The Impacts on Peer Tutors of Leading Group Supplemental Instruction for First-Year Engineering Students

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Abstract

The purpose of this study was to investigate the impact of peer tutoring experiences on upper-class male and female tutors who provided supplemental instruction (SI) for first-year engineering students enrolled in required general chemistry and physics courses at Northeastern University. Our previous research has shown a correlation between regular use of SI by first-year engineering students and increased GPA, as well as gender-based differences in SI usage and effects of SI. In this study, we turned our focus to the effects of the tutoring role on the tutors and sought to elucidate 1) whether tutors perceived that they benefitted from the SI experience, and if so, in what ways, 2) how gender affected attitudes towards tutoring and the impact of serving as a peer educator, and 3) whether level of commitment to group SI correlated with tutors' perceptions of how they were impacted.

Forty-one individuals who served as peer tutors at Northeastern University between 2005 and 2018 were invited to respond to online surveys. Those who completed the online survey were invited to participate in follow-up phone interviews. Subjects were asked about their experiences with SI, their motivations to provide instruction, their level of commitment to the program, and—as they reflected on their college and post-graduation endeavors—their perceptions of the value of their tutoring experience. Statistical comparisons were drawn from the responses of 20 female and 9 male tutors to the online survey, and qualitative analysis of transcripts of follow-up phone interviews with 13 women and 4 men were performed.

Through the application of grounded theory to transcripts, supported by statistical analysis of data from the online survey, it was deduced that increased confidence and preparedness in future endeavors was the core category that linked individuals' tutoring experiences. Participants reported that relationships developed with tutees, fellow tutors, and faculty mentors during their tutoring experiences impacted them beyond their experiences as tutors. Participants reported improved soft skills, including communication, teamwork, and leadership, and strengthened academic abilities, which resulted from a deeper understanding of the tutored subject matter. Serving as tutors also caused tutors to be more open to receiving tutoring themselves in their coursework. Improvement in soft skills along with enhanced academic ability contributed to an increased sense of confidence and preparedness. Analysis of the role of gender showed that females were more likely than males to perceive an increase in self-confidence and to view themselves as confidence builders for tutees. Women were also more likely than men to become a tutor to improve their communication skills and help others. Years spent as a tutor correlated positively with greater perceived benefits for both genders. This study demonstrates that peer tutoring can have a significant impact on the academic performance and professional development of tutors, particularly females, in addition to tutees.

Introduction

Since 2012 our research team has been analyzing impacts of supplemental instruction (SI) on first-year engineering students at Northeastern University, with an emphasis on how gender and other traits, such as pre-college background and attitudes toward school, affect academic success. [1] - [6]. These studies have highlighted the potential benefits for women engaging in these programs during college including: higher grades, increased attendance at structured tutoring sessions, and greater comfort reaching out to relatable role models for support.

The Connections Program at Northeastern University was founded in 2000 with National Science Foundation (NSF) funding to provide additional resources to first-year women enrolled in historically challenging required general chemistry and physics classes for engineers [7]. This program also has emphasized the role of upper-class women as peer educators to increase retention of first-year females in engineering [1]. The tutors who have worked in the Connections Program have shown a high level of commitment to SI– they attended lectures, hosted weekly review and homework help sessions, and prepared review sheets based on class lectures to promote success within the freshman class. Although this program's efficacy with first-year tutees has been documented in detail, its impact on the upper-class tutors, particularly female tutors, has yet to be explored. In order to clarify potential benefits of this program for all engineering students involved, it is essential to understand how these tutors have been impacted by holding these leadership roles, what factors affected their experiences, and how their experiences in these roles have impacted subsequent academic and professional achievements.

Studies have shown that having female role models and teachers is beneficial to the retention of women in STEM [8]. Additionally, previous research in non-engineering disciplines has shown that tutors not only gain knowledge in their tutored topic, but also improve their soft skills, such as communication and leadership [9], [10]. Further, tutors can gain confidence in themselves and develop empathy towards struggling students [11]. This study strived to enhance the understanding of the benefits of holding leadership roles on women studying engineering, as well as the impacts tutoring has on tutors within engineering education. In particular, we sought to investigate how tutoring has affected tutors' careers, skill sets, and opinions of tutoring.

Background

Effects of leadership roles on women in STEM

Studies on the impact of SI in higher education tend to be one-sided: while the beneficial impacts of peer tutoring on students receiving instruction is well-documented, the benefits that peer tutors themselves receive from these programs are not as well understood, particularly for women in engineering. This consideration is especially important given that women are still underrepresented within many STEM fields, including engineering. In fact, according to the ASEE yearly report, only 21.9% of bachelor's degrees in engineering were earned by women in the 2017-2018 academic year [12]. For women to become more equally represented in engineering, it is essential to provide them with the opportunity to hold leadership roles to promote retention and academic success, as well as understand ways to best encourage women to

hold such positions. In light of the positive outcomes associated with being a peer tutor in other disciplines [9] - [11], understanding the impacts of holding such roles on women within engineering is warranted.

