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From the Undergraduate Student Perspective: The Role of Graduate Students in an Undergraduate Research Program

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Abstract

Research experiences for undergraduates have increased in availability at universities and government laboratories throughout the nation. Government agencies, universities and private donors support these activities with a variety of expectations, including providing a more skilled workforce, creating a greater emphasis on graduate education and increased retention of students in highly technical fields. While the value of these programs has been well-established, there is a paucity of empirically-based research on the various models and practices of these experiences that have the greatest impact on the students. The focus of this study was a National Science Foundation funded Research Experience for Undergraduate (REU) program at a 4-year college in the Midwest funded for over 7 years. In a previous study we found that REU students interacted more frequently with graduate students than their faculty advisor while in the program. In this study we examined more closely the role of the graduate student mentors and how it directly influenced the REU student experience. Two data sources analyzed in this study were pre- and post-program surveys and semi-structured interviews, both administered to the REU students. Three main themes emerged from the data, including: 1) *Academics and Careers*, 2) *Teaching and Learning*, and 3) *Building Relationships*.

When examining the nature of these interactions, 75% of REU students reported having influential experience with their graduate student mentors related to *Academic Programs and Careers* and 100% reported influential experiences related to *Teaching and Learning* and *Building Relationships*. In exploring *Academic Programs and Careers* further, many of the experiences were related directly to the undergraduates' academic and career paths and exposure to graduate school and laboratory careers. In *Teaching and Learning*, REU students described various methods and strategies (i.e., demonstration, questioning, and discussion) the graduate students used to teach them about their research project. In regards to *Building Relationships*, the graduate students were described as mentors, collaborators, and supervisors. In summary, this research provides insight into role of the graduate student mentors in an REU program and how they directly influence undergraduate students experiences with engineering research, graduate school and careers while in the program.

Introduction

Participation in undergraduate research programs continues to increase at universities, national laboratories and other institutions across the United States. [1,2]. While other models can be used, undergraduate research typically involves undergraduate students working collaboratively with a senior scientist mentor to conduct authentic research that produces original work. The development and expansion of undergraduate research at research universities can be directly attributed to reform efforts throughout the 1980s and 1990s. Reform efforts emerged due to research universities being highly criticized for emphasizing research over teaching [2]. The Boyer Commission report in 1998 was the main change agent of undergraduate education reform. This report called for universities to provide more research opportunities to undergraduate

students. The report also outlined strategies and recommendations for research universities on how to integrate research into undergraduate education. Undergraduate research was viewed as the solution to balance out research and teaching at research universities and improve the undergraduate education experience Boyer Commission, [3].

Since 1998, there has been a substantial increase of student participation in undergraduate research and a widespread trend at research universities to develop institution-wide, centralized undergraduate research programs [1,2]. Furthermore, empirically-based studies have measured student benefits of undergraduate research, though, most of these studies were conducted on liberal art colleges [4-8]. In general, these studies suggest that undergraduate research has professional, intellectual, and personal benefits on undergraduate students. However, further research on student benefits of undergraduate research at all types of institutions, especially research universities, is critical in order to gain a better understanding of their impact and to develop the most effective practices for various educational environments. As more undergraduate students seek out research opportunities, research universities have been challenged with offering a sufficient number of quality experiences. [9-11].

Traditionally, the model of undergraduate research consists of a faculty member providing one-on-one mentoring to an undergraduate student. However, this model becomes impractical with the disproportional student-faculty ratio and the faculty members' other demanding professional responsibilities that are typically more valued in the tenure and promotion process [6,9,12,13]. To offer more undergraduate research opportunities, alternative models that involve graduate students have been developed and examined [8,9,12-14]. In addition, national position reports such as one published by the National Science Foundation in 1996NSF, [15] support and encourage universities to provide graduate students with the opportunity to mentor in undergraduate research programs[15]. The influence of graduate student involvement in undergraduate research has largely been unexamined in the literature. Thus, the purpose of this study was to examine the interactions between undergraduate students and graduate students to help define the graduate student role in undergraduate research program.

