisor generally keeps their scheduled meetings with me	0.707
International students (n = 270)		
<i>Academic interaction (Cronbach's alpha = 0.939)</i>		
1	My faculty advisor is generally available to answer my questions regarding academic topics (e.g., research or coursework)	0.870
2	My faculty advisor is willing to help me when I need support with my dissertation research*	0.837
3	My faculty advisor assists me in developing my research skills*	0.821
4	My faculty advisor provides me with guidance I need to make progress as a doctoral student*	0.817
5	My faculty advisor generally sets aside time to have individual research meetings with me	0.805
6	My faculty advisor generally keeps their scheduled meetings with me	0.797
7	My faculty advisor assists me in finding resources (e.g., materials, instruments, etc.) needed for my dissertation research*	0.713
8	My faculty advisor can see academic challenges I may encounter in my dissertation research*	0.707
9	My faculty advisor is someone I feel comfortable talking to about academic topics (e.g., research or coursework)	0.644
<i>Non-academic, i.e., personal, social, or cultural interaction (Cronbach's alpha = 0.885)</i>		
10	My faculty advisor and I talk about non-academic topics (e.g., personal, social, or cultural)	0.897
11	My faculty advisor and I have often talked about our families	0.803
12	My faculty advisor is willing to listen to me talk about non-academic topics (e.g., personal, social, or cultural)	0.782
13	My faculty advisor regularly asks me how I am doing with my life*	0.681
14	My faculty advisor has showed me an interest in my cultural background(s)	0.663
15	My faculty advisor provides me with emotional support when I am experiencing stress*	0.653

Note: *Items only retained for domestic and international subgroup, respectively.

Scale 1.1 Domestic students' interaction with a faculty advisor. Both the KMO test (score = 0.960) and Bartlett's test ($p = 0.000$) determined that the item correlation matrix for this scale was factorable. Results of the parallel analysis and the scree plot each suggested that a three-factor model should be extracted (Table 6). Factor 1 contains nine items related to students' academic interaction with their faculty advisor and Factor 2 includes six items associated with students' non-academic, i.e., personal, social, or cultural interaction. Three items that specifically represent the faculty advisor's availability clustered onto Factor 3 for domestic students. The Cronbach's alpha value for each factor is 0.928, 0.886, and 0.812, respectively, indicating a high internal consistency among the items.

Scale 1.2 International students' interaction with a faculty advisor. The factorability of the item correlation matrix for this scale was confirmed by the KMO test (score = 0.966) and Bartlett's test ($p = 0.000$). A two-factor structure was supported by the parallel analysis and the scree plot tests; this was also in accordance with the research team's hypothesized factor structure. The final two-factor solution consisted of nine items on Factor 1 that capture students' academic interaction with their faculty and six items on Factor 2, representing the students' non-academic, i.e., personal, social, or cultural interaction with their faculty advisor. The two factors had Cronbach's alpha values of 0.939 and 0.885, indicating a high internal consistency among both sets of items.

Table 7

Scale 2a. Peer Interaction

	Item	Factor loading
Domestic students' interaction with international peers (n = 358)		
<i>Academic and non-academic interaction (Cronbach's alpha = 0.939)</i>		
1	At least one of my peers is someone I consider to be a friend	0.902
2	At least one of my peers would provide me with emotional support when I am experiencing stress related to my dissertation	0.833
3	I feel comfortable talking to at least one of my peers about non-academic concerns (e.g., personal, social, or cultural)	0.829
4	At least one of my peers is someone who listens to me empathetically	0.824
5	My peers and I socialize enough to have meaningful interactions	0.777
6	At least one of my peers would be willing to help me if I needed non-academic help (e.g., personal, social, or cultural)	0.767
7	At least one of my peers and I talk about non-academic topics (e.g., personal, social, or cultural)	0.698
8	At least one of my peers is someone I feel comfortable working with on class assignments	0.696
9	I feel comfortable talking to at least one of my peers about academic concerns (e.g., research or coursework)	0.692
10	At least one of my peers and I have spent time together outside of school	0.656
11	At least one of my peers would be willing to study with me	0.647
<i>Culture-related problem behavior (Cronbach's alpha = 0.782)</i>		
10	None of my peers have demonstrated discrimination toward me due to my cultural background	0.797
11	None of my peers have expressed negative stereotypes regarding my cultural background(s)	0.768
12	My peers view me as an individual rather than a representative of my cultural background(s)	0.612
International students' interaction with domestic peers (n = 221)		
<i>Academic and non-academic interaction (Cronbach's alpha = 0.962)</i>		
1	At least one of my peers is someone who listens to me empathetically	0.845
2	At least one of my peers is someone I consider to be a friend	0.835
3	My peers and I socialize enough to have meaningful interactions	0.823
4	At least one of my peers and I talk about non-academic topics (e.g., personal, social, or cultural)	0.821
5	I feel comfortable talking to at least one of my peers about non-academic concerns (e.g., personal, social, or cultural)	0.819
6	At least one of my peers is someone I feel comfortable talking to about academic topics (e.g., research or coursework)	0.800
7	At least one of my peers would provide me with emotional support when I am experiencing stress related to my dissertation	0.790
8	At least one of my peers and I have spent time together outside of school	0.787
9	At least one of my peers would be willing to study with me	0.770
10	At least one of my peers is someone I feel comfortable working with on class assignments	0.761
11	My peers and I have plenty of opportunities to have academic discussions (e.g., research or coursework)	0.760
12	At least one of my peers has invited me to their home for social gatherings	0.734
13	I feel comfortable talking to at least one of my peers about academic concerns (e.g., research or coursework)	0.733
14	At least one of my peers would be willing to help me if I needed non-academic help (e.g., personal, social, or cultural)	0.727
15	At least one of my peers has praised my research	0.700
16	At least one of my peers would be willing to help me if I needed academic help (e.g., research or coursework)	0.637
17	At least one of my peers and I talk on a daily basis	0.627
<i>Culture-related problem behavior (Cronbach's alpha = 0.749)</i>		
18	None of my peers have demonstrated discrimination toward me due to my cultural background	0.797
19	None of my peers have expressed negative stereotypes regarding my cultural background(s)	0.768
20	My peers view me as an individual rather than a representative of my cultural background(s)	0.612

Note: *Items only retained for domestic and international subgroup, respectively.

Scale 2a.1 Domestic students' interaction with international peers. The KMO test (score = 0.944) and Bartlett's test ($p = 0.000$) supported the use of factor analysis. A two-factor structure was suggested by parallel analysis and the scree plot. The two resultant factors each had 11 and three items, respectively, and Factor 1 corresponds to the students' *academic interaction* with their international peers. However, among the preliminary set of items relevant to the students' non-academic, i.e., personal, social, or cultural interaction, only the items that measure the students' experiences related to the *culture-related problem behavior* were retained on Factor 2. The items for both factor structures had high internal consistency reliability, as indicated by a Cronbach's alpha value of 0.939 and 0.782, respectively.

Scale 2a.2 International students' interaction with domestic peers. The factorability of this scale was also demonstrated by KMO test (score = 0.958) and Bartlett's test ($p = 0.000$). For this scale, parallel analysis suggested one-dimensional factor structure whereas the other two examinations (i.e., Kaiser's criterion method and the scree plot) supported a two-factor structure. The research team decided to extract the two-factor structure supported by Kaiser's criterion method and the scree plot. The decision was grounded in the examination of evidences of reliability (i.e., item factor loadings and internal consistency reliability), the validity with which each scale appropriately represents the international students' interaction with domestic students based on the literature, and the purpose of the study. According to this examination, the one-factor structure suggested by parallel analysis fell short of capturing the comprehensive picture of the international doctoral students' interaction with domestic peers, capturing only the academic dimension

of student interaction and losing the personal / cultural / social interactions which have been shown in other studies to be important to sense of belonging (Brunsting et al. 2018; Glass & Westmont, 2013; Glass et al., 2015b; Lee et al., 2019; Yao et al., 2015). The resultant two-dimensional factor solution consists of a 17-item *academic interaction* factor and a three-item *culture-related problem behavior* factor. The factors showed a high and moderate internal consistency reliability, respectively, with Cronbach's alpha values of 0.962 and 0.749.

Table 8

Scale 2b. Peer Interaction

	Item	Factor loading
Domestic students' interaction with other domestic peers (n = 349)		
<i>Academic and non-academic interaction (Cronbach's alpha = 0.932)</i>		
1	At least one of my peers is someone I consider to be a friend	0.844
2	My peers and I socialize enough to have meaningful interactions	0.840
3	At least one of my peers would be willing to help me if I needed non-academic help (e.g., personal, social, or cultural)	0.822
4	I feel comfortable talking to at least one of my peers about non-academic concerns (e.g., personal, social, or cultural)	0.821
5	At least one of my peers is someone who listens to me empathetically	0.818
6	At least one of my peers would provide me with emotional support when I am experiencing stress related to my dissertation	0.783
7	At least one of my peers would be willing to study with me	0.707
8	My peers and I have plenty of opportunities to have academic discussions (e.g., research or coursework)	0.697
9	At least one of my peers and I talk on a daily basis	0.655
International students' interaction with other international peers (n = 240)		
<i>Academic and non-academic interaction (Cronbach's alpha = 0.959)</i>		
1	At least one of my peers is someone I feel comfortable talking to about academic topics (e.g., research or coursework)	0.821
2	At least one of my peers and I talk about non-academic topics (e.g., personal, social, or cultural)*	0.807
3	At least one of my peers is someone I consider to be a friend	0.803
4	At least one of my peers is someone who listens to me empathetically	0.798
5	At least one of my peers would be willing to help me if I needed academic help (e.g., research or coursework)*	0.795
6	I feel comfortable talking to at least one of my peers about non-academic concerns (e.g., personal, social, or cultural)	0.792
7	I feel comfortable talking to at least one of my peers about academic concerns (e.g., research or coursework)*	0.791
8	At least one of my peers is someone I feel comfortable working with on class assignments*	0.790
9	My peers and I socialize enough to have meaningful interactions	0.777
10	At least one of my peers would be willing to study with me	0.772
11	At least one of my peers would provide me with emotional support when I am experiencing stress related to my dissertation	0.771
12	At least one of my peers would be willing to help me if I needed non-academic help (e.g., personal, social, or cultural)	0.767
13	My peers are generally friendly to me*	0.764
14	My peers and I have plenty of opportunities to have academic discussions (e.g., research or coursework)	0.707
15	At least one of my peers has praised my research*	0.660
16	At least one of my peers has showed me an interest in my cultural background(s)*	0.651
17	At least one of my peers and I talk on a daily basis	0.649

Note: *Items only retained for domestic and international subgroup, respectively.