Various programs have sought to encourage women to pursue engineering, including efforts by the federal government to foster mentoring support for women throughout their education and to retain women in STEM careers [13], [14]. Studies have shown that academic help, among other types of support, has a positive impact on the retention of women in engineering. Our previous research has shown that female tutees are more responsive to peer tutoring and take the initiative to seek tutoring more often than their male counterparts [2] - [4]. From the tutor's perspective, Espinoza and Cole have reported that peer tutoring enhanced the academic performance of female tutors, but not male tutors within a group of 229 students in STEM [15]. Additionally, supporting first-year female engineering students with female tutors has been shown to promote women's sense of belonging, success, future aspirations, and retention in engineering during the important first-year transition period [8]. From these findings, it is evident that providing role models for women in STEM has been a successful strategy in improving retention, support, and representation of women in STEM.

Qualities gained through peer tutoring—knowledge, confidence, and communication skills

The positive effects of peer tutoring on SI leaders extend beyond academic performance; tutors also improve valuable soft skills through tutoring. By becoming peer educators, students take on leadership roles that introduce them to challenges they likely would not face during regular coursework. These challenges include overcoming gaps in mastery of subject matter, explaining course material to struggling students, adjusting to different learning styles, and acting as a mentor for other students [9], [16]. Through addressing these challenges, peer tutors are provided the opportunity to foster a variety of skills that are essential for their personal development. Previous research has revealed that by participating in peer tutoring programs in science, engineering, or writing, peer tutors can develop key leadership skills, including communication, ability to work in a team, empathy, and presentation skills that follow them after graduation into their professional lives [10], [17] - [21]. Another impact associated with being a peer tutor in fields like nursing, science, and engineering is the enhancement of qualities relating to self-development, such as self-confidence, time management, writing skills, and knowledge of course material. [10], [11], [16] - [18]. Furthermore, the cultivation of relationships among tutors and faculty has been a reported benefit of peer tutoring [22]. These connections have the potential to influence peer tutors' attitudes towards their courses and foster a sense of academic community during college and beyond [21] - [24]. Together, these findings demonstrate the significant benefits students can experience by having a peer tutoring role during college. While these findings are promising, it is crucial to note that most of these studies focused on peer tutoring within either non-STEM [11], [16], [19] or non-engineering STEM [10], [17], [20], [21] disciplines, with the study of Malm *et al.* [18] as a rare exception that focused on impacts on engineering students specifically.

Using grounded theory for qualitative research

To fully grasp the impact peer tutoring can have on the personal development of tutors, a qualitative research approach can be insightful. Grounded theory, introduced in 1967 by Glaser & Strauss [25], is a common research technique within social sciences that provides a versatile framework reliant on the collection and analysis of data to develop hypotheses. This model contrasts with typical quantitative research approaches, which start with a set of hypotheses that are then tested against collected data [25]. Grounded theory relies on data collected from sources, such as interviews and conversations that are then analyzed to generate a working hypothesis that evolves throughout the study. As more data are collected, trends and repeated ideas become apparent and are tagged as codes. These codes are grouped together and further categorized to identify common trends across data sets. The constant comparative method associated with this technique is essential to grounded theory methodology as it allows for continual comparison and contrasting of data to refine and develop key concepts over time that are eventually used to generate a theory [26]. Outhred & Chester previously have demonstrated the insight offered by utilizing grounded theory principles to assess the experiences of female tutors during college [27]. Case & Light previously have discussed the potential application of grounded theory to perform qualitative analysis specifically within the scope of engineering education [28].

Methods

Data Collection

A set of 41 individuals who previously served as peer tutors within the Connections Program at Northeastern University between the years 2005 and 2018 were offered the opportunity to participate in an IRB-approved online survey. These individuals, who were upper-class engineering students (with the exception of one male tutor who was a graduate student), led weekly group tutoring sessions for students enrolled in required first-year chemistry and physics courses. Many of these individuals tutored for multiple years, including in some cases beyond the Connections Program as one-on-one tutors. The online survey served as an anonymous, initial assessment of how being a peer tutor impacted their soft skills, attitudes towards tutoring, and professional development after graduation. At the end of the online survey, participants were asked if they would be willing to schedule a follow-up phone interview to further discuss their peer tutoring experiences. Interviews allowed participants to provide more in-depth and personal responses. These structured individual interviews (each lasting 10-20 minutes) consisted of 12 questions and were recorded for transcription purposes after obtaining consent from interviewees and subsequently analyzed. Table 1 provides key demographic background information on the 29 online survey participants and the 17 follow-up phone interviewees.

Statistical analysis of responses to online survey

Raw data from the online surveys were coded for analysis, in particular representing survey responses for total time spent on tutoring activities outside of scheduled reviews, increase in understanding of subject matter tutored, and impact of tutoring on overall development as a student on a Likert scale. Validation of survey responses was based on checking self-consistency

Table 1. Demographics of Study Participants

Factor	Sub-Population	Participants	
		Online Survey	Follow-up Interview
Gender	Female	20	13
	Male	9	4
Years as a tutor	Less than 3	17	8
	At least 3	12	9
Time spent in tutoring activities outside of scheduled reviews (studying subject matter, preparing review sheets, reviewing homework and discussing teaching strategies)	Less than 60 min	9	4
	At least 60 min	20	13
Pursued/planned to pursue further post-graduate education	Yes	21	15
	No	8	2

for each individual as well as comparison with known attributes (*e.g.*, years tutored) for respondents who were willing to participate in a follow-up phone interview. Statistical analysis focused on identifying statistically significant differences (expressed in terms of p values) and effect sizes (expressed in terms of Cohen's d for means, Cohen's h for proportions, and Pearson's r for correlations). Reporting both p values and effect sizes provided distinct identification of non-random differences (for testing of null hypotheses) and magnitudes of effects. Differences between means were evaluated (with α=0.1) using t tests; differences between percentages/proportions were evaluated (also with α=0.1) using Fisher Exact Tests with mid-p adjustment, based on recommendations for small sample sizes. Linear regression for correlation between years spent as a tutor and impact of tutoring on overall development as a student and increase in understanding of subject matter tutored were analyzed in terms of Pearson's correlation. Differences with p<0.1 were identified as statistically significant. Parameters for effect size were interpreted as summarized by Lee [29].