Methods

Description of Program

From 2006 - 2012, a Midwest research university has delivered a Research Experience for Undergraduate (REU) program. For 10-weeks in the summer approximately 10 - 15 undergraduate students participate in this program. Students are paired with a faculty member based on project rankings, student background, academic level and experience. Depending on the structure of the laboratory, the undergraduate student either works directly with the faculty member or the faculty member assigns a graduate student to work with the undergraduate student. Under the guidance of the faculty member or faculty member/graduate student, the undergraduate students conduct a research project focused on engineering approaches to study the treatment of diabetes or its complications. In the model of graduate student mentors, the graduate student and undergraduate have periodic meetings with the faculty member to report their progress and discuss data/results.

Participating faculty are from a variety of departments, including Biomedical Engineering, Chemical Engineering, Mechanical Engineering, Biology, Chemistry, and the School of Medicine. Diabetes is a complex pathologic condition and addressing the disease requires a diverse set of approaches from fundamental understanding of disease pathology, disease management and treatment either of the disease directly or one of its many complications. The students' research projects are developed from ongoing work in the laboratories. The research projects of the undergraduate students covered a diversity of topics related to diabetes, including metabolic engineering, biomaterials, biosensors, and tissue engineering.

In addition to conducting research, students participated in weekly seminars on topics related to diabetes (basic research, clinical treatment public health and policy), weekly ethics seminars, and off-campus tours of research and clinical facilities. These activities were designed to expose students to the broad health implications of the disease and the importance of research related to the treatment and potential cures for this disease and its complications.

Sample

Since the inception of the REU program in 2009 at the Midwest research university, there have been a total of 50 undergraduate student participants. This study focused on the undergraduate students who participated in a Research Experience for Undergraduate (REU) in 2012. There were a total of thirteen undergraduate students who participated in the program in 2012. Five of the 13 students worked directly with a faculty member and eight students were assigned a graduate student mentor in addition to working with faculty mentor. This study focused only on the eight undergraduate students who were assigned a graduate student mentor. Of the eight students, six students attended four-year universities and two attended local community colleges. Four of the student attending four-year universities had declared/planned to major in biomedical engineering, one in bioelectronics, and one in industrial engineering and economics. One of the community college students was planning on pursuing a degree in biology and the other was considering engineering, biostatistics or economics. The race/ethnicity of the students were White (62.5%), two Hispanic (25%), and one Libyan American (12.5%).

Data Collection of Analysis

There were two assessments that gathered data on the research question. The two assessments were a pre- and post-survey and an exit interview and both were administered at the end of the program. The pre-surveys asked students for demographic information (i.e., race/ethnicity) and both the pre- and post-survey asked the students about their academic and career plans. There were three items in the post-survey and three items in the exit interview that asked the undergraduate students about their graduate student mentor. The three survey questions were: 1) How many hours per week did you work with the graduate student?; 2) What role did the graduate student have in the REU program?; and, 3) What experiences did you share with the graduate student?. The semi-structured interview items were: 1) Describe your overall experience with your graduate student; 2) Describe the learning experiences you had with your graduate student; 3) Describe relationship-building experiences you had with your graduate student; and 4) Describe personal development experiences you had with your graduate student. To maintain consistency across the interviews, the first author conducted all interviews.

The constant comparative method was used to analyze the survey and interview data. This method of analysis was developed by Glaser and Strauss in 1967 as a process to develop grounded theory[16]. The constant comparative method is used to analyze qualitative data by constructing themes and/or categories and the interpretations of the emergent constructs constitute the findings of the study. Units of data from the student responses, from the survey and interview, deemed relevant to the study were constantly compared with one another. The reoccurring incidents and patterns in the data were constructed into themes. Criteria used to allocate data to a theme became more clearly defined throughout the data analysis. Triangulation of the survey and interview data sources established the validity of the emergent findings.