Scale 2b.1 Domestic students' peer interaction with domestic students. The KMO test (score = 0.944) and Bartlett's test ($p = 0.000$) illustrated that the item correlation matrix for this scale was factorable. Although a two-factor structure was suggested by parallel analysis and the scree plot, one of the resulting factors contained only two items, which will not support an appropriate evaluation of internal consistency (McCoach et al., 2013). A total of nine items from academic and non-academic dimensions loaded together in this one factor solution, capturing a broad range of interactions that encompass academic and non-academic dimensions. A high internal consistency reliability of the factor structure is represented by Cronbach's alpha value of 0.932.

Scale 2b.2 International students' peer interaction with other international students. Both the KMO test (score = 0.960) and Bartlett's test ($p = 0.000$) supported the use of factor analysis. A one-dimension factor structure was suggested by both parallel analysis and the scree plot. Similar to the resultant factor structure among domestic students, 17 items measuring either academic or non-academic interactions were randomly clustered on one factor. The factor had a high internal consistency reliability determined by Cronbach's alpha value of 0.959.

Table 9

Scale 3. Staff Interaction

	Item	Factor loading
Domestic students (n = 341)		
<i>Academic and non-academic interaction (Cronbach's alpha = 0.932)</i>		
1	Staff members at my institution generally listen to me empathetically	0.845
2	At least one staff member at my institution is a person I have sufficient access to when I need academic support (e.g., course selection, advisor selection, TA/RAship, etc.)	0.815
3	At least one staff member at my institution would be willing to help me if I needed non-academic support (e.g., personal, social, or cultural)	0.814
4	At least one staff member at my institution is someone I can reach out to when I need non-academic support (e.g., social, personal, or cultural)	0.775
5	Staff members at my institution are generally friendly to me*	0.758
6	Staff members at my institution generally welcomed me when I began my doctoral program	0.755
7	At least one staff member at my institution would be willing to help me if I needed academic support (e.g., course selection, advisor selection, TA/RAship, etc.)	0.744
8	At least one staff member at my institution helped me when I needed non-academic support (e.g., personal, social, or cultural) as I transitioned into my doctoral program	0.713
9	Staff members at my institution view me as an individual rather than a representative of my cultural background(s)	0.679
10	Staff members at my institution are familiar with non-academic resources (e.g., personal, social, or cultural) relevant to my citizenship (e.g., US citizen or F1 visa holders)	0.65
11	At least one staff member at my institution helped me with my academic transition into my doctoral program (e.g., research or coursework)*	0.644
International students (n = 234)		
<i>Academic and non-academic interaction (Cronbach's alpha = 0.918)</i>		
1	At least one staff member at my institution would be willing to help me if I needed non-academic support (e.g., personal, social, or cultural)	0.792
2	Staff members at my institution generally listen to me empathetically	0.768
3	At least one staff member at my institution is someone I can reach out to when I need non-academic support (e.g., social, personal, or cultural)	0.753
4	At least one staff member at my institution is a person I have sufficient access to when I need academic support (e.g., course selection, advisor selection)	0.741
5	Staff members at my institution are familiar with non-academic resources (e.g., personal, social, or cultural) relevant to my citizenship (e.g., US citizen or F1)	0.740
6	Staff members at my institution view me as an individual rather than a representative of my cultural background(s)	0.734
7	At least one staff member at my institution would be willing to help me if I needed academic support (e.g., course selection, advisor selection, TA/RAship, etc.)	0.719
8	Staff members at my institution are familiar with academic resources relevant to my citizenship (e.g., US citizen or F1 visa holders)*	0.690
9	At least one staff member at my institution helped me when I needed non-academic support (e.g., personal, social, or cultural) as I transitioned into my doctoral	0.688
10	Staff members at my institution generally welcomed me	0.655

Note: *Items only retained for domestic and international subgroup, respectively.

Scale 3.1 Domestic students' interaction with staff. The appropriateness of the use of factor analysis was determined by KMO test (score = 0.912) and Bartlett's test ($p = 0.000$). A unidimensional factor structure was extracted following the results of parallel analysis, and 11 items were retained. The factor had a high internal consistency reliability represented by a Cronbach's alpha value of 0.932. The items capture diverse dimensions (i.e., academic, personal, social, or cultural dimensions) of the students' interaction with staff members in their academic unit.

Scale 3.2 International students' interaction with staff. Results of the KMO test (score = 0.892) and Bartlett's test ($p = 0.000$) confirmed the factorability of the item correlation matrix for this scale. Parallel analysis suggested to extract a unidimensional factor structure, and the resultant factor contains ten items that measure the students' interaction with staff members associated with academic, personal, or cultural dimensions, similar to the final factor solution for domestic students. Factor loadings ranged from 0.655 to 0.792 with a Cronbach's alpha value of 0.918, indicating a high internal consistency reliability among the items in this scale.

Sense of belonging scale. All three original items were retained on a unidimensional factor structure for both international and domestic students. The factorability of the scale was determined by KMO test (International: score = 0.748 / Domestic: score = 0.751) and Bartlett's test (International: $p = 0.000$ / Domestic: $p = 0.000$) and parallel analysis suggested a unidimensional factor structure for each group. Factor

loadings ranged from 0.866 to 0.838 for international students and from 0.873 to 0.951 for domestic students with a Cronbach's alpha value of 0.888 and 0.929, respectively.

20. PART II. REGRESSION ANALYSIS

Data collected using the EDQI was then examined using two different regression analyses (sequential and multiple linear) to explore the influence of the quality and quantity of interactions as well as other student characteristics on students' sense of belonging. The information on the examination process will be provided in the following subsections, which provide details pertaining to methods, results, and models. IBM SPSS® 24 was used to impute missing data and to conduct further analyses, including multiple linear regression and *t*-test analyses.

20.1 Methods

Participants and Data Collection

The Part 2 sample comprised of 531 of the engineering doctoral students (210 international and 321 domestic) at R1 universities in the US who completed the entire EDQI, sense of belonging, and demographic survey packet described in Part 1 (Table 2). To be noted is that not all participants included in Part 1 were included in Part 2 because of incomplete responses.

Measures and Variables

The dependent variable for this multiple linear regression is *Sense of belonging*. The independent variables include four *Frequency of interaction* variables (with a faculty advisor, international and domestic peers, and staff, separately), four *Quality of interaction* variables (with a faculty advisor, international and domestic peers, and staff, separately)

and *Student characteristic* variables (nine variables for domestic subgroup and ten variables for international subgroup). Variables were obtained through the EDQI consisting of five scales measuring *Sense of belonging* and *Quality of interactions* variables, four individual items assessing *Frequency of interaction* variables, and a demographic survey for *Student characteristic* variables.

Sense of belonging. Students' perceived *Sense of belonging* was measured by adopting a three-item scale from Bollen and Hoyle (1990) measuring the students' sense of belonging for undergraduate students. All three items were modified for contextualization considering the differences in reference groups of belonging at depending on the level of education (see *1.2 Participant Recruitment and Data Collection Procedure* and *3 Results: EFA Factor Structures in Part 1*).

Frequency + Quality of interaction. Students' perceive *Frequency* and *Quality of interaction* with a faculty advisor, international and domestic peers, and staff were measured by the EDQI. The survey includes four individual items to ask *Frequency of interaction* and a set of scales that ask *quality of interaction* with a faculty advisor, international and domestic peers, and staff (see *1.1 Instrument development and content validity* and *3 Results: EFA Factor Structures in Part 1*).

Student characteristic variables. A total of ten variables were selected, which included *Institution type* (public or private), *Years in program*, *Previous foreign education* (previous educational experiences in countries other than the participant's home country),

Faculty advisor nationality (international or domestic), and *Membership in a research lab*, including having a *Workspace* and/or *Labmates*. Participants' *Gender* and *Age* were also included as variables. An additional variable for international students only was included to capture *Years in the US*. Some variables, such as *Institution type*, *Faculty advisor nationality* (international or domestic), *Gender*, *Age*, and *Years in the US* as they were documented as factors influencing international students' experience (Migration Policy Institute, 2017; McCormack, 2007) Other variables, such as *Previous foreign education*, *Faculty advisor nationality*, *Membership in a research lab*, *Workspace* and *Labmates* were selected considering their potential influence on the students' multicultural interactions or lab-based peer interactions. Participants' race and ethnicity was not included as a variable due to the limited number of independent variables that the research team could use in regression analysis in relation to the number of responses. Student characteristic variables include seven categorical variables, which were dummy-coded to convert into quantitative, dichotomous variables. Table 10 provides information on the reference and other group for the dummy coded student characteristic variables.