Qualitative analysis of phone interviews

Two qualitative analysis techniques were used to evaluate trends across phone interviews to determine the impacts peer tutoring had on interviewees. Temi, an online automated transcription service, was used to generate the initial draft of interview transcripts. Each transcription was reviewed by listening to the audio while reading through and correcting the transcription to ensure accuracy. Interview transcriptions were then analyzed separately by two team members conducting this study to cross-reference and improve the reliability of the results.

For the first approach to analysis, the reviewed transcripts were uploaded into NVivo, a software used for preliminary qualitative data analysis. Based on the themes observed while manually reviewing the transcriptions, text query searches within NVivo were used to confirm the presence and strength of a given trend. A summary sheet was then created by paraphrasing each

interviewee's response to each question to better compare responses. These responses were placed into subcategories based on their similarities with those of other interviewees. Total tallies of these subcategories identified the most common trends, themes, and keywords mentioned or alluded to by respondents.

The second approach to qualitative analysis of phone interviews also employed NVivo, but organized the transcript files based on participant background and experiences reported in responses to the online survey. Sub-populations considered were gender, whether participants had previous experience being tutored or serving as a tutor, and whether they spent more than or less than 60 minutes per week on tutoring activities outside of scheduled SI sessions (Table 1). After all the interviews were coded, the nodes were cross-referenced with the cases using NVivo's crosstab functionality to observe trends present within each subgroup. Trends and categories were further analyzed and identified.

The totals for each subcategory/node were reviewed, in addition to the identified subpopulations, and through inductive reasoning a theory was proposed that connected several trends and subcategories. This approach yielded a core category that represented the effect tutoring had on tutors.

Results

Applying grounded theory to the analysis of phone interviews with former peer tutors in the Connections Program at Northeastern University resulted in the development of a theory (Figure 1) that connected the identified themes voiced by the respondents and proposes that the skills gained as a peer tutor positively affected the future endeavors of our respondents. The common categories among respondents included: the challenges tutors faced when they started tutoring led to mentorship from more-experienced tutors, a greater understanding of the material being tutored, and a greater openness to being tutored. These attributes led to both greater success in their studies and improvements in their soft skills, including communication, leadership, and teamwork. The culmination of these effects resulted in tutors having greater confidence in their post-graduation endeavors, regardless of whether they pursued a job in industry or attended graduate school. This increased confidence in future endeavors was considered the core category for this analysis.

Core category: confidence in future endeavors

Through application of grounded theory, increased confidence at several levels was identified as the primary effect tutoring had on respondents. Confidence was interpreted from transcripts of phone interviews as an individual's improved sense of ability to succeed in a given environment or task. Individuals expressed increased self-confidence in response to multiple questions in the phone interviews, frequently when asked what the greatest benefit they received from being a tutor and/or the effects tutoring had on their experience as a graduate student. In a number of phone interviews participants expressed the sentiment that being a tutor aided them in their future endeavors, regardless of whether they attended graduate school or pursued positions in industry. Interviewees commented that they not only gained confidence in their knowledge of