Based on the data collected from the surveys and interviews, there were three themes to the graduate student role in undergraduate research: 1) ACADEMIC PROGRAMS AND CAREERS in STEM fields; 2) TEACHING AND LEARNING in the STEM fields; and, BUILDING RELATIONSHIPS in the STEM fields. Frequencies were calculated of the themes. The frequencies were used as a way to gauge, from the undergraduate students' perspective, the importance of certain aspects of the graduate students role. In addition, definitions and student quotes that represent the aspects of the graduate student role will be presented in the results section.

Results

On average, the eight undergraduate students indicated that they worked with the graduate student mentors for approximately 23 hours per week compared to the three hours with their faculty mentor. As described below the nature of the interactions evolved over the 10 weeks of the program. Initially, significant hands-on guidance and training on research techniques was performed by the graduate students. In later weeks graduate students allowed the undergraduates more freedom in performing research but provided guidance and input on data analysis and presentation.

Based on the data collected from the surveys and interviews with the undergraduate students, the graduate student role was analyzed. In total, there were 269 units of data from the surveys and interviews that were deemed relevant to the research question. At the theme level, 47 units of data (18% of the total units) were placed in the ACADEMICS AND CAREERS theme, 97 units of data (36% of the total units) in the TEACHING AND LEARNING theme, and 125 units of data (46% of the total units) in the BUILDING RELATIONSHIPS theme. The frequencies of the themes are displayed in Figure 2. As mentioned, the frequencies were calculated to gauge the how much the undergraduate students emphasized certain aspects of the graduate student role.