Table 10

Dummy-coded Student Characteristic Variables

<i>Student characteristic variables</i>		
Categorical variable	Reference group	Other group
Institution type	Public	Private
Previous foreign edu.	Yes	No
Faculty advisor nationality	Yes	No
Membership in a research lab	Yes	No
Workspace	Yes	No
Labmates	Yes	No
Gender	Female	Male

Analysis Approach

Multiple imputation. Among 531 responses used for Part 2, 7.3% of participants had at least one item with missing data. Multiple imputation was conducted to handle the missing data for the regression analyses. Little's test (Little, 1988) was used to test the assumption that missing data for each of the scales were missing completely at random (MCAR) and any missing Likert-scale items were imputed. The multiple imputation model included all independent and dependent variables. Ten imputed data sets were created for this multiple imputation using the multivariate normal distribution method following White et al.'s (2011) suggestion, "rule of thumb that the number of imputations should be at least equal to the percentage of incomplete cases" (p. 388).

Descriptive statistics and t-test. Independent sample *t*-tests were conducted to examine whether the differences in the descriptive statistics results between international and domestic student subgroups are statistically different. Those descriptive statistics were conducted to assess the mean differences in students' *Sense of belonging*, *Quality of interaction*, and *Frequency of interaction* variables between international and domestic student subgroups.

Multiple linear regression. Two regression analyses were conducted. First, a sequential multiple linear regression was conducted to examine the influence of the following groups of independent variables on *Sense of belonging*, *Frequency of interaction*, *Quality of interaction*, and *Student characteristics*. Next, a multiple linear regression with a forward selection procedure was conducted to find the fitted model that best predicts

Sense of belonging. Each analysis was conducted for international and domestic student subgroups separately. The results from each subgroup were compared.

Sequential regression analysis is the theoretically preferred method as the independent variables are entered into the model in a theoretical order (Kim, n.d.). This study is grounded in the '*Belongingness hypothesis* (Baumeister and Leary's, 1995)', which theorizes positive and meaningful interpersonal interactions as contributors to sense of belonging. Based on this theory, the research team was interested in whether *Quality of interaction* variables explain a statistically significant amount of variance in *Sense of belonging* while accounting for all other variables in our sample. Three sets of sequential regression models were created as follows:

- Model 1: Sense of belonging = Constant + Frequency of interaction
- Model 2: Sense of belonging = Constant + Frequency of interaction
+ Quality of interaction
- Model 3: Sense of belonging = Constant + Frequency of interaction
+ Quality of interaction
+ Student characteristic

The variance explained was examined at every entry point to determine whether a set of newly added variables showed a significant change in the R-squared value. This sequential regression analysis was conducted to help determine which sets of variables (e.g., *Quality of interaction*, *Frequency of interaction*, and *Student characteristic* variables) have statistically significant effect to *Sense of belonging*. Multiple linear regression analysis was then conducted for each subgroup to determine which specific variables among all independent variables were statistically significantly influencing sense of belonging. A

data-driven order, i.e., forward selection procedure, for entering independent variables was used for the multiple linear regression analysis.

Assumptions of multiple linear regression (e.g., homoscedasticity, normality of residuals, and linearity) were tested prior to conducting the regression analyses. Scatter plots, histogram, and a bivariate correlation matrix were used to determine if these assumptions were met. Variance inflation factors (VIF) were also calculated to detect multicollinearity. For all the final regression models, there were no multicollinearity issues as all VIF coefficients were below the cut-off value of 10 (Hair et al., 2009).

20.2 Descriptive Statistics and *t*-test Results

Table 11 presents the independent sample *t*-test results between international and domestic subgroups, for the dependent variable, *Sense of belonging*, four independent *Frequency of interaction* variables, and four independent *Quality of interaction* variables. These *t*-tests showed that the international students had a higher perceived *Sense of belonging* than domestic students ($p < 0.001$), contrasting to findings from existing literature in the context of undergraduate, non-engineering-specific disciplines (Glass et al., 2015; Van Horne et al., 2018; Singh, 2018). There were statistically significant differences in *the Frequency of interaction* with domestic peers ($p < 0.05$) and staff members ($p < 0.05$); in both cases, domestic students reported higher frequency of interaction with each group compared to their international counterparts. Similarly, domestic students reported significantly higher scores for perceived *Quality of interaction* with other domestic peers ($p < 0.001$) and staff members ($p < 0.05$). An interesting, yet statistically not significant finding was that, international students reported a higher perceived *Quality of interaction*

with a faculty advisor than their domestic counterparts, while the mean scores for other *Quality of interaction* variables were lower than domestic students.

Table 11

Descriptive Statistics and t-test Results

	Domestic student (n=210)		International student (n=210)		t-test
	M	SD	M	SD	
Sense of belonging	3.794	0.967	3.954	0.787	1.998**
Frequency of interaction					
Faculty advisor	3.826	1.432	3.657	1.340	-1.359
Peers (Domestic)	4.514	0.818	4.033	1.018	-6.001**
Peers (Int'l)	4.343	0.922	4.376	0.878	0.417
Staff	3.196	0.920	2.995	0.8156	-2.574**
Quality of interaction					
Faculty advisor	3.911	0.757	3.985	0.767	1.090
Peers (Domestic)	4.310	0.772	3.876	0.840	-6.111***
Peers (Int'l)	4.254	0.698	4.193	0.750	-0.961
Staff	4.115	0.685	3.971	0.719	-2.311**

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$.

20.3 Regression Models

Bivariate correlation. Table 12 displays the correlations for the continuous variables for both international and domestic students. All bivariate correlation coefficients for both subgroups were less than 0.70, indicating the constructs of each independent variable did not overlap with one another at a problematic level (Meyers, Gamst, & Guarino, 2006). For both international and domestic students, all independent variables had statistically significant correlations with the dependent variable except one, *Frequency of interaction* with faculty advisor for international students. The correlation results showed that having high frequencies and qualities of interaction with

international/domestic peers and staff was positively correlated with the likelihood of having a sense of belonging regardless of student citizenship. *Quality of interaction* with faculty advisor variables also showed significantly positive correlations with the *Sense of belonging* variable for all students, while demonstrating a significantly negative correlation between *Frequency of interaction* with *Sense of belonging* variables for domestic students. Negative correlations were also observed between *Sense of belonging*, and three continuous *Student characteristic* variables: *Age*, *Year in program*, and *Year in the US* (International students only), for all students.

Table 12

Bivariate Correlation between Dependent and Independent Variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12
Domestic students												
1. Sense of belonging	1											
2. Frequency (Faculty advisor)	.039	1										
3. Frequency (Int'l peers)	.373**	-.066	1									
4. Frequency (Domestic peers)	.372**	-.171**	.499**	1								
5. Frequency (Staff)	.457**	-.064	.234**	.189**	1							
6. Quality (Faculty advisor)	.468**	-.153**	0.101	.118*	.150**	1						
7. Quality (Int'l peers)	.547**	-.031	.507**	.306**	.139*	.154**	1					
8. Quality (Domestic peers)	.600**	-.124*	.275**	.556**	.220**	.163**	.534**	1				
9. Quality (Staff)	.248**	-.039	.153**	.146**	.403**	.327**	.307**	.225**	1			
10. Age	-0.102	.168**	-.130*	-.315**	-.121*	-.047	-.179**	-.349**	-0.055	1		
12. Year in program	-0.113	.171**	-.011	-.166**	-.158**	-.170**	-0.045	-0.105	-0.103	.454**	1	
International students												
1. Sense of belonging	1											N/A
2. Frequency (Faculty advisor)	-.170**	1										N/A
3. Frequency (Int'l peers)	.260**	.029	1									N/A
4. Frequency (Domestic peers)	.350**	.093	.441**	1								N/A
5. Frequency (Staff)	.259**	.007	.283**	.248**	1							N/A
6. Quality (Faculty advisor)	.375**	-.127	.137*	.166*	.075	1						N/A
7. Quality (Int'l peers)	.447**	.050	.583**	.296**	.209**	.293**	1					N/A
8. Quality (Domestic peers)	.482**	.025	.324**	.634**	.211**	.283**	.576**	1				N/A
9. Quality (Staff)	.448**	-.043	.264**	.269**	.304**	.324**	.531**	.529**	1			N/A
10. Age	-.178**	-.02	-.206**	-.268**	-.051	-.082	-.034	-.197**	-.115	1		N/A
11. Year in program	-.224**	-.006	-.025	-.133	-.172*	-.219**	.086	-.051	-0.02	.323**	1	N/A
12. Year in the US (1 only)	-.153*	.052	-.08	-.146*	-.035	-.137*	.004	-.051	-0.035	.309**	.483**	1

* $p < 0.1$; ** $p < 0.005$; *** $p < 0.001$.

Multiple linear regression models. Table 13 shows the results of sequential regression models to predict *Sense of belonging* for international and domestic student subgroups.

Table 13

Results of Sequential Linear Regression Models for Sense of Belonging

Variables	Domestic student			International student			
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 3.2
	β			β			
Constant	1.719***	-1.331***	-1.331*	1.921***	-0.128	-0.128	-0.425
Frequency of interaction							
Faculty advisor	-0.074*	-0.053	-0.045	0.006	0.037	0.035	0.037
Peers (Domestic)	0.302***	0.111	0.121	0.184***	-0.04	-0.056	0.099
Peers (Int'l)	0.087	-0.019	-0.033	0.209***	0.097	0.098	0.061
Staff	0.193***	0.036	0.036	0.118	0.079	0.082	0.085
Quality of interaction							
Faculty		0.258***	0.232***		0.305***	0.291***	0.292***
Peers (Domestic)		0.284***	0.285***		0.365*	0.381*	0.389
Peers (Int'l)		0.267***	0.262**		0.153***	0.150***	0.143***
Staff		0.345***	0.335***		0.044	0.051	0.048
Student characteristics							
Institution type			-0.081			0.108	0.114
Year in program			-0.071**			-0.014	0.001
Foreign/US edu.			0.076			-0.157*	-0.097
Advisor-international			0.107			-0.083	-0.088
Lab			-0.111			0.117	0.157
Workspace			0.188			-0.132	-0.123
Labmate			-0.049			0.118	0.110
Gender			0.08			-0.101	-0.083
Age			0.016			0.01	0.012
Year in the US (I only)			-			-	-0.025
Adj. R ²	0.166	0.417	0.424	0.191	0.496	0.496	0.495
Adj. Δ R ²	-	0.251	0.007	-	0.305	0.000	-0.001
F test	16.966** *	29.587***	14.790** *	13.342***	26.676** *	13.035***	12.347***

Note: All terms are unstandardized regression coefficients. Foreign/US edu. = previous educational experience in foreign countries (for domestic students) previous educational experience in US (for international students). Adj. R² = adjusted R-squared, Adj. Δ R² = change in adjusted R-squared. F test is conducted to evaluate significance in change in adjusted R-squared after the addition of new set of variables. * $p < 0.1$; ** $p < 0.005$; *** $p < 0.001$.

Model 1 included all four *Frequency of interaction* variables as predictors. This model was significant for both subgroups ($F = 13.342$, $p < 0.001$, $R^2 = 0.191$ for international students and $F = 16.966$, $p < 0.001$, $R^2 = 0.166$ for domestic students). In Model 2, all four *Quality of interaction* variables were added. The change in explained variance with this step was statistically significant for both subgroups. For international students, 30.5% out of 49.6% of the variance of the students' perceived *Sense of belonging* was explained by *Quality of interaction* variables ($F = 26.676$, $p < 0.001$). Similarly, for domestic students, an additional 25.1% of variance was explained by the addition of *Quality of interaction* variables ($F = 29.587$, $p < 0.001$). These results provide strong empirical evidence to support the '*Belongingness hypothesis* (Baumeister and Leary's, 1995)', which argues the significance of having positive, meaningful, and quality interactions with members of a community in order to develop a sense of belonging to that community. Model 3 added nine *student characteristic* variables and resulted in another statistically significant change that did not produce a significant change in R^2 for either international ($F = 13.305$, $p < 0.001$, $\Delta R^2 = 0.000$) or domestic students ($F = 14.790$, $p < 0.001$, $\Delta R^2 = 0.007$). Finally, for the international student subgroup only, Model 3.2 was generated to examine the effects of the addition of *Years in US* variable, which is a *Student characteristic* variable only applicable to international students. Similar to Model 3, Model 3.2 did not generate a significant change in R^2 after the addition of new set of variables ($F = 12.347$, $p < 0.001$, $\Delta R^2 = -0.001$).

Table 14

Forward regression models for Sense of belonging

Variables	Domestic student	Variables	International student
	β		β
Quality of interaction			
Constant	-0.997*	Constant	0.498*
Faculty advisor	0.251***	Faculty advisor	0.282***
Peers (Domestic)	0.361***	Peers (Domestic)	0.348***
Peers (Int'l)	0.245***	Peers (Int'l)	0.265***
Staff	0.358***	Staff	-
Student characteristic variables			
Year in program	-0.065**	Year in the US	-0.034*
Adj. R ²	0.426	Adj. R ²	0.495
F test	48.277***	F test	52.249***

* $p < 0.1$; ** $p < 0.005$; *** $p < 0.001$.

The purpose of the sequential regression analysis is to determine the influence collectively made by the *Quality of interaction* (with a faculty advisor, international peers, domestic peers, and staff) variable in predicting *Sense of belonging*. A follow-up step taken was to discuss the effects of individual predictors for each subgroup using a forward selection procedure. Table 14 summarizes these final regression models for each student subgroup that resulted from multiple linear regressions with a forward selection procedure.

For domestic students, the regression model to predict *Sense of belonging* consisted of five of the 17 independent variables. The prediction equation of the final emergent model is:

$$\begin{aligned}
 \text{Sense of belonging} = & -0.997 + 0.361 (\text{Quality of interaction with domestic peers}) \\
 & + 0.358 (\text{Quality of interaction with staff}) \\
 & + 0.251 (\text{Quality of interaction with a faculty advisor}) \\
 & + 0.245 (\text{Quality of interaction with international peers}) \\
 & - 0.034 (\text{Year in program})
 \end{aligned}$$

This model resulted in a $R^2 = 0.426$ ($F = 48.277$, $p < 0.001$), indicating that the model has a strong predictive power. All four *Quality of interaction* variables were significant positive predictors of *Sense of belonging* in this model whereas all four *Frequency of interaction* variables were not included in the model. *Years in program*, which is the only *Student characteristic variable* that ended up in the final model, negatively predicted *Sense of belonging*, but aligned with previous literature (Bhochhibhoya et al., 2017; Wong et al., 2014) For statistical inference, the most significant predictor of *Sense of belonging* among domestic students was the *Quality of interaction* with other domestic peers ($\beta = 0.361$, $p < 0.001$). The *Quality of interaction* with staff was the second significant predictor with a coefficient value of 0.358, which is higher than those for a faculty advisor ($\beta = 0.251$, $p < 0.001$) and international peers ($\beta = 0.245$, $p < 0.001$).

For international students, the model for predicting the students' perceived *Sense of belonging* consists of four of the 18 independent variables (including the international-specific variable, *Year in US*). The prediction equation of the final emergent model is:

$$\begin{aligned}
 \text{Sense of belonging} = & 0.498 + 0.348 (\text{Quality of interaction with domestic peers}) \\
 & + 0.282 (\text{Quality of interaction with a faculty advisor}) \\
 & + 0.265 (\text{Quality of interaction with international peers}) \\
 & - 0.065 (\text{Year in the US})
 \end{aligned}$$

The model showed a strong predictive power as it explained 49.5% of a total variance of *Sense of belonging* ($F = 52.249$, $p < 0.001$). Contrary to the regression model for the domestic students, the *Quality of interaction* with staff variable was not included as a predictor in this model. The predictor of *Sense of belonging* with the highest coefficient value was the students' perceived *quality of interaction* with domestic peer ($\beta = 0.348$, p

< 0.001), which was higher than those for the faculty advisor and other international peers.

The only *Student characteristic* variable that predicted the international students' perceived *Sense of belonging* was the students' *Year in the US*, which was a negative predictor.

21. DISCUSSIONS, IMPLICATIONS, AND FUTURE WORK

Part I. An EFA analysis of the four *Quality of interaction* scales (e.g., faculty advisor, international and domestic peers, and staff interaction) using the same set of preliminary items, for different subgroups of international and domestic peers was conducted. The developed instrument was supported by appropriate validity and reliability evidence, and so should be of use to other researchers interested in studying engineering doctoral students or doctoral students in other multicultural educational settings.

The findings of the EFA showed differences between the domestic and international student groups, underscoring the importance of gathering empirical evidence to support potentially different factor structures for different sub-populations. Specifically, there were differences in factor structures on the *Faculty advisor interaction* scale, and different items retained for the *Peer interaction* and *Staff interaction* scales. These findings support the recent arguments to consider demographic attributes in studies of student interaction and sense of belonging (Curtin et al., 2013; Gardner et al., 2014; Twale et al., 2016). A culture-related factor - *A culture-related problem behavior* factor emerged for both groups despite the differences in EFA results between domestic and international students. The presence of this factor in both domestic and international students suggests that the effect of diversity in citizenship and associated linguistic and cultural differences impacts (Twale et al., 2016) not only international students, but domestic students as well.

Part II. The results of the regression analyses contain valuable information about the significant role of interpersonal interactions to student sense of belonging, and the associated impact from the students' interaction with different groups. First, the sequential regression analysis results provided empirical evidence supporting the '*Belongingness*

hypothesis (Baumeister and Leary's, 1995)' for both domestic and international student groups. The results confirmed the predictability of *Sense of belonging* from the variables on students' perceived *Quality of interactions* for both subgroups. This finding provides insights that should assist in developing support structures for engineering doctoral students' sense of belonging regardless of their citizenship status by providing an understanding 'what' to support. Developing social supports as facilitators of sense of belonging is a clear potential next step for academic programs given the recent literature outlining that there are fewer facilitators of sense of belonging within STEM doctoral program environments than in non-STEM programs (O'Meara et al., 2017).

The multiple regression analysis results also have the potential to provide insight on identifying the groups of people who make significant impact on students' sense of belonging for each subgroup. For example, the most significant predictor of student *Sense of belonging* among international students was the *Quality of interaction* with domestic peers variable, aligning with the previous findings about the positive impacts of having meaningful peer interaction with domestic students on international students' sense of belonging (Brunsting et al., 2018; Glass et al., 2015; Hendrickson et al., 2011). The mean score for the international students' *Quality of interaction* with domestic peers was the lowest among the four *Quality of interaction* variables (see Table 8), which diagnoses the current problem that possibly hinders the development of sense of belonging among international engineering doctoral students. The implication of these findings may include developing support structures for international students that are structured to encourage authentic interpersonal interactions between international and domestic students.

For domestic students, having a *Quality interaction* with staff members showed the second most significant positive influence on their sense of belonging. Its coefficient value was even higher than that of the faculty interaction quality even though the mean score for the domestic students' frequency of interaction with staff members was the lowest among the four *Frequency of interaction* variables., More attention to understand the majority domestic students' interaction with staff are suggested considering that the staff interaction component was only emphasized in the sense of belonging literature among international students or domestic, underrepresented students (Lee et al., 2019; Fisher et al., 2019). Implications from these findings include further investigations on the reason why and how the staff interaction plays a bigger role than people with whom they interact with more frequently (e.g., a faculty advisor or international peers). Although statistically not significant, for domestic students, the *Frequency of interaction* with a faculty advisor as a negative predictor of *Sense of belonging* and the lowest mean value for their *Quality of interaction* with a faculty advisor should also be taken into consideration for any future support structure development.

Neither the *Frequency* nor *Quality of interaction* with staff variable was included in the final regression model for international students (Table 14). This result misaligns with the findings of the qualitative research from Part 1 on the conceptualization of the international students' sense of belonging (Lee et al., 2018). According to Lee et al., 2018, staff interactions emerged in association with institutional support, one construct of sense of belonging among international students. The majority of this study's participants described their interactions with staff as positive and regarded them to have positive contributions to their sense of belonging, which contradicted the current findings. Further

investigation is necessary to clarify what aspects of staff interactions with international students were perceived positively considering that interactions with staff are critical in the receipt of institutional support from the students' perspective. For example, is actual quality of interaction with staff or the institutional supports they receive through having interactions with staff more important to their sense of belonging?

Lastly, only one *Student Characteristic* variable was included in the final regression model for each student group, *Year in the US* for international students and *Year in program* for domestic students. Both variables were negative predictors of student sense of belonging, which align with findings from previous literature. The length of residence in the US (*Year in the US*) among undergraduate international students is known to have negative impacts on their psychological adjustment to the US. For example, *Year in the US* predicted increased homesickness (Tochkov et al., 2010), psychological distress (Wong et al., 2014), and negative affect (Bhochibhoya et al., 2017). Also, doctoral students' years in their doctoral study (*Year in program*) and the related funding issues (Ehrenberg, 1992) are considered to have negative impact on students' satisfaction, persistence intention (Van Rooij et al., 2019), and completion probability (Ehrenberg, 1992). Our findings (e.g., negative influence of *Year in program* on students' *Sense of belonging* among domestic students) support the current arguments that understanding the factors influencing doctoral students' sense of belonging can help improve student retention (O'Meara et al., 2017). The implications of these findings taken together may include further discussion on the appropriate time it takes for individuals to receive their doctorate in engineering, which currently averages 5.3 years (NSF, 2018).

The findings of this research indicate the significance of acknowledging and considering the role that the diversity in students' citizenship plays in studying the engineering doctoral students' experiences, including their interpersonal interactions and sense of belonging. Most previous studies on engineering students sense of belonging at all levels has investigated international or domestic students independently (Glass & Westmont, 2013). The comparative analysis results of this study have potential to broaden the breadth of knowledge on the study's population. Additional quantitative research that addresses the limitations of this study (e.g., sub-grouping of international students per their cultural backgrounds or underrepresented students among domestic students) will provide added value about this population. Lastly, further qualitative research that addresses the questions that emerged in this study (e.g., a bigger influence of interaction with domestic peers and staff on the sense of belonging of international and domestic students, respectively) for each of domestic and international student populations are suggested to understand the reasons behind these quantitative results.

22. CHAPTER V. CONCLUSION

This dissertation research explored the concept of a 'sense of belonging' among engineering doctoral students focusing on the perspective of international students. This study used a multi-phase mixed methods research approach to: 1) explore international engineering doctoral students' sense of belonging and the dynamics of multicultural interactions among different groups of people (CHAPTER II), 2) conceptualize sense of belonging from the international engineering doctoral students' perspective (CHAPTER II), and 3) separately investigate the factors contributing to students' sense of belonging for international and domestic engineering doctoral students (CHAPTER IV). Conceptual understandings on the constructs/defining components of students' sense of belonging in higher education gained by a literature review (CHAPTER III) helped elaborate on the conceptual structure of sense of belonging developed in CHAPTER II.

The findings of this dissertation research included developing a multifaceted concept of 'sense of belonging' for international students in the context of engineering doctoral education. The qualitative findings from CHAPTER II suggest a significant influence of students' interpersonal interactions with a faculty advisor, peers, and staff on their perceived sense of belonging among international engineering doctoral students. These findings were supported and understood in detail through the quantitative findings from CHAPTER IV. Among the frequency and quality of interaction (e.g., a faculty advisor, international and domestic peers, and staff) variables, only the quality of interaction variables statistically significantly influenced students' sense of belonging. In addition, using a comparative analysis between international and domestic students (CHAPTER IV) extended the understanding of how the dynamics of interaction among

different groups of people varied by the students' citizenship (e.g., international or domestic). The findings of this dissertation research collectively indicate the significance of acknowledging and considering the role that the diversity in students' citizenship plays in studying engineering doctoral students' experiences, including their interpersonal interactions and sense of belonging.

The implications of these findings include developing support structures for doctoral students that take into consideration the factors that have positive or negative impacts on students' sense of belonging, which are different for international and domestic students. Examples of such support structures might include developing social opportunities for international students that are structured to encourage authentic interpersonal interactions between international and domestic students and conducting further investigations on domestic students' relatively lower quality of interaction with their faculty advisor.

Future research may also address the limitations of this study (e.g., sub-grouping of international students per their cultural backgrounds or underrepresented students among domestic students) or questions that emerged from this study (e.g., greater influence of interaction with domestic peers and staff on the sense of belonging of international and domestic students, respectively) for domestic and international student populations. Finally, another direction of future research may include the development of an instrument to measure international and domestic students' sense of belonging based on the conceptual structure of sense of belonging developed in this dissertation research.

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APPENDIX A

CHAPTER II: IRB APPROVAL LETTER



EXEMPTION GRANTED

Jennifer Bekki
 Polytechnic Engineering Programs (EGR)
 480/727-5127
 jennifer.bekki@asu.edu

Dear Jennifer Bekki:

On 8/20/2018 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Qualitative interview research to understand international students' sense of belonging and peer/faculty interactions.
Investigator:	Jennifer Bekki
IRB ID:	STUDY00008654
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	<ul style="list-style-type: none"> • Demographic _ Background Survey_Submitted.pdf, Category: Screening forms; • Interview protocol_submitted.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • IRB application_revised 081718.doc, Category: IRB Protocol; • RecruitmentLetter_ProgramChairs_Submitted.pdf, Category: Recruitment Materials; • Consent form_revised 081718.pdf, Category: Consent Form; • EligibilityLetters_submitted 081418.pdf, Category: Recruitment materials/advertisements /verbal scripts/phone scripts;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 8/20/2018.

APPENDIX B

CHAPTER II: RECRUITMENT LETTER

RECRUITMENT LETTER

Dear [],

I am a doctoral student in the Engineering Education Systems and Design PhD program at Arizona State University. I am working with Drs. Jennifer Bekki, Adam Carberry, and Nadia Kellam on a research project designed to increase our understanding about the experiences of international students in engineering Ph.D. programs. This letter is an invitation for international doctoral students in your program to participate in an interview as part of this study.

We are currently recruiting international F1 Visa students in engineering Ph.D. programs at multiple universities to participate. Study participants will be asked to complete a brief survey that we expect to take approximately 5 minutes and participate in an (in-person or Skype/Zoom) interview that will last no more than 90 minutes. Participation in this study is confidential and voluntary.

With this letter, we request that you please:

1. Forward the recruitment email below to international doctoral students in your department.
2. Copy me (elee78@asu.edu) on your email when you distribute it. This will help as part of our record keeping on the project.

This study has been approved by the Arizona State University Institutional Review Board (protocol number: STUDY00008654). For further information regarding this research, please feel free to contact Eunsil Lee at elee78@asu.edu or Dr. Jennifer Bekki at jennifer.bekki@asu.edu, Dr. Adam Carberry at adam.carberry@asu.edu, Dr. Nadia Kellam at nadia.kellam@asu.edu.

Thank you in advance for distributing the recruitment email!

Sincerely,

Eunsil Lee
elee78@asu.edu
PhD student
Ira A. Fulton Schools of Engineering
Arizona State University

Dear Doctoral Student,

I am a doctoral student in the Engineering Education Systems and Design PhD program at Arizona State University. Our research team previously distributed the same survey, but unfortunately, we found out that a contact information question was missing from that survey. My apologies for this inconvenience. However, because many students expressed their interest in our research and we did not want to miss their valuable experiences, we decided to ask you for participating in the survey again especially if you previously participated in the survey. I do appreciate for sharing some of your time again, and we look forward to hearing about your stories.

Our research team is currently conducting a study to increase our understanding about the experiences of international students in engineering Ph.D. programs, and we would like to invite your participation. In order to participate in this study, you must be currently enrolled in a Ph.D. program in engineering as an international F1 Visa student.

Study participants will be asked to complete a brief survey that we expect to take approximately 5 minutes and to participate in an (in-person or Skype/Zoom) interview that will last no more than 90-minutes. If you are interested in participating, please fill out the screening/demographic survey (the link below). Once you express your interest in participation, a member of the research team will communicate with you about the eligibility of interview participation according to the information you provided through the survey. Participants who complete the interview will receive a \$20 Amazon gift card as a courtesy of participation.

To participate, please click on the following link:

[https://asuengineering.co1.qualtrics.com/jfe/form/SV_9Yo2caxumPPrMah]

This study has been approved by the Arizona State University Institutional Review Board (protocol number: STUDY00008654). For further information regarding this research, please feel free to contact Eunsil Lee at elee78@asu.edu or Dr. Jennifer Bekki at jennifer.bekki@asu.edu, Dr. Adam Carberry at adam.carberry@asu.edu, Dr. Nadia Kellam at nadia.kellam@asu.edu.

We appreciate your time and contribution to this research!

Sincerely,

Eunsil Lee

elee78@asu.edu

PhD student

Ira A. Fulton Schools of Engineering

Arizona State University

APPENDIX C

CHAPTER II: ELIGIBILITY LETTERS

ELIGIBILITY LETTERS

1. Eligible participants.

Dear <<NAME>>,

Thank you for expressing your interest in participating in our study to better understand international engineering doctoral students' sense of belonging. Based on the Demographic and Background survey you submitted, I am pleased to let you know that you are eligible for participation.