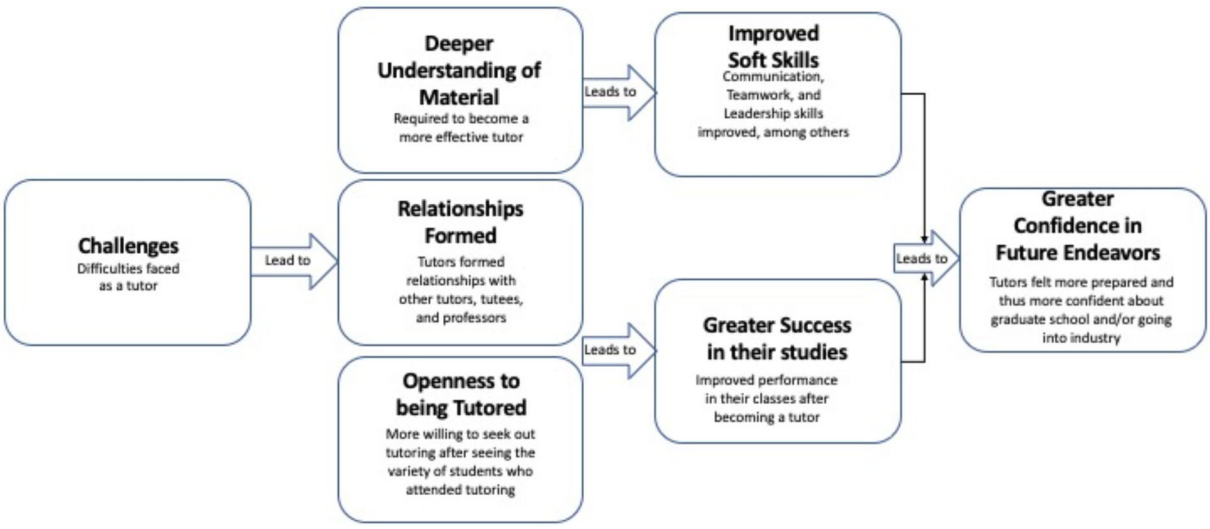

Figure 1. How being a tutor leads to greater confidence in future endeavors

material, but also in their ability to communicate concepts to tutees. This change was more commonly noted by interviewees who tutored for multiple years and identify as female. This latter qualitative observation based on 17 phone interviews was supported by statistical analysis of responses given in the online survey with 29 participants (Table 2): females were more likely than males to report being a peer educator increased their self-confidence (p = .0055, h = 1.1152, corresponding to a large effect size). This gender based difference in self-confidence also correlated with results from the online survey in regards to expectations for the role of a peer educator: female respondents were more likely than their male peers to view a tutor's role as being a confidence-builder for students (p = .0443, h = 0.9818, corresponding to a large effect size).

Table 2. Gender-Based Differences in Perceptions of Confidence from Online Survey

%-Participants Reporting:	Gender	
	Female (20)	Male (9)
Tutoring Increased Their Self-Confidence	85.0	33.3
Role of Tutor Is a Confidence Builder	100.0	77.8

Responses to challenges encountered during tutoring

Phone interview respondents shared the many challenges they encountered in their tutoring duties. These challenges included having to develop multiple ways to explain material to struggling tutees, and six interview participants mentioned that it was challenging when students had difficulties understanding the material despite their efforts to explain the concepts. One individual shared they had to "…come up with two or three different ways to explain the same thing so that I'm…reaching all of the different styles or personalities in the group…" and that it

was, “difficult to walk away a little bit. I stayed late a lot and... got really involved in...caring about how the students were doing.”

To meet the aforementioned challenges, tutors commonly engaged in self-study and practiced material. We found that in phone interviews individuals who spent more time each week preparing for tutoring sessions expressed that they had difficulty finding different ways to explain material. Several interviewees also mentioned that not knowing answers to questions and doubting their ability to be an effective tutor was challenging. Time management was commonly cited as another challenge. One interviewee explained that tutoring, “...definitely added some time management skills...to balance the tutoring with all the other coursework that I had going on as well.” It was clear from the analysis of the interviews that the majority of participants experienced similar challenges, which required them to adapt to become an effective tutor.

Consequences of mastering tutored material

Respondents in our study noted that they learned from discussions with more experienced peer tutors and faculty mentors, from tutees’ questions posed, and from the explanations offered by other tutors during tutoring sessions. Some interviewees commented that based on these experiences, they learned it was acceptable to not have an immediate answer to all questions posed by tutees. Interviewees also reported an increased understanding of the tutored material due to these preparation experiences. The interviewees emphasized the importance of understanding course material to be an effective tutor, and that this increased understanding helped them develop confidence. One participant reported, “I think [preparation]…probably made me more confident and better able. You know, as you explain things to other people you understand it better.” Based on responses to the online survey, both genders experienced similar increases in their understanding of course material. However, there were differences between genders in their motivation for understanding the tutored material: 25.0% of female respondents reported being motivated by gaining a sense of achievement, compared to none of the male respondents ($p = .0876$, $h = 1.0472$).

The mastery of basic subjects helped some of the interviewees excel in both their subsequent undergraduate and graduate coursework. One shared that, “remembering the fundamentals is important [because] sometimes, especially in grad school, [you] get your head in the weeds of some convoluted science and it's nice to take a step back… and…have those principles at my disposal.” Another respondent felt that, “for me, it helps to reinforce concepts that I also needed time to absorb. And so by learning it myself and then teaching it a few times it became more second nature and helped me do better at those subjects even in more advanced parts of those subjects.” These sentiments support the theory that as the tutors mastered the material they were teaching, their confidence in their capabilities as peer educators increased.

Benefits from relationships developed as a tutor

Participants in phone interviews frequently identified the benefits they received from working with tutees, other tutors, and faculty—including the strengthening of those relationships—as one of the greatest overall benefits from their tutoring experiences. Many respondents described the satisfaction of befriending students who frequently attended tutoring sessions and found

happiness in the success of these tutees, reporting, for example, “seeing the joy and it being…the pride of having helped them” as a benefit of tutoring. Relationships and satisfaction derived from helping others not only improved respondents’ abilities as tutors, but also were reported to have helped these respondents in other classes and subsequent graduate studies and career searches. One individual described how they helped a younger tutor find an internship in industry: “[I] brought her on when I graduated. I brought her on as a co-op student and…since then we've been friends.” They went on to mention how they are still good friends and would not have met if they had not been tutors in the Connections Program.

The collaborative relationships study participants developed with faculty and with other tutors were also frequently mentioned as having helped tutors see the potential for a future career in academia. One study participant described the satisfaction she felt from relationships developed as a result of tutoring when asked what the greatest benefit she had from tutoring**:** “...The connections. I was able to meet the other tutors, as well as all of the students that we were tutoring … as well as with professors who knew that you were tutoring and knew that you had the ability to relay the information and teach in that way.” This benefit may have had more significance for females: 30.0% of female respondents to the online survey reported pursuing a teaching career after graduation, compared to none of the male respondents ($p = .0967$, $h = 1.1593$, corresponding to a large effect size).