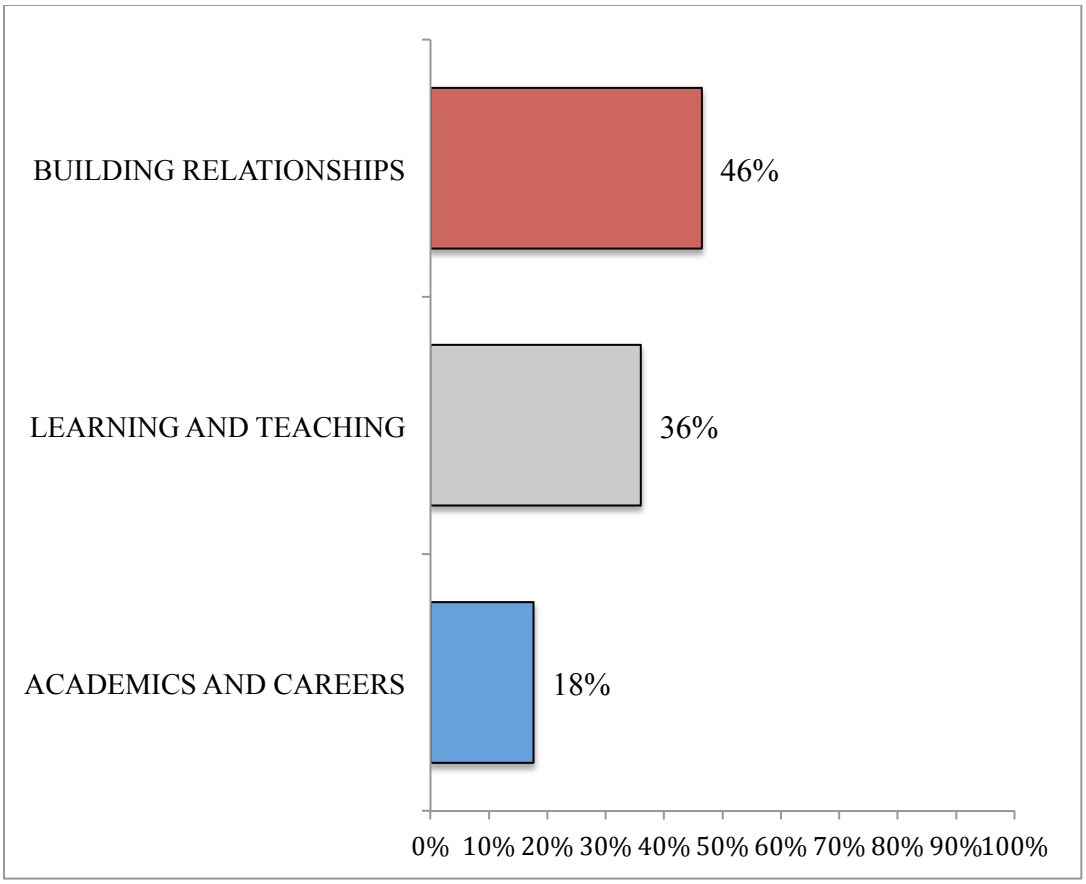

Figure 1. The frequency of student responses on the graduate student role that had emerged from the data analysis and placed into the three themes of ACADEMICS AND CAREERS, LEARNING AND TEACHING, and BUILDING RELATIONSHIPS.

Academics and Careers

The ACADEMICS AND CAREERS theme related to the graduate students providing undergraduate students with experiences that influenced their understanding of academic programs and careers in the STEM fields. Six of the eight students indicated having experiences with the graduate students that related to this theme. The undergraduate students described the discussions they had with their graduate student about academics and careers. The discussions with the graduate students helped the undergraduates clarify and solidify their own academic and career plans. Four had plans to go directly to graduate school and the other four had plans to work one or two years before going to graduate school. According to the survey and interview responses, the graduate students helped the undergraduate students' "plan and prepare" for their next steps and to understand "what it takes to succeed". As indicated in an interview with a community college student,

> *"I have to say working with my graduate student mentor definitely put some thoughts into my head that I didn't think would be there about my future academic plans. So for someone like me who comes from a very humble background and who goes to a community college…I mean that is a huge deal".*

Second, within the ACADEMICS AND CAREERS theme, students described experiences that had to do with how the graduate student influenced the undergraduate students' understanding of the realities and rewards with working in a laboratory. The graduate student introduced the undergraduate students to the "day to day" at work tasks involved in a laboratory career. The undergraduate students indicated that the graduate students helped them gain a better understanding of laboratory career "roles" and the hierarchy and dynamics of the laboratory work environment. In addition, undergraduate students indicated that the graduate students influenced their level of "value" for the work that occurs in a laboratory. As indicated in an interview response of a 4-year university student,

> *"...at the end of the project I did all of the analysis of our results. So doing that and actually seeing that and being like oh look at this this is something that other studies hadn't seen before I mean that was pretty cool. It was rewarding it made me feel like this is really is important..."*

Lastly, within the ACADEMICS AND CAREERS theme, experiences were related to the graduate student providing the undergraduate students with firsthand experience with graduate school. Specifically, the undergraduate students indicated that their experiences with the graduate students allow them to experience the "life" of a graduate. As indicated in an interview response of a 4-year university student,

> *"Seeing what the life of the graduate student was like. So her schedule was very sporadic. Some days she would have to come in at nine. Other days she wouldn't get in until noon or one and so that was like interesting to me and it had to do with the schedule she had to do."*

Teaching and Learning

The TEACHING and LEARNING theme related to the approaches used by the graduate students to develop the undergraduates understanding of concepts and skills relevant to the STEM fields. All eight students indicated having experiences with the graduate students that related to this theme. First, within the TEACHING and LEARNING theme, the undergraduate students often described the approaches that the graduate students used to help them with their research projects. Specifically, the undergraduate students indicated that the graduate students used "discussion and questioning", "demonstrations and scaffolding", and "resources". The undergraduate students often described the graduate students being very helpful and accessible to answering their questions. A couple undergraduate students mentioned that their graduate students provided them with journal articles and other additional readings to help them better understand the purpose of the research. It was often mentioned that the graduate students would demonstrate procedures and how to use equipment to the undergraduate students, multiple times if needed. Particularly, for the more complicated procedