AC 2010-2050: FOSTERING DISSEMINATION SKILLS IN STEM DOCTORAL STUDENTS: TIPS FOR THE PH.D. STUDENT AND THE GENERAL IMPACT ON STEM UNDERGRADUATES

Melanie Watson, Louisiana Tech University

Krystal Corbett, Louisiana Tech University

Kyle Prather, Louisiana Tech University

Jenna Carpenter, Louisiana Tech University

Stanley Cronk, Louisiana Tech University
Faculty member of College of Engineering and Science at Louisiana Tech University.

Fostering Dissemination Skills in STEM Doctoral Students: Tips for the Ph.D. Student and the General Impact on STEM Undergraduates

Abstract

Science, technology, engineering and mathematics (STEM) graduate programs typically provide insufficient instruction for doctoral students electing to pursue a career in higher education instruction. Often, doctoral students who teach classes are required to offer lectures or even full courses without any formal training[1, 2]. Therefore, a doctoral student's transition to a faculty position may raise concerns from a university administration concerned with maintaining the quality of its course delivery. This paper documents the account of three doctoral students and two engineering faculty members while co-teaching/teaching a project-centered first-year introductory engineering course. The implementation of a preparatory teaching program for doctoral students in the first-year engineering curriculum provides a unique opportunity for faculty to mentor "on the spot." The doctoral students are given one quarter of mentorship by co-teaching an introductory engineering class with an experienced faculty member. If their faculty mentor then judges that they are ready to instruct a course on their own, they are then given that opportunity. The main focus of this paper examines the doctoral students' experiences as they conclude their mentorships and develop responsibility for their own classes. Tips are provided to give insight from the doctoral students' perspective. These tips are for students attracted to a faculty career or for those institutions that may find a need to use their own doctoral students as instructors. A few of these tips include: setting the standards for classroom professionalism, gaining self-confidence while lecturing and promoting respect in the classroom. Also, the paper's assessment data evaluates the instructional efficacy of the doctoral students during their transition period from student to faculty based on several factors one of which includes the overall teaching effectiveness of the two female doctoral students versus the male doctoral student in first-year engineering classrooms.

Introduction

Program Introduction

In the undergraduate level science, technology, engineering and mathematics (STEM) courses at _________ ____University, graduate students are placed as instructors. This practice offers a valuable resource to _________ ____ as well as for graduate students. From the university's point of view, having graduate students teach courses in the undergraduate programs allows for lighter teaching loads of full time faculty members as well as flexibility in teaching schedules. Moreover, the practice is beneficial for the graduate student because it offers them the opportunity to be the instructor over a class during their graduate studies. This hones various skill sets that future employers would desire whether the graduate students pursue careers in academia or industry. For the most part, however, the graduate students are not provided with the necessary resources from the university to prepare them properly to oversee a course[1]. Thus, the university and the graduate students will not achieve the full benefits of having graduate student instructors. The common practice is graduate students are assigned a course by the university with little to no training and will be expected to have the skills of an experienced professor[1]. In contrast, the skills expected of the graduate students will not appear instantly; they will develop over time from experience. Through an understanding of successful lecturing practices and the participating in a mentorship program the graduate student development can be accelerated.

Three Ph.D. students with aid from experienced faculty members and relevant works on the subject, tips were developed outlining successful lecturing practices to assist the graduate student before beginning their first instructional course[2, 3]. The tips were developed throughout the phases of the graduate student development process. The phases included one quarter of co-teaching a course with a mentor then instructing the same course the next quarter independently. Through the experiences with the mentoring to teaching program tips were developed.