Another common theme expressed in phone interviews was that the more time an individual invested in being a tutor, the more their relationships and connections developed. This outcome appeared more pronounced among individuals who spent at least three years tutoring than among individuals who tutored for less than three years. Additionally, expressing relationships and connections as a benefit was a frequent sentiment among tutors who spent a minimum of 60 minutes weekly preparing for tutoring.

Increase in openness to being tutored

Interviewees frequently described how their tutoring experiences made them more open to receiving tutoring themselves. This sentiment was derived from interacting with motivated, intelligent students who attended their tutoring sessions. One tutor discussed her attitude on going to tutoring before and after being a tutor herself, “My freshman year, I really didn't go to tutoring a lot... In my head I'm like, tutoring is just for people who…really need it and who are…failing the course. And then I went and realized that it made me be able to really understand my homework so much better. And it took a lot for me to go the first time. But I think part of tutoring broke down those barriers for me [because] … I see all these other smart students that I'm like tutoring here and they know what's going on. They just need this connection.” This benefit was mentioned in phone interviews more commonly by respondents who had a deeper level of engagement in tutoring. Interviewees who tutored for at least three years and/or who spent at least 60 minutes weekly outside of scheduled reviews preparing for tutoring commonly expressed increased openness to being tutored subsequently. Individuals stated that this openness to seeking tutoring helped improve their class performance, built their confidence, and academically prepared them for subsequent studies. Here, gender appeared to play no role: both genders experienced similar increases in their subsequent pursuit of tutoring based on responses to the online survey.

Improved soft skills: communication, teamwork, and leadership

Another benefit from tutoring commonly expressed in phone interviews was improved soft skills, such as the ability to communicate effectively, work in, and lead teams. Participants commented that these improvements impacted their efforts as tutors in addition to affecting their performance in their undergraduate classes, future education, and careers. An improved ability to communicate was a frequently noted result of being a tutor, particularly for female respondents. Interviewees often noted it as an important quality of effective tutoring, indicating that the development of communication skills likely contributed heavily to the development of self-confidence, which was helpful for respondents who planned to pursue future education and careers in academia where teaching skills are needed. One respondent commented on the effect this development had on her graduate school experience, "I'm in graduate school now and explaining my research to people...I started…at a better spot than some of my peers in terms of…recognizing where you need to lower the level of technicality of your discourse…to make sure that whoever you're talking to actually understands it."

Complementary results were found based on statistical analysis of responses to the online survey (Table 3). In this survey participants were asked about why they became a tutor. Women tended to have different motivations for becoming peer educators compared to men. In particular, females were more likely to become a tutor to improve their communication skills compared to their male peers ($p = .0719$, $h = .8911$, corresponding to a large effect size). Interestingly, altruism appeared gender dependent: female participants were more likely than their male counterparts to be motivated to be a tutor in order to help others ($p = .0443$, $h = .9818$, corresponding to a large effect size), but differences in motivation based on receiving financial compensation between the genders was not statistically significant ($p > .1$, $h = .1838$, corresponding to a small effect size).

Table 3. Gender and Motivations to Become a Tutor

%-Participants Who Became a Tutor:	Gender	
	Female (20)	Male (9)
To Improve Their Communication Skills	50.0	11.1
To Help Others	100.0	77.8
To Receive Financial Compensation	75.0	66.7

Correlations between depth of engagement in tutoring and perceived benefits

Responses from the online survey allowed us to consider further the impact of a tutor's depth of engagement in tutoring on the benefits received from the tutoring experience. We found that dedication to tutoring—represented by the total number of years spent tutoring—was a factor that affected a respondent's experience. In particular, the impact on overall development of a tutor as an undergraduate student correlated positively with years spent as a tutor (Figure 2), with

a Pearson's $r = .5631$ ($p = .0015$) corresponding to a large effect size. Additionally, as the number of years tutored increased, the understanding of the tutored subject matter increased (Figure 3), with a Pearson's $r = .3229$ ($p = .0876$) corresponding to a medium effect size. Further, individuals who tutored as little as two years experienced significant and large differences in both perceived impact ($p = .0898$, $d = 0.7146$) and increased understanding ($p = .0252$, $d = 1.0798$) compared to peers who tutored only one year. There were no statistically significant differences between genders in the average number of years tutored, the average amount of time spent weekly outside of scheduled reviews preparing for tutoring, or the perceived impact of tutoring on overall development as a student.