Correspondingly, I'd like to set up a time for your interview. The following are some time windows that we've set aside for interviewing. Could you please identify up to three of these times that would work with your schedule? Also, could you please send me your Skype ID or [Zoom: link] so that we can use it to contact you for the interview?

- Oct 24th (Wed)/ 10 – 11:30 am, 1:00 – 2:30 pm, or 3:00 – 4:30 pm (MDT/PDT)
- Oct 26th (Fri) / 10 – 11:30 am, 1:00 – 2:30 pm, or 3:00 – 4:30 pm
- Oct 31st (Wed)/ 10 – 11:30 am, 1:00 – 2:30 pm, or 3:00 – 4:30 pm
- Nov 2nd (Fri) / 10 – 11:30 am, 1:00 – 2:30 pm, or 3:00 – 4:30 pm
- Nov 7th (Wed)/ 10 – 11:30 am, 1:00 – 2:30 pm, or 3:00 – 4:30 pm

Thank you again for your interest in our study! I look forward to talking with you soon!

Sincerely,

Eunsil Lee

elee78@asu.edu

PhD student

Ira A. Fulton Schools of Engineering

Arizona State University

2. Eligible, but not determined as interview participants.

Dear <<NAME>>,

Thank you for your interest in participating in our study to better understand international engineering doctoral students' sense of belonging.

However, if you're open to it, we'd like to keep your demographic/background survey and contact information so that we can contact you regarding participation in future interview round (or future participation opportunity). If you're willing to have us retain your information for this purpose, please reply accordingly. If you are not willing to have us retain your information, no response from your end is required. Thank you again for your interest in our studies!

Sincerely,

Eunsil Lee

elee78@asu.edu

PhD student

Ira A. Fulton Schools of Engineering

Arizona State University

3. Ineligible participants.

Dear <<NAME>>,

Thank you for your interest in participating in our study to better understand international engineering doctoral students' sense of belonging. Based on the Demographic and Background survey you submitted, I am sorry to let you know that you are not eligible for participation in this particular study. According to the consent form you submitted, we will not retain your information. Thank you again for your interest in our study!

Sincerely,

Eunsil Lee

elee78@asu.edu

PhD student

Ira A. Fulton Schools of Engineering

Arizona State University

APPENDIX D

CHAPTER II: SEMI-STRUCTURED INTERVIEW PROTOCOL

INTERVIEW PROTOCOL

Introduction

Good morning/afternoon/evening. Thank you for sharing your time with me to participate in this interview. I am [interviewer to provide name/professional title]./ I am interested in understanding the experiences you've had as an international doctoral student in engineering, specifically experiences that have contributed to whether you feel valued as a member of the community within your academic unit. In the hour we have together, I will ask you to describe such experiences in detail and to share the thoughts, feelings, and reactions you had related to those experiences./ Please feel free to let me know whenever you have questions about what I am asking. The interview will be audio recorded, and I will also be taking notes.

Interview questions

Icebreaker

: Can you tell me a little bit about your academic program? For example, I'm interested in the official name, your perception of the relative proportion of domestic and international students, and how you'd generally describe the culture.

: If applicable, can you share the same kinds of information with me about your lab or center (if you have one) and/or the institution itself?

1. Sense of Belonging [Belonged/ Valued/ Respected]

Before the interview, I asked you to think about an experience that took place during your time as a graduate where you felt 1) that you belonged to (are connected/ included) / valued or respected in (cared/ supported by) 2) that you do not belong to (are disconnected/ lonely)/ valued or respected in (cared/ supported by) the community within your academic program. Could you tell me about any experiences that stand out to you? Please describe that in as much detail as possible.

[Probing questions (standards probing questions)]

: relating to the participants' answer. It may begin with "You mentioned _____"

: begins with "Describe that in more detail for me" "Tell me what that was like for you." "What does 'something mentioned' mean?" "Can you give me some more detail?" "What is an example of that?"

2. Students' interactions with faculty/peers

Before the interview, I asked you think of a time when you had 1) a memorable or positive/ or 2) negative experience interactions with 1) a faculty member/ 2) peers (including US and international) from your academic program. Could you tell me about any experiences that stand out to you? Please describe that in as much detail as possible.

[Probing questions]

: I'm interested in how being an international student has influenced your experiences as a graduate student (if at all).

[note: if they believe that their experiences have been impacted by being an international student, then ask the following question]. Think of a time when you feel you were treated differently (in a negative way) because you are an international student and describe that in as much detail as possible.

3. Final advice

Drawing from your experience, what advice would you give to another international student who feels that they are not valued or supported as a member of the community within their academic program?

What advice would you give faculty and students in your academic program who want to be supportive of that student?

Closing instructions

Thank the individual for participating!

APPENDIX E

CHAPTER II: CONSENT FORM

Title of research study: Qualitative interview research to understand international students' sense of belonging and peer/faculty interactions.

Why am I being invited to take part in a research study?

We invite you to take part in a research study, which investigates the status quo of student perceived sense of belonging and quality of interpersonal interactions, among the international engineering students in the US engineering doctorate programs.

The data collected will be used for the researcher (Eunsil Lee)'s first qualitative research of Ph.D. dissertation, and will be shared within the research team. The research team includes Eunsil Lee, the researcher herself, Dr. Nadia Kellam (a committee member) and Drs. Jennifer Bekki and Adam Carberry (co-advisors). We are currently conducting a study to build knowledge about international engineering doctoral student's sense of belonging in the US engineering education context.

Why is this research being done?

The purpose of this research is to gain an in-depth understanding of international doctoral students' sense of belonging with their peer/faculty interactions, in the US engineering education setting. This study aims to answer the two research questions; 1. How international doctoral students perceive sense of belonging and peer/faculty interactions, and 2. In which incidents they feel belongingness and the lack thereof, and positive interactions with peer/faculty and vice versa.

Sense of belonging, which is defined as 'a fundamental human need for individuals to belong and to be respected and valued members of a group or community of people' has been reported as a key indicator of academic integration and inclusive culture. In spite of the current call for taking account of discipline specific features, prevalent study on engineering doctoral students' sense of belonging' are regarded as falling short of considering the demographic variances in engineering. Consequently, this proposed study focuses on investigating 'sense of belonging' in engineering doctoral education context; in consideration of national diversity of the student population.

How long will the research last?

We expect that individuals will be interviewed less than 90 minutes.

How many people will be studied?

We expect approximately eight people will participate in this research study.

What happens if I say yes, I want to be in this research?

You will firstly participate in the demographic and background survey. Participants who meet the eligibility will be sent an email from a member of the research team about the

further interview, which will be either in-person or online interview (less than 90 minutes). Interview will be taking place in your convenience time/location (in-person) or in your convenience time via Skype or Zoom (online). Audio recordings will be made during the interviews, if you click 'yes' so submit this consent form. The recorded audio or video files will be only used for the purpose of transcription. You are free to decide whether you wish to participate in this study. To participate, you must be 18 or older.

What happens if I say yes, but I change my mind later?

You can leave the research at any time it will not be held against you.

What happens to the information collected for the research?

Efforts will be made to limit the use and disclosure of your personal information, including research study records, to people who have a need to review this information. We cannot promise complete secrecy. The results of this study may be used in dissertation, presentations or publications but your name will not be used.

Contact information of eligible participants collected from the demographic and background survey will be maintained after notification and consent processes, but that of ineligible participants will be deleted. Confidentiality of interview participants will be maintained by using participant ID in the place of the participant's name across databases. All collected data will be stored on a password-protected ASU Dropbox accessible only by the researcher. Access to the data will only be permitted to the investigators. Data will be shared among the research team which includes researcher herself, co-advisors, and committee members. Data will be maintained for however long it requires the investigator to analyze and publish the results, in a manner consistent with the IRB protocol.

Who can I talk to?

If you have questions, concerns, or complaints, talk to the research team at (480) 238-7994 or by email at elee78@asu.edu, or to Drs. Nadia Kellam at nadia.kellam@asu.edu, Jennifer Bekki at jennifer.bekki@asu.edu, Adam Carberry at adam.carberry@asu.edu (PIs) by email.

This research has been reviewed and approved by the Social Behavioral IRB. You may talk to them at (480) 965-6788 or by email at research.integrity@asu.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide input about this research.

APPENDIX F

CHAPTER IV: IRB APPROVAL LETTER



EXEMPTION GRANTED

[Adam Carberry](#)
[IAFSE-PS: Polytechnic Engineering Programs \(EGR\)](#)
480/727-5122
Adam.Carberry@asu.edu

Dear [Adam Carberry](#):

On 3/31/2020 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Investigating the engineering doctoral students' sense of belonging through understanding their interpersonal interaction with faculty, peers, and staff: In consideration of the diversity in students' citizenship
Investigator:	Adam Carberry
IRB ID:	STUDY00011772
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	<ul style="list-style-type: none">• IRB protocol, Category: IRB Protocol;• Participant Consent Form, Category: Consent Form;• Participant Recruitment Script, Category: Recruitment Materials;• Survey Questions, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 on 3/31/2020.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

APPENDIX G

CHAPTER IV: EDQI AND DEMOGRAPHIC SURVEYS

International Engineering Doctoral Students' faculty/peers/staff interaction

Note: All items for section 1, 2, and 3 will be asked on a five-point Likert scale, from 1=Strongly disagree to 5=Strongly Agree (except the last item for each section regarding the quantity of interaction).