In order to foster the ideal qualities of successful lecturers within the graduate students, the mentoring to teaching program was designed by the College of ___________ and _______at _________ ____ . The graduate students work closely with experienced faculty members on a one on one basis in the first course of the freshman engineering series. This course has well-developed curriculum and dedicated instructors, therefore allowing a positive atmosphere for the inexperienced graduate student instructors to gain their initial lecturing experience. The project-based course was created through an NSF grant the courses were developed with themes from "___ ________ __ _____ _______ __ ___________ __ ___ ___ _______" and ideals from the National Science Foundation Educational Coalitions[4, 5]. The curriculum lasts three quarters spanning the undergraduate students' freshman year. Each quarter has a length of ten weeks, and classes meet twice a week for 110 minutes[6]. Using a microcontroller as a learning platform, general engineering fundamentals are taught. Seven themes, systems, electromechanical devices, fabrication and acquisition, software, fundamental engineering concepts, communication, and broadening activities, each interwoven throughout the three quarters of the first year experience are the course objectives[6, 7]. The curriculum is aptly entitled "______ ____ ___ ___" because the microcontroller acts as a mobile lab for the students. The undergraduate students are expected to maintain the microcontroller bringing it to and from class for projects and homework, essentially living everyday with their "lab." The fully developed curriculum has been refined over the years by experienced faculty members. The instructors can access pre-written lesson plans and master notes for the course, thus minimizing the amount of preparatory work required from the graduate students. Therefore, allowing for more focus to be placed on the lecturing and classroom management required for a college course. The mentorship aspect of the program helps the graduate student transition easily into the role of instructor more comfortably than just being assigned to a class without the co-teaching experience. In addition, the co-teaching aspect helps the graduate student become accustomed to various learning tools in the course that they may not have been exposed to, such as the microcontroller. As a result, this helps them become familiarized with all the material in the course prior to becoming the lecturer solely responsible for disseminating the information to the undergraduate students. Another benefit to the mentorship program is that once the co-teaching phase of the graduate student development is complete, they are still able to consult their mentor for advice throughout future quarters whenever issues arise.

Since _________ ____ utilizes graduate students as instructors, an understanding of their effect in the undergraduate students is of particular interest. Through a survey developed by graduate student instructors with aid from experienced faculty, measurement of this impact was conducted. The three graduate students designed each survey question based on core survey concepts deemed imperative to graduate student lecturing as well as determining the role that graduate student gender plays in the classroom. Certain concepts were repeated in the survey and placed in question sets so that statistical data trends would reaffirm core survey topics. Three graduate students at _________ ____ who completed their co-teaching requirement and are the sole lecturer in the undergraduate classrooms provided the surveys to their classes, yielding three class sets of data for analysis. The three classes consisted of a total of 69 undergraduate students divided amongst the classes. A 21-question survey was given early in the quarter. The survey questions were categorized into three main sections, which include:

- The graduate students age, gender, and students status,
- Having a graduate student as an instructor versus a full time faculty member,
- The graduate student instructor from the undergraduate student's experience (one group of questions worded negatively and one group of questions worded positively).

Through the information gathered from the surveys and the experiences of the graduate students and faculty members with inspiration from related works , tips for being a successful graduate student lecturer were developed[2, 3]. From the combination of the tips and the mentorship program, an easy implementable model is created that will aid other universities in maximizing the benefits associated with properly utilizing graduate students as lectures.

Tips

As a result of the graduate students' respective mentorships, a set of tips was generated from the advice of experienced faculty and influential relevant works to aid other graduate student instructors in maximizing their effectiveness in teaching[2, 3]. The following is a list of the tips in decreasing order of perceived importance from faculty.

1. Focus on the students' learning of the material as opposed to the graduate student's performance as an instructor.
2. Teach the curriculum alongside a professor and use their feedback
3. Exhibit confidence to gain respect.
4. Become comfortable with content knowledge through lecture preparation, practice, and proven lesson plans.
5. Dress professionally.
6. Be comfortable with making mistakes.
7. Keep it fun.

Despite each of these tips, the undergraduate students' learning precedes the instructor's developing skill set[7, 8]. An experienced teaching professor can provide a critical analysis of the graduate student's communication skills. Teaching alongside them provides opportunities for this feedback, allows opportunities to see how the material might successfully be taught, and familiarizes the graduate students with the material in a sheltered environment. Dressing professionally helps to set a precedent of seriousness in the coursework and authority in the lectures. Exposure to the material, both through the mentorship and through lecture preparation, serves to make the graduate student more comfortable and confident, which will help establish authority and gain the respect of students. In the event of a mistake, which is common, it is recommended that the instructor correct their error and carry on the steady pace of the lecture, maintaining their focus on student learning. Graduate student teachers are perceived as approachable and relatable. Their strength is in nearness in age and experience to their pupils, both of which are traits typified by energy and enthusiasm[2, 3].

Methods

Survey Description

The following study was conducted in conjunction with an entry-level freshman engineering curriculum. Three graduate students conducted a course alongside faculty instructors for one quarter before being assigned a course of their own. The purpose of the mentorship was to familiarize the graduate degree candidates with the curriculum, make them comfortable with the course material and teaching in the freshman course environment, as well as provide opportunities for faculty instructor feedback.