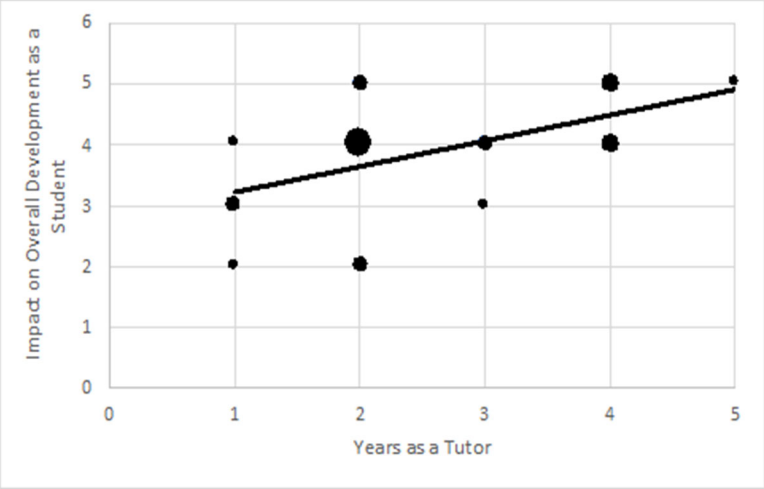

Figure 2. Overall impact participants in the online survey rated tutoring correlated with number of years tutored. Symbol size reflects number of respondents in that subgroup.

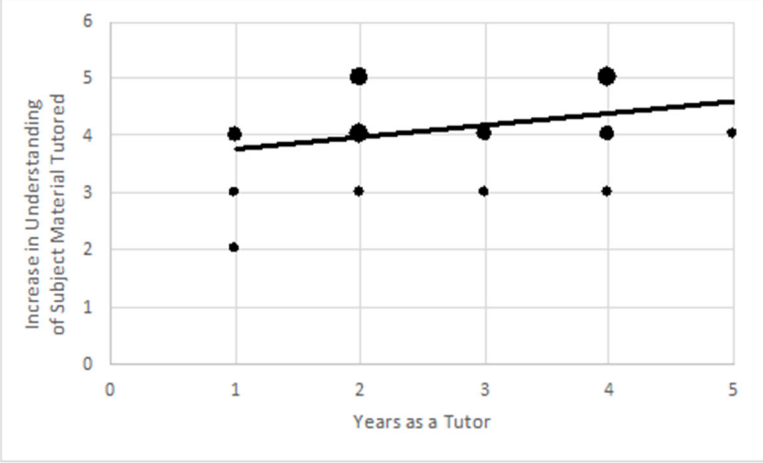

Figure 3. Increased understanding of the tutored materials had a direct correlation with the years spent tutoring. Symbol size reflects number of respondents in that subgroup.

Discussion

The overall aim of this study was to investigate the impact of tutoring on peer educators providing SI for required science courses for first-year engineering students and to analyze the effect of gender and depth of engagement in tutoring on the tutors and their attitude towards tutoring. A specific goal was to determine if providing peer-based education impacted post-graduation success experienced by tutors in any way along with the perceived importance of the tutoring experience on this success. Analysis applying grounded theory to phone interviews with study participants revealed a common trend in interviews, identifying confidence in future goals and endeavors as the core category. This qualitative analysis, complemented by statistical analysis of responses to an online survey, also identified additional sub-categories, specifically understanding of material, relationships, willingness to being tutored, and improved soft skills that aided in the development of confidence and the subject's belief in their ability to attend graduate school.

Experience and time—in terms of both the total number of years spent as a tutor as well as time dedicated weekly to prepare for tutoring sessions—were factors that impacted perceived benefits and outcomes. We observed that respondents who dedicated more time to tutoring perceived a greater and deeper benefit from their experiences tutoring, with significant increases in perceived benefits arising merely by tutoring a second year. In particular, study participants commonly reported building relationships that they highly valued with tutees, fellow tutors, and faculty, corroborating reports shared in the literature that these relationships aided students in both their college experience and post-graduation endeavors [21] - [24]. We also found that respondents who tutored for more years had improved relationships with other tutors and associated faculty and showed a greater willingness to receive tutoring themselves. Through forming relationships with other tutors, many tutors found peers that supported them in their other classes and encouraged them to go to graduate school and/or helped them find jobs. Statistical analysis of responses from an online survey supported these findings, showing that the students who tutored over a longer period of time received a greater impact on their overall development as a student compared to their peers who tutored for a shorter period of time. Similarly, understanding of material tutored increased with duration of the tutoring experience. In interviews, individuals discussed how increased knowledge improved their performance in other classes, in graduate school, and at their jobs. This material knowledge was pivotal in setting them up for futures as leaders in careers in STEM and complemented by the improved soft skills they gained through tutoring.

Respondents in both interviews and online surveys expressed how a variety of their soft skills improved through tutoring. More specifically, many of the individuals who participated in phone interviews felt that their communication skills benefited from their tutoring experience, upholding previously-reported research that showed communication is a skill that has been emphasized as a benefit of working as a peer tutor [10], [17] - [21]. One novelty of our study is that we identified gender-based differences: females more frequently reported that they became a tutor in order to improve their communication skills. Further, interviewees in this study described how their ability to communicate technical ideas improved, which was of significant benefit to individuals who subsequently held teaching-oriented positions (*e.g.*, as a teaching assistant in graduate school) or consulting roles. Additionally, it was evident that many

individuals felt their leadership and teamwork skills improved because of their experiences as a peer educator.

As a major focus of our group's work has been to identify factors that increase retention of females in engineering, we had particular interest in distinguishing gender-based differences. Analysis in this study showed that although females and males may have had different motivations for becoming tutors, they reported receiving similar benefits from their tutoring experience. These observations differ from what has been reported in previous literature. For example, Cole & Espinoza [15] found that working as a peer tutor enhanced the academic performance of females, but not males.