Total number of items: 68 Quality of interaction (30 Faculty interaction + 26 Peer interaction + 13 staff interaction) + 3 Quantity of interaction + 1 Others + 17 Demographic information = 90 items in total

Screening questions (Number of items: 5/17)

Screening question (before beginning the survey)	
Consent	1. Ready to go? Please read the form below and confirm your consent to participate by DA 2. I have read the text above, I am 18 years of age or older, and I agree to participate in this 1. Yes 2. No
1. Enrollment	Are you currently enrolled in an engineering doctoral program within the US? 1. Yes 2. No (Go to the end of survey)
2. Advisor	Do you currently have an advisor or co-advisors? 1. Yes 2. No (Go to the end of survey)
3. Residency status	What is your residency status? 1. US citizen 2. US Permanent Resident (e.g., green card holder) 3. Student visa holder 4. Work visa holder 5. Refugee 6. Work authorization through Deferred Action for Childhood Arrivals (DACA) 7. Undetermined 8. Others, please specify: > For adjusting the survey questions (mostly for this demographic survey) accordingly, is i (If 3/4/5 selected) In what country or countries do you have citizenship(s)? • Open ended question
4. Country of birth	Were you born in the country where you currently hold citizenship? 1. Yes 2. No 3. Dual citizenship 4. Others, please specify: (If 'No' selected) What is your country of origin? • Open ended question

5. Primary language	What is your primary language? <ul style="list-style-type: none"> • Open ended question
---------------------	--

1. Faculty advisor interaction

Academic interaction (Number of items: 19/29)

Instruction: Please indicate your level of agreement with each of the following statements about your academic or non-academic (e.g., personal, social, or cultural) experiences with faculty advisor in your academic unit.	
‘Faculty advisor’ definition: The faculty member who is most closely associated with your doctoral dissertation	
‘Academic interaction’ definition: Interactions regarding academic issues (e.g., research, coursework, academic/professional development, etc.) regardless of the physical space (in/outside of school) where the interactions occurred.	
1	My advisor is someone I feel comfortable talking to about academic (e.g., research or coursework) topics
2	My advisor is willing to help me when I need support with my dissertation research
3	My advisor is typically available to answer my questions regarding academic (e.g., research or coursework) topics
4	My advisor typically sets aside time to have individual research meetings with me
5	My advisor typically sets aside time to have regular lab meetings with the members of their lab
6	My advisor typically keeps their scheduled meetings with me
7	My advisor provides me with guidance I need to make progress as a doctoral student
8	My advisor encourages me to develop as an independent scholar
9	My advisor assists me in finding funding to support me financially during my degree program
10	My advisor assists me in finding resources (e.g., materials, instruments, equipment, experts, etc.) needed for my dissertation research
11	My advisor assists me in developing my research skills
12	My advisor anticipates challenges I may encounter in my dissertation research
13	My advisor demonstrated patience with me as I transitioned into my doctoral program
14	My advisor demonstrates patience with me as I develop research skills
15	My advisor makes me feel like I can succeed in my program
16	My advisor speaks highly of my research to others
17	My advisor provides me with the appropriate amount of pressure to deliver research results
18	My advisor provides me with emotional support when I am experiencing stress
19	My advisor has praised my work

Non-Academic, i.e., personal, social, or cultural interaction (Number of items: 9/29)

‘Personal, social, or cultural interaction’ definition: Interactions regarding social and/or personal and/or cultural topics regardless of physical space (in/outside of the school) where the interactions occurred.	
1	My advisor is generally friendly to me
2	My advisor and I talk about non-academic (e.g., personal, social, or cultural) topics
3	My advisor is willing to listen to me talk about non-academic (e.g., personal, social, or cultural) topics
4	My advisor views me as an individual rather than a representative of my cultural background(s)
5	At least one faculty member in my academic unit has showed me an interest in my cultural background(s)
6	My advisor is aware of how aspects associated with my citizenship (e.g., US citizen or F1 visa holders) impact my student experience
7	My advisor generally listens to me empathetically
8	My advisor has invited students to their home for social events (e.g., group gathering, holidays, etc.)
9	My advisor regularly asks me how I am doing with my life
10	My advisor and I have talked about their family

Quantity of interaction

Instruction: Please indicate the frequency with which you interacted with your advisor prior to the current social distancing restrictions caused by the COVID-19 pandemic.
1. Never, 2. 1-2 times/year, 3. 1-2 times/month, 4. 1-2 times/week, 5. 3+ times/week

2. Peer interaction

Academic interaction (Number of items: 10/26)

Instruction: Please indicate your level of agreement with each of the following statements regarding your academic or non-academic (e.g., personal, social, or cultural) experiences with domestic (born in the United States) and international peers in your academic unit.	
'Peer' definition: Peers referred to in the items include classmates, lab mates, and other peers in your academic unit.	
'Academic interaction' definition: Interactions regarding academic topics (e.g., research, coursework, academic/professional development, etc.) regardless of physical space (in/outside of the school) where the interactions occurred.	
1	At least one of my peers is someone I feel comfortable talking to about academic (e.g., research or coursework) topics
2	At least one of my peers is someone I feel comfortable talking to about my academic (e.g., research or coursework) concerns
3	At least one of my peers would be willing to help me if I needed academic (e.g., research or coursework) help
4	At least one of my peers is someone I feel comfortable working with on class projects
5	At least one of my peers would be willing to study with me
6	My peers and I have plenty of opportunities to have academic (e.g., research or coursework) discussions
7	At least one of my peers would provide me with emotional support when I am experiencing stress related to my dissertation
8	At least one of my peers has praised my research
9	At least one of my peers has asked me to critique their work
10	At least once, I have witnessed segregation among student study or work groups based on country of origin

Non-Academic, i.e., personal, social, or cultural interaction (Number of items: 16/26)

'Personal, social, or cultural interaction' definition: Interactions regarding social and/or personal and/or cultural topics regardless of physical space (in/outside of the school) where the interactions occurred.	
1	My peers are generally friendly to me
2	I feel comfortable attending social events organized by my academic unit
3	At least one of my peers and I talk on a daily basis
4	At least one of my peers and I talk about non-academic (e.g., personal, social, or cultural) topics
5	At least one of my peers and I talk about non-academic (e.g., personal, social, or cultural) concerns
6	At least one of my peers would be willing to help me if I needed non-academic (e.g., personal, social, or cultural) help
7	My peers view me as an individual rather than a representative of my cultural background(s)
8	At least one of my peers has showed me an interest in my cultural background(s)
9	At least one of my peers is someone who listens to me empathetically
10	At least one of my peers has invited me to their home for social gatherings
11	At least one of my peers and I have spent time together outside of school
12	At least once, I have witnessed segregation among student social groups based on country of origin
13	At least one of my peers is someone I consider to be a friend

14	None of my peers have demonstrated discrimination toward me due to my cultural background
15	None of my peers have expressed negative stereotypes regarding my cultural background(s)
16	My peers and I socialize enough to have meaningful interactions

Quantity of interaction

Instruction: Please indicate the frequency with which you interacted with your peers prior to the current social distancing restrictions caused by the COVID-19 pandemic.	
1. Never, 2. 1-2 times/year, 3. 1-2 times/month, 4. 1-2 times/week, 5. 3+ times/week	

3. Staff interaction (Number of items: 4+9=13)

Instruction: Please indicate your level of agreement with each of the following statements about your experiences with staff members at your institution.	
‘Staff’ definition: Staff referred to in the items are include any university employee working in an office that provides student support (e.g., academic advising, graduate college, international student offices, housing, etc.) who is not a faculty member.	
1	At least one staff member at my institution would be willing to help me if I needed academic support (e.g., course selection, advisor selection, TA/RAs, etc.)
2	At least one staff member at my institution is a person I have sufficient access to when I need academic support (e.g., course selection, advisor selection, TA/RAs, etc.)
3	At least one staff member at my institution helped me with aspects pertaining to my academic transition into my doctoral program
4	Staff members at my institution are familiar with academic resources relevant to my citizenship (e.g., US citizen or F1 visa holders)
5	Staff members at my institution are generally friendly to me
6	Staff members at my institution generally welcomed me when I began my doctoral program
7	At least one staff member at my institution would be willing to help me if I needed non-academic (e.g., personal, social, or cultural) support
8	Staff members at my institution view me as an individual rather than a representative of my cultural background(s)
9	At least one staff member at my institution has showed me an interest in my cultural background(s)
10	Staff members at my institution are familiar with non-academic resources (e.g., personal, social, or cultural) relevant to my citizenship (e.g., US citizen or F1 visa holders)
11	Staff members at my institution generally listen to me empathetically
12	At least one staff member at my institution is a person I have sufficient access to when I need non-academic support (e.g., social, personal, or cultural)
13	At least one staff member at my institution helped me with aspects pertaining to my non-academic transitions (e.g., personal, social, or cultural) into my doctoral program

Quantity of interaction

Instruction: Please indicate the frequency with which you interacted with your peers prior to the current social distancing restrictions caused by the COVID-19 pandemic.	
1. Never, 2. 1-2 times/year, 3. 1-2 times/month, 4. 1-2 times/week, 5. 3+ times/week	

4. Sense of belonging (Number of items: 3+10=13)

Sense of belonging (Adopted from Bollen & Hoyle, 1990)

Instruction: Please indicate your level of agreement with each of the following statements regarding how you feel about the community of your academic program.	
Definition: Students’ personal sense of how much they belong to their academic program	
1	I see myself as a part of my academic program
2	I feel that I am a member of my academic program

3	I feel a sense of belonging to my academic program
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Need to belong (Adopted from Leary et al., 2013)