The Ph.D. candidates gave approximately one half of lectures and assisted with hands-on assignments in a project-based curriculum. The effectiveness of the graduate student-faculty instructor mentorship was evaluated via the following survey. Undergraduate students were presented these statements and prompted to respond by circling “Completely Disagree”, “Disagree”, “Neutral”, “Agree”, and “Completely Agree” from a Likert scale, in that order. The survey questions are as follows:

1. I am more comfortable with the graduate assistant because he/she is closer to my age.
2. The graduate assistant was more approachable than other faculty members.
3. I am more comfortable with the graduate assistant due to the student-status of the graduate assistant.
4. The instruction that I received from the graduate assistant was more effective than similar instruction from a faculty member.
5. I am more comfortable with my graduate assistant than the instructor due to gender.
6. It was evident that the graduate assistant had minimal college teaching experience.
7. I feel that the graduate assistant communicates effectively.
8. The graduate assistant improved in his or her ability to teach over the course of the quarter.
9. I would consider choosing a class taught by a graduate assistant in the future, even if one were also offered by a faculty member.
10. It is important that a graduate assistant dress professionally to gain the respect of the students.
11. I prefer a graduate assistant to teach my class instead of a faculty member.
12. I would be disappointed to have to take a class taught solely by a graduate assistant.
13. I feel the graduate assistant displayed mastery of the technical content delivered in this course.
14. The graduate assistant was a confident instructor.
15. The graduate assistant treated me with respect.
16. I am comfortable approaching the graduate assistant for help outside of class.
17. I have not felt discouraged about pursuing an engineering degree.
18. I will be an excellent engineer.
19. I have friends in engineering.
20. I can have a fulfilling career in engineering.
21. I feel like I belong in engineering.

Questions 1, 2, and 3 address possible perceived strengths to having graduate students as instructors. Nearness in age and student status are cited as reasons for perceived increases in approachability and comfort level. Questions 4, 9, 11, and 12 are intended to highlight disparities in the perceptions of graduate students as instructors and faculty instructors. Questions 6, 7, 8, 10, 13, and 14 are designed to critically assess the graduate students' communication and teaching skills. Question 5 addresses student perception of the gender of their graduate student instructors. Questions 17, 18, 19, 20, and 21 are focused on the undergraduate students and their personal experience in the curriculum, and provide insight as to how the students feel about their entry-level engineering courses apart from their graduate student teachers. In addition to the survey questions, students were prompted for their genders and the gender of their instructor to aid in analysis.

Description of Statistical Analysis

Based on the survey results, the overall graduate instructor impact regarding student responses were accessed using Microsoft Excel statistical methods incorporating graphical analysis and statistical significance computations. Specifically, several analysis of variance (ANOVA) tests were administered using an alpha value of 0.05 producing confident interval of 95% for statistical independency or dependence. Of the ANOVA tests, Single ANOVA and Two-Factor ANOVA with Replication were utilized to compile results based on questions compared to one another, questions compared to one another in reference to the graduate instructor and questions compared to the student's gender. The ANOVA P-value gives us a statistical confidence in the interrelated nature of the data. For P-values less than 0.05, the data are considered statistically significant and independent of one another. For values equal to or above 0.05, the data are considered dependent. Correlations are independent of ANOVA results, and are given as the Pearson correlation coefficient, r^2, for a given pair of data sets. In practical terms, a least-squares regression on the first set of data accounts for r^2 percent of the data in the second set, with the sign of the coefficient identifying whether the relationship is direct or inverse. The way the data are organized, a correlation would be a measure of how individual students opinions relate between sets. In identically distributed statistically indistinguishable sets, low correlations would show that students did not necessarily have similar opinions between questions, though in aggregate they appear to, while for high correlations they would be very likely to have had the same opinion between questions. For sets that are independent, the interpretations remain the same, although the strength or significance of those conclusions cannot be strongly asserted. It is also important to note that the ANOVA statistical significance and correlation coefficient are all in reference to student responses based on the terms of word phases utilized in each question.

Results

_________ ____'s "______ ____ ___ ___" program offers an outstanding resource for graduate student instructor development of teaching skills through in-class mentoring of first-year college students [9, 10]. Aforesaid survey question categories were utilized to discern the student's graduate instructor perception. The premise of these categories include perceived age, approachability, student status and gender of the graduate instructor. From the three graduate instructor classes, 21 survey questions using the Likert scale and one comment section were provided to 69 first-year students. Analogous questions especially those illustrating specific concepts were categorized into question sets viewed below.

Of the three graduate instructor classes, 69 students responded to the 21 questions. These results were tallied and averaged. Figure 1 displays an average per question summary of the student responses. Based on the Likert scale, means ranged from 1 to 5 with 1 representing completely disagree to 5 as completely agree. Standard deviation error bars were employed to accentuate the data uniformity between several survey questions.