Many of the tutors who participated in this study decided to pursue graduate school. The soft skills they gained, the material knowledge they mastered, and the relationships they formed appeared to have impacted their confidence in their capability to succeed in graduate study and to obtain positions as teaching assistants, researchers, and mentors. Furthermore, we have presented evidence suggesting that relationships developed by respondents with their fellow peer educators and with their mentoring faculty further benefited them as tutors in that the respondents seemed to develop a strong sense of collegiality with these two groups. This camaraderie helped them to view themselves as capable, doing something of value, and fitting more comfortably into the world of not only engineering, but also academia. Although a majority of the participants (72% and 88% of respondents to the online survey and follow-up phone interviews, respectively) did attend graduate school, those respondents who did not also reported substantial benefits from tutoring that aided them in their careers, including as engineers in industry and consultants.

There are some important limitations to this study meriting further comment. First, the overall size of our sampled population was relatively small, placing challenges on statistical analysis and restricting generalizations to some extent. Additionally, only 59% of the individuals who completed the online survey participated in follow-up phone interviews. This pool of interview participants does not best represent the pool of respondents from the online survey in terms of distributions of gender, time spent tutoring, and possibly overall experiences. We note that because the Connections Program was founded with the intention of promoting upper-class women engineering students as role models for first-year students, the pool of invitees to this study and actual participants was weighted towards females. Further, any conclusions of this paper are based on self-reflective results, as all responses to the online survey and interview questions were self-reported. Finally, qualitative analysis involved interpretation of responses and judgement regarding the categories for which data best fit, which introduced some inherent human error.

Conclusions

We have investigated the impact of being a peer educator on the experiences and beliefs of undergraduate engineering tutors leading structured SI for first-year engineering students at Northeastern University between 2005 and 2018, with a particular focus on differences associated with gender. Two complementary approaches were combined in this study: statistical comparison of responses of 20 female and 9 male tutors to an online survey, and qualitative

analysis of transcripts of follow-up phone interviews with 13 women and 4 men. Applying grounded theory to transcripts allowed us to deduce that increased confidence and preparedness in future endeavors was the core category that linked participants' tutoring experiences. This increased self-confidence was the outcome of improved soft skills in communication, teamwork, and leadership and strengthened academic abilities, both resulting from a deeper understanding of subject matter. Additionally, relationships formed with fellow tutors and mentoring faculty, and a greater openness to receiving tutoring, were gained by recognizing and persevering through challenges encountered while tutoring. Females were more likely than males to both perceive increased self-confidence as well as view themselves as confidence builders for tutees. Participants in our study frequently cited that their experiences and connections formed as a peer educator have had profound impacts on their professional and personal development, not only during their time as a student but also in their post-graduate careers in graduate school and industry, with females more likely to pursue teaching as a vocation. However, regardless of whether they pursued further education or direct employment following their undergraduate degree, participants felt more prepared for, and thus more confident in, their future endeavors because of their experiences as a tutor. We also found genders differed in their tutoring motivations: women were more likely than men to be motivated by the desire for achievement to become a tutor to improve their communication skills and help others. For both genders, increased depth of engagement in tutoring, measured especially in terms of years spent as a tutor, correlated with greater perceived benefits.

This present study, combined with our previous reports focused on the efficacy of structured SI on the academic success and retention of first-year engineering students and the role of gender, demonstrates that peer tutoring can have a significant impact on the academic and professional development of both tutees and tutors, particularly female engineering students. Motivated deliverers and recipients of peer-based SI view each other as role models, an important development especially for women: tutees see tutors as individuals to whom they can aspire, and tutors perceive attending SI as not a sign of weakness, but as a tool that has a positive impact on all students, and thus become more open to receiving SI. This outcome may be key to convincing even strong students that tutoring can help them gain additional mastery of a subject area.

References

[1] K. B. Coletti, M. Covert, P. A. DiMilla, L. Gianino, and R. Reisberg, "Integrating supplemental instruction into freshman chemistry programs to support women in engineering," in *Proceedings of the American Society for Engineering Education 2012 Annual Conference and Exhibition*, San Antonio, TX, June 10-13, 2012.

[2] K. B. Coletti, M. Covert, P. A. DiMilla, L. Gianino, R. Reisberg, and E. Wisniewski, "Understanding the factors influencing student participation in supplemental instruction in freshman chemistry," in *Proceedings of the American Society for Engineering Education 2013 Annual Conference and Exhibition,* Atlanta, GA, June 23-26, 2013.

[3] K. B. Coletti, E. O. Wisniewski, R. Shapiro, P. A. DiMilla, R. Reisberg, and M. Covert, "Correlating freshman engineer's performance in a general chemistry course to their use of supplemental instruction," in *Proceedings of the American Society for Engineering Education 2014 Annual Conference and Exhibition*, Indianapolis, IN, June 15-18, 2014.

[4] E. O. Wisniewski, R. L. Shapiro, E. Kaeli, K. B. Coletti, P. A. DiMilla, and R. Reisberg, "The impact of supplemental instruction on the performance of male and female engineers in a freshman chemistry course," in *Proceedings of the American Society for Engineering Education 2015 Annual Conference and Exhibition,* Seattle, WA, June 14-17, 2015.