Instruction: Please indicate your level of agreement with each of the following statements regarding how you feel about the community of your academic program.	
Definition: Students' desire for interpersonal acceptance and belonging within their academic program	
1	I don't let it bother me if other people in my academic program don't seem to accept me
2	I try hard not to do things that will make other people in my academic program avoid or reject me
3	I seldom worry about whether other people in my academic program care about me
4	I need to feel that there are people in my academic program I can turn to in times of need
5	I want other people in my academic program to accept me
6	I prefer to be with colleagues (vs. alone) in my academic program
7	Being apart from people in my academic program for long periods of time does not bother me
8	I have a strong need to belong in my academic program
9	It bothers me a great deal when I am not included in the plans of other people in my academic program
10	My feelings are easily hurt when I feel that others in my academic program do not accept me

Additional question to mediate Covid-19 effects

Instruction: Please use the following space to provide additional information on how, if at all, the current COVID-19 pandemic has influenced your perceived quality of interaction with your faculty, peers, staff, and/or sense of belonging to your academic unit?
Open-ended question

5. Demographic information (Number of items: 12/17)

Section 1 (after completing the survey): Academic information	
1. Institution	At which institution are you currently pursuing your doctoral degree? <ul style="list-style-type: none"> • Answer options (= Selected institutions for survey distribution)
2. Degree fields	What degree field are you currently pursuing? <ul style="list-style-type: none"> • Answer options (= Engineering doctoral programs at the selected institutions)
3. Years	In what year did you begin your doctoral program? <ul style="list-style-type: none"> • A scroll down option (years need to be decided, from 2010 to 2020?, Fall/Spring?) <ol style="list-style-type: none"> 1. 2010 2. 2011 ... 3. 2019 4. 2020
4. The highest academic degree	Which of the following corresponds with your highest academic degree earned? <ol style="list-style-type: none"> 1. BS 2. MA 3. MS 4. MBA 5. PhD 6. EdD 7. DSc

	<p>8. JD</p> <p>9. MD</p> <p>10. Other, please specify: _____</p> <p>In which country did you earn the above degree?</p> <ul style="list-style-type: none"> • Open ended...?
<p>5. Previous educational experience in the US (for Intl.?)</p> <p>Vs. in other countries outside of the US (for domestic students?)</p>	<p>(For international students) Have you received education in the US prior to your current degree program? (For international)</p> <ol style="list-style-type: none"> 1. Yes 2. No <p>> Different demographic surveys for domestic & international students? Or asking their experience outside of the US for domestic students?</p> <p>(For domestic students) Have you received education outside of the US prior to your current degree program?</p> <p>(If 'Yes' selected)</p> <p>1. Please select the level of education that you've received (Please select all that apply)</p> <ol style="list-style-type: none"> 1. Elementary 2. Secondary 3. Bachelor's 4. Master's 5. Other, please specify
<p>6. Years in the US (for intl.?)</p>	<p>How many years have you lived in the US? (For international)</p> <ul style="list-style-type: none"> • Dropdown option (years need to be decided, the same questions with Q4)
<p>7. Advisor's immigration status</p>	<p>Is your advisor or at least one of your co-advisors international?</p> <ol style="list-style-type: none"> 1. Yes 2. No <p>(If 'Yes' selected only for international students)</p> <p>Does your advisor or at least one of your co-advisors hold the same citizenship with you?</p> <ol style="list-style-type: none"> 1. Yes 2. No
<p>8. Lab</p>	<p>Have you joined a research lab?</p> <ol style="list-style-type: none"> 1. Yes 2. No <p>(If 'Yes' selected)</p> <p>Do you have a physical workspace in the research lab?</p> <ol style="list-style-type: none"> 1. Yes 2. No
<p>9. Lab mates</p>	<p>(If 'Yes' selected for the above question, 'Have you joined a research lab?')</p> <p>Do you have lab mates in your research lab?</p>

	<ol style="list-style-type: none"> 1. Yes 2. No <p>(If 'Yes' selected)</p> <p>Approximately how many international lab mates do you have in your research lab?</p> <ul style="list-style-type: none"> • Open ended question <p>How many domestic (US born) lab mates do you have in your research lab?</p> <ul style="list-style-type: none"> • Open ended question
Section 2 (after completing the survey): Background information	
10. Gender	<p>What is your current gender identity?</p> <ol style="list-style-type: none"> 1. Male 2. Female 3. Trans male/ Trans Man 4. Trans female/ Trans woman 5. Genderqueer/ Gender Non-conforming 6. Prefer to self-describe, please specify: 7. Prefer not to say
11. Ages	<p>What is your current age?</p> <ul style="list-style-type: none"> • a scroll down option from 24 or younger to 45 or older
12. Race/ Ethnicity	<p>How would you describe your race/ethnicity? Please select all that apply.</p> <ol style="list-style-type: none"> 1. American Indian or Alaska native 2. Asian 3. Black or African American 4. Hispanic or LatinX 5. Native Hawaiian or Other Pacific Islander 6. White
13. Relationship status	<p>What best describes your relationship status?</p> <ol style="list-style-type: none"> 1. Single/ Never married 2. Separated, Divorced, or Widowed 3. Married 4. In a committed relationship

APPENDIX H

CHAPTER IV: RECRUITMENT LETTER

RECRUITMENT LETTER

Subject: Requesting Your Assistance with Recruiting Engineering Doctoral Student Participants

Dear [NAME],

My name is Eunsil Lee and I am a doctoral student in the Engineering Education Systems and Design PhD program at Arizona State University. I am working with Drs. Jennifer Bekki and Adam Carberry on my dissertation research designed to increase our understanding of engineering doctoral students' interactions and sense of belonging within their academic unit.

We are recruiting doctoral students currently enrolled in engineering doctoral programs across the US to participate. Study participants will be asked to complete a short questionnaire that will take approximately # minutes. With this letter, I am requesting that you please:

1. Forward the recruitment email below to doctoral students in your department/program.
2. Copy me (elee78@asu.edu) on your email when you distribute the email to help with our record keeping on the project.

This study has been approved by the ASU Institutional Review Board (protocol number: STUDY00011772). For questions or further information regarding this research, please feel free to contact me at elee78@asu.edu.

Thank you in advance for distributing the recruitment email. Hope you stay healthy and safe in these unusual and uncertain times.

Sincerely,
Eunsil Lee

On behalf of

Dr. Jennifer Bekki, Associate Professor, The Polytechnic School, Ira A. Fulton Schools of Engineering, Arizona State University

Dr. Adam Carberry, Associate Professor, The Polytechnic School, Ira A. Fulton Schools of Engineering, Arizona State University

Subject: Invitation to Help Improve Engineering Doctoral Students' Experiences

Dear Engineering Doctoral Students,

We are a team of investigators in the Ira A. Fulton Schools of Engineering at Arizona State University. We are conducting a research project designed to increase our understanding of engineering doctoral students' sense of belonging and interactions with faculty, peers, and staff. You are invited to participate in the following study as a current doctoral student in an engineering program.

Participation includes completion of a survey that should take about 10 minutes to complete.

To participate, please follow the link to the survey:

[Survey URL link]

Or copy and paste the URL below into a web browser:

[https://asuengineering.co1.qualtrics.com/jfe/form/SV_8oXe23vzLjPqOZn]

This study has been approved by the ASU Institutional Review Board (protocol number: STUDY00011772). For questions or further information regarding this research, please feel free to contact the research team at elee78@asu.edu.

We appreciate your time and contribution to this research. Stay well and connected during these uncertain times.

Sincerely,

Eunsil Lee, PhD Student

Ira A. Fulton Schools of Engineering

Arizona State University



APPENDIX I

CHAPTER IV: CONSENT FORM

CONSENT FORM

STUDY TITLE: Investigating the Engineering Doctoral Students' Sense of Belonging Through Understanding Their Interpersonal Interaction with Faculty, Peers, and Staff: in Consideration of the Diversity in Students' Citizenship

INVESTIGATORS:

Eunsil Lee | Doctoral Student | Ira. Fulton Schools of Engineering, Arizona State University

Dr. Jennifer Bekki | Associate Professor | Ira. Fulton Schools of Engineering, Arizona State University

Dr. Adam Carberry | Associate Professor | Ira. Fulton Schools of Engineering, Arizona State University

We are asking you to participate in a research study. This form gives you information to help you decide whether or not to be in the study. Participation is voluntary. Please read this carefully.

PURPOSE OF THE STUDY: The purpose of this study is to better understand the experiences of engineering doctoral students' interaction with others and belongingness. You are invited to participate in this research study because you are at least 18 years of age and are currently enrolled in an engineering doctoral degree program at an institution in the US.

STUDY PROCEDURES: You will be asked to complete a one-time online survey that is anticipated to take a total time 10 minutes to complete. The survey will consist of questions about you and your experiences within your academic unit.

RISKS, STRESS, OR DISCOMFORT: There are no significant risks associated with your participation

COMPENSATION: There is no compensation for participating in this study.

BENEFITS OF THE STUDY: Participation will provide valuable information that may help university faculty, administrators, and researchers improve the quality of interactions for engineering doctoral students. You may also benefit from the opportunity to reflect on your learning and experiences in your doctoral education throughout the study.

ANONYMITY & CONFIDENTIALITY: Participation in this study is completely confidential and participants will be kept anonymous. Contact information of participants will not be collected, and confidentiality of survey participants will be maintained by not collecting participant's name. Results from this study will be published, only in aggregate, in journal and conference papers. All data, including demographic information and survey responses), will be stored electronically on password-protected computers and cloud storage. The principal investigators will be the only people who have access to the data.

FREEDOM TO WITHDRAW: You are free to withdraw from this study at any time. You may also choose to not respond to any question without penalty.

QUESTIONS OR CONCERNS: If you have questions about this research, please contact Eunsil Lee at elee78@asu.edu. If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you can contact the Arizona State University Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788 or Research.Integrity@asu.edu.

I have read the CONSENT FORM above and agree with all the terms and conditions, specifically my participation in this one-time online survey study. I provide my consent for the investigators to use my information for research purposes in the study and acknowledge that I am 18 years or older.

- Yes