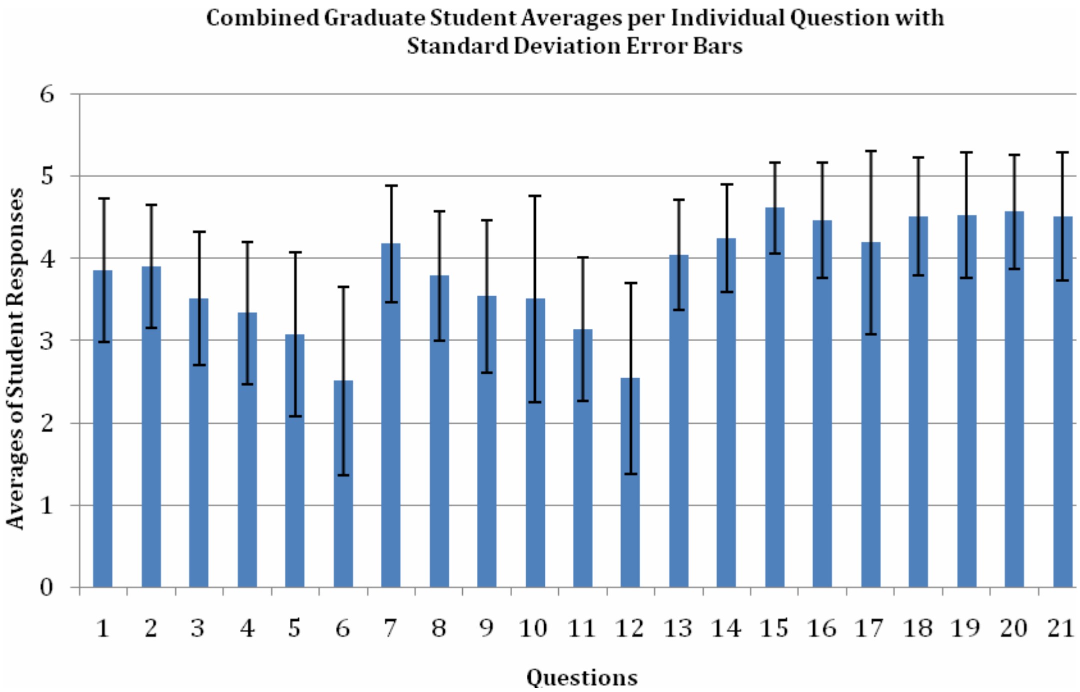

Figure 1 – Combined graduate instructor averages.

In Figures 2A and 2B, student responses were broken down into the individual graduate instructor means and means based on the gender of the graduate instructor. These averages in both figures were comparable with the standard deviation error bars as a way to verify small dissimilarities between each question. To compliment Figure 2A, a Two-Factor ANOVA with Replication test was utilized to signify statistical dependency. The ANOVA results quantified a dependence of the interactions from the three graduate instructors for each question with a P-value 0.143 thus greater that the 0.05 alpha threshold. In Figure 2B, the standard deviation error bars corroborate an overall overlap of all questions except Questions 5 and 10.