[5] R. L. Shapiro, E. O. Wisniewski, E. Kaeli, T. B. Cole, P. A. DiMilla, and R. Reisberg, "Role of gender and use of supplemental instruction in a required freshman chemistry course by engineering students on their course grades and subsequent academic success," in *Proceedings of the American Society for Engineering Education 2016 Annual Conference and Exhibition*, New Orleans, LA, June 26-29 2016.

[6] B. J. Priem, C. Ghio, H. Boyce, S. A. Morris, E. Kaeli, T. B. Cole, P. A. DiMilla, and R. Reisberg, "A longitudinal study of the effects of pre-college preparation and use of supplemental instruction during the first year on GPA and retention for women in engineering," in *Proceedings of the American Society of Engineering Education 2019 Annual Conference and Exhibition*, Tampa, FL, June 16-19, 2019.

[7] R. Reisberg, A. Funai, A. Interrante, S. Wadia-Fascetti, and B. Maheswaran, "Connections Physics Review (CPR) Program," in *Proceedings of the American Society of Engineering Education 2006 Annual Conference and Exhibition*, Chicago, IL, June 18-21, 2006.

[8] T. C. Dennehy and N. Dasgupta, "Female peer mentors early in college increase women's positive academic experiences and retention in engineering," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 114, no. 23, pp. 5964-5969, 2017.

[9] S. A. Lipsky and M. Kapadia, "Effects of work experiences on undergraduate peer educators," *Synergy*, vol. 6, pp. 1-10, 2013.

[10] J. Galbraith and M. Winterbottom, "Peer-tutoring: What's in it for the tutor?," *Educational Studies*, vol. 37, no. 3, pp. 321-332, 2011.

[11] A. J. T. Y. Loke and F. L. W. Chow, "Learning partnership-the experience of peer tutoring among nursing students: A qualitative study," *International Journal of Nursing Studies,* vol. 44, no. 2, pp. 237-244, 2007.

[12] J. Roy, "Engineering by the numbers," *American Society for Engineering Education*, 2019.

[13] J. LeClair, L. Shih, and S. Abraham, "Women in STEM and cybersecurity fields," in *Proceedings of the 2014 Conference for Industry and Education Collaboration*, American Society for Engineering Education, Savannah, GA, February 2014.

[14] "President Obama's record on empowering women and girls," https://obamawhitehouse.archives.gov/issues/women, (Accessed January 2020).

[15] D. G. Cole and A. Espinoza, "When gender is considered: Racial ethnic minority students in stem majors," *Journal of Women and Minorities in Science and Engineering*, vol. 15, no. 3, pp. 263-277, 2009.

[16] K. Bouthillette, "Tutor, guide, lead: examining the experiences of peer tutors," M.S. dissertation, School of Education and Social Policy, Merrimack College, North Andover, MA, 2016.

[17] L. Gafney and P. Varma-Nelson, "Evaluating peer-led team learning: A study of long-term effects on former workshop peer leaders," *Journal of Chemical Education*, vol. 84, no. 3, pp. 535-539, 2007.
[18] J. Malm, L. Bryngfors, and L.-L. Mörner, "Benefits of guiding supplemental instruction sessions for SI leaders: A Case Study for Engineering Education at a Swedish University," *Journal of Peer Learning*, vol. 5, no. 1, pp. 32-41, 2012.
[19] B. Hughes, P. Gillepsie, and H. Kail, "What they take with them: findings from the Peer Writing Tutor Alumni Research Project," *The Writing Center Journal*, vol. 30, no. 2, pp. 12-46, 2010.
[20] D. Young, L. Rudman, H. Buettner, and M. McLean, "The influence of female role models on women's implicit science cognitions," *Psychology of Women Quarterly,* vol. 37, no. 3, pp. 283-292, 2013.
[21] D. Young, D. Hoffman, and S. Reinhardt, "An exploration of the connection between participation in academic peer leadership experiences and academic success," *Journal of Peer Learning*, vol. 12, pp. 45-60, 2019.
[22] N. M. Lockie and R. J. Van Lanen, "Impact of the supplemental instruction experience on science SI leaders," *Journal of Developmental Education*, vol. 31, pp. 2-12, 2008.
[23] N. Lozada and A. Johnson, "Perspective transformation in the supplemental instruction (SI) leader," *Journal of Transformative Education*, vol. 17, no. 3, pp. 112-132, 2018.
[24] A. Badura, M. Millard, C. Johnson, A. Stewart, and S. Bartolomei, "Positive outcomes of volunteering as a peer education: a qualitative study," ERIC Document Reproduction Service no. ED 473426, 2003.
[25] B. Glaser and A. Strauss, *The Discovery of Grounded Theory*, Aldine, Chicago, 1967.
[26] K. Charmaz, "Teaching theory construction with initial Grounded Theory tools: a reflection on lessons and learning," *Qualitative Health Research*, vol. 25, no. 12, pp. 1610-1622, 2015.
[27] T. Outhred and A. Chester, "The experience of class tutors in a peer tutoring programme: a novel theoretical framework," *Australasian Journal of Peer Learning*, vol. 3, pp. 12-23, 2010.
[28] J. M. Case and G. Light, "Emerging methodologies in engineering education research," *Journal of Engineering Education*, vol. 100, pp. 186-210, 2011.
[29] D.K. Lee, "Alternatives to p value: confidence interval and effect size," *Korean Journal of Anesthesiology*, vol. 69, pp. 555-562, 2016.