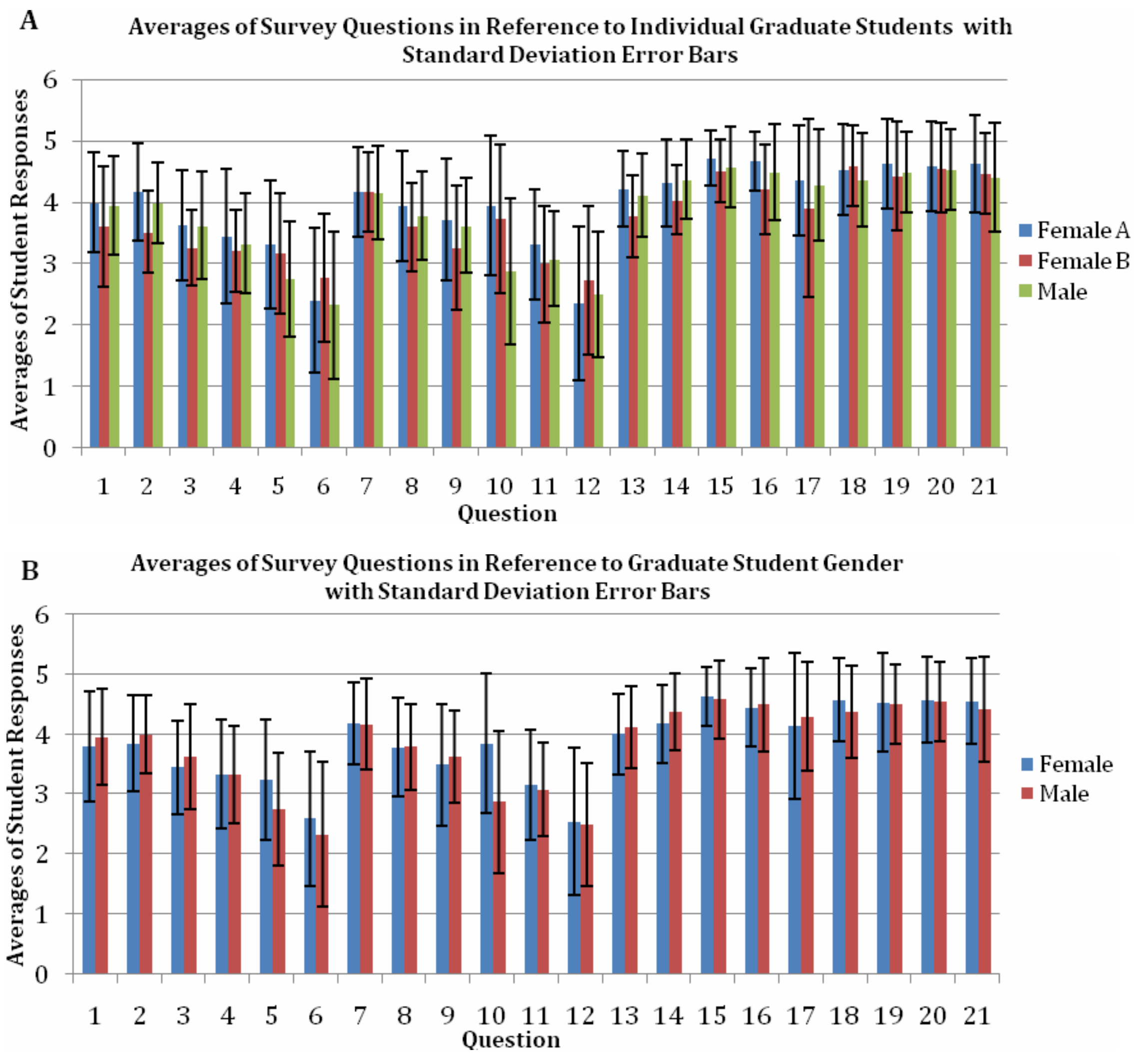

Figure 2 - A) Individual graduate instructor question averages. B) Graduate instructor question averages based on the gender of the graduate instructor.

Question sets 1, 2, 3, 4 and 5 are displayed in Figure 3. Each set represents a pairing of two to three questions. These combinations are employed to highlight particular concepts. Figure 3A uses Question set 1 to illustrate how the students perceive graduate instructors compared to full-time faculty. The results indicated an ambivalence between Questions 9 and 11. Question set 2 in Figure 3B elucidates negatively posed questions against the graduate instructors. The diagram exhibits Questions 6 and 12's mean scores of 2.5. Derived from the Likert scale, the two averages ranged between disagree and neither disagree nor agree. From Figure 3C, Question set 3 integrated Questions 7, 13 and 14 to display averages from positively posed questions. Question set 4 in Figure 3D contrasts positive and negative Questions 6 and 13 illustrating an approximate 1.5 variation between the two questions. The perceived approachability of the graduate instructors based on the student response averages is exhibited in Figure 3E as Question set 5. The diagram confirmed a clear approval of agree to completely agree.

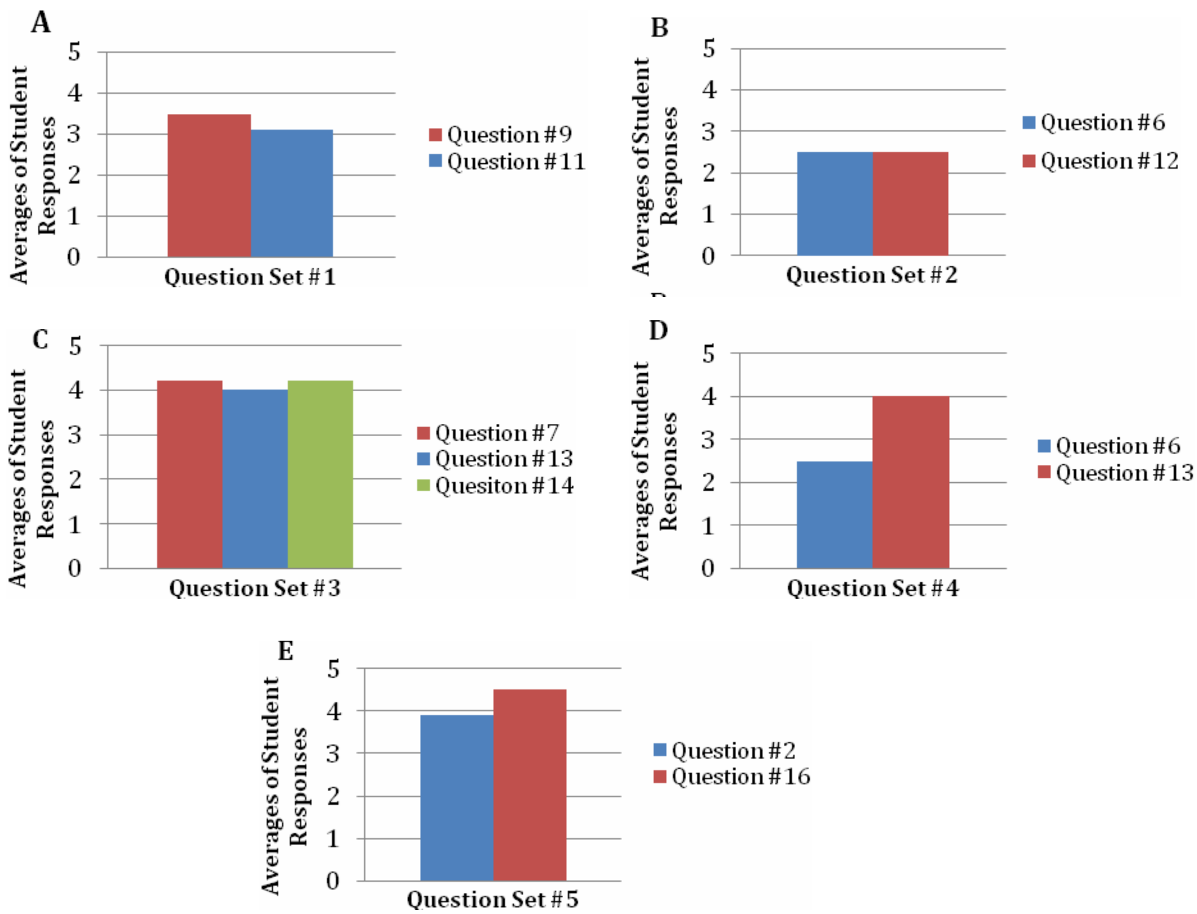

Figure 3 – Question set average pairings. A) Question set 1 B) Question set 2 C) Question set 3 D) Question set 4 E) Question set 5

A summary of Single ANOVA results and correlations data is provided in Table 1. The five question sets previously proffered are utilized in Table 1 to elucidate Figure 3 by providing ANOVA P-values and correlation results. Question set 1's P-value of 0.009 and correlation of 0.581056. The P-value is less than 0.05 implying that the results are independent between Questions 9 and 11. Though the data are not strongly correlated, the positive correlation shows an expected relationship. Contrary to Question set 1's low P-value, Question set 2 presents the highest P-value of 0.883 denoting a strong statistical dependency between Questions 6 and 12 with only slight variations between data. However, Question set 2 has a relatively low correlation of 0.324086 compared to other question sets. Question set 3 also reveals a P-value greater than the 0.05 threshold. Question set 3 maintains fair correlation for Questions 7 to 13, 7 to 14 and 13 to 14. The smallest P-value of the questions sets was computed for Questions set 4. Set 4 also calculated the only negative correlation value at -0.12425. Negative correlation data suggests, as antecedently proposed, that as one question such as Question 6 decreases the other Question 13 increases in response. Similar to set 4, Question set 5 has a P-value showing independency between Questions 2 and 16. The data also presented a low correlation.

	ANOVA	*Correlation*		
	P-value	1st Question to 2nd Question	1st Question to 3rd Question	2nd Question to 3rd Question
Question Set 1 - #9, #11	0.009299	0.581056		
Question Set 2 - #6, #12	0.882703	0.324086		
Question Set 3 - #7, #13, #14	0.206449	0.602007	0.577236	0.511718
Question Set 4 - #6, #13	5.54E-17	-0.12425		
Question Set 5 - #2, #16	1.04E-05	0.427879		

Table 1 – ANOVA P-values and correlations based on question sets 1, 2, 3, 4 and 5.

Results from Questions 17-21 are illustrated in Figure 4 below. Of the original 69 students answering the survey, only 46 students circled their gender. Of those 46 students, only 10 replied female. To compensate for the imbalance, 10 male responses to Questions 17-21 were randomly selected. This was performed by assigning a number to the 36 male results and running a random number generator for 10 numbers between 1-36. Those numbers calculated were used to compute the following diagram and Table 2. Of the 20 student responses, means for female and male answers were computed along with standard deviation error bars to emphasize the slight variations between the female and male students.

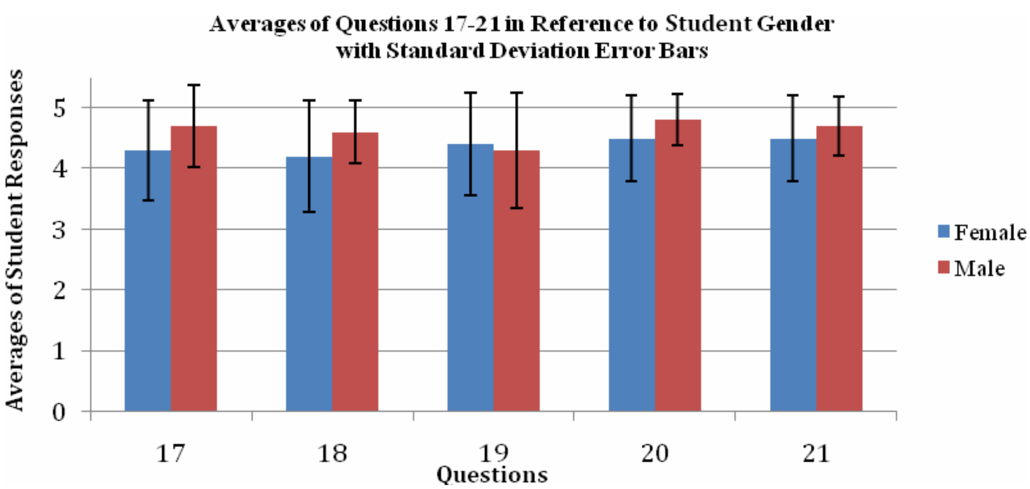

Figure 4 – Student gender related to survey Questions 17-21

A reciprocal relationship between Table 2 and Figure 4, compliment one another by defining P-values for Questions 17-21 in the table. The values were computed with a Two-Factor ANOVA with Replication so that female and male students were compared to one another in Samples. Questions 17-21 were also analyzed for statistical significance and referenced in Table 2 as Columns. From Table 2, Interactions indicate a statistical relationship between female/male students and the question averages. Each P-value exceeds the 0.05 alpha threshold for statistical insignificance in reference to their aforesaid student/questions relationships. Hence, respective P-values exhibit some to very slight variations between data sets.

Two-Factor ANOVA	
Source of Variation	*P-value*
Sample	0.1017
Columns	0.6515
Interaction	0.8023

Table 2 – Two-Factor ANOVA of Questions 17-21 in reference to the Student's Gender.

Conclusion

From Figure 1, standard deviation error bars were utilized as a method for determining the variation in responses between each question. From Questions 1, 2, 7, 8 and 13 to 21, the average responses showed little variation, all clustered at approximately 4 on the Likert scale. This implies that students as an aggregate group selected "agree" for the majority of survey questions. Questions 3, 4, 5, 9, 10 and 11 averaged around 3 suggesting that students as a whole were ambivalent in their responses. Questions 6 and 12 elicited the only average responses below 3, indicating the students as a whole selected "disagree" for their responses. It is noted that these questions were negatively posed questions directed toward the graduate instructors while the other questions were either positively posed or completely unrelated to the graduate instructors.

In Figure 2A, the standard deviation errors bars were found to overlap on several questions showing very little variation among the graduate instructors. Therefore, the results gathered from this survey must be similar, as demonstrated by the highly similar responses from the classes of each graduate instructor. This was confirmed with the Two-Factor ANOVA results. The interactions of the three graduate instructor classes for each question show a P-value of 0.143 suggesting a statistical dependency between the three graduate instructors. Similar student responses between classes reaffirm each class survey's Likert scale rating.

Figure 2B shows that student responses were indifferent as to the gender of the graduate instructor for all questions except Questions 5 and 10. Question 5 asked if the students are more comfortable with the graduate instructor due to the graduate instructor's gender. Both male and female students preferred the female graduate instructors. Interestingly, the average response to Question 10 indicates something of a double standard, as it implicitly displays an overwhelming suggestion to only female graduate students to dress professionally so that they may gain the respect of the students.

Question sets were used to compare responses to specific questions. This allows topics of interest to be examined. As stated in Table 1, the information presented was used to further verify the significance of each chart in Figure 3. In Figure 3A, Questions 9 and 11 requested students to determine whether or not they prefer the graduate students or faculty members for course instruction. Results from the figure, correlation and the P-value indicate that the students were ambivalent. One reason students may have responded in such a way is due to a majority of students are only in their first or second quarter of college and thus have had little experience with faculty members or other graduate instructors. From Figure 3B, students generally disagreed with the negatively posed questions, suggesting that they are responding positively to being instructed by graduate instructors. According to Question set 3 in Figure 3C, the students across the board agreed that each graduate instructor was effective in teaching, respectful toward students and proved a mastery of technical content. Question set 4 in Figure 3D and its coinciding data in Table 1 portrayed the most variation between two questions in a set. These results imply a completely opposite opinion between Questions 6 and 13 with Question 6 as the negative query and Question 13 as the positive. The opinion appears in favor of the graduate instructor. Figure 3E and Question set 5 results in Table 1 confirm the student's approving assessment of graduate instructors.

Figure 4 and Table 2 annotations conclude a significant relationship between female and male students, Questions 17-21 and the interaction between female/male students and the questions. The Sample row in Table 2 correlates with the female and male sets in Figure 4. The Sample 0.101 P-value implies a dependency from the female and male responses. Thus, female and male students tended to reply in a similar fashion although it is important to note that female and male students responses are not dependent on one another. The Columns' P-value of 0.651 indicates a dependency between each question. As these questions were posed in a similar nature, it is logical that student responses would maintain slight variations between questions. A high 0.802 Interaction P-value suggests strong statistical relationships between student responses and questions. These results affirm female students answered similarly to male students. The data account for an approximation of first-year students' feelings of comfort in an engineering program. The graduate instructor's dissemination abilities and confidence may correspond to the male and female students' self-confidence in becoming an engineer. The positive female/male responses in Figure 4 support the previous postulation.

The overall results of the survey validate the positive influences of the graduate instructors on the first-year college students and support the strategies suggested in the Introduction section. The objectives of this paper have been met by providing a lecturing model for other graduate students based on student survey responses with advice for teaching skills in hopes that other graduate students succeed in their early lecturing experiences.

Bibliography

1. J. D. Nyquist, L. Manning, D. H. Wulff, A. E. Austin, J. Sprague, P. K. Fraser, C. Calcagno, B. Woodford, "On the Road to Becoming a Professor: The Graduate Student Experience" *Change*, **31**[3] (1999) 18-27
2. A. S. Pruitt-Logan, J. G. Gaff, J. E. Jentoft, "Preparing Future Faculty in the Sciences and Mathematics: A Guide for Change" *Association of American Colleges and Universities*, Washington, DC (2002) ISBN 0-9702680-1-7
3. W. J. McKeachie, M. Svinicki, "McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers: 12th edition" *Houghton Mifflin*, Geneva, IL (2006) ISBN 0-6185155-6-9
4. National Academy of Engineering, "The Engineer of 2020." *The National Academies Press*, Washington DC, (2004) www.nap.edu
5. J. Richardson, C. Corleto, J. Froyd, P. K. Imbrie, J. Parker, R. Roedel, "Freshman Design Projects in the Foundation Coalition." *1998 Frontiers in Education Conference*, Tempe, Arizona (1998)

6. S. Cronk, D. E. Hall, J. Nelson, "Living with the Lab: A Project-Based Curriculum for First-Year Engineering Students", *American Society for Engineering Education Gulf Southwest Division Annual Conference*, Waco, Texas (2009)
7. D. E. Hall, S. Cronk, J. Nelson, P. Brackin, "The Facilitation of Lifelong Learning Skills through a Project-Based Freshman Engineering Curriculum" *American Society for Engineering Education Annual Conference and Exposition*, (2009)
8. J. W. Rushin, J. De Saix, A. Lumsden, D. P. Streubel, G. Summers, C. Bernson, "Graduate Teaching Assistant Training: A Basis for Improvement of College Biology Teaching & Faculty Development" *The American Biology Teacher*, **59**[2] (1997) 86-90
9. A. E. Austin, "Preparing the Next Generation of Faculty: Graduate School as Socialization to the Academic Career" *The Journal of Higher Education*, **73**[1] Special Issue: The Faculty in the New Millennium (2002) 94-122
10. L. R. Prieto, E. M. Altmaier, "The Relationship of Prior Training and Previous Teaching Experience to Self-efficacy Among Graduate Teaching Assistants" *Research in Higher Education*, **35**[4] (1994) 361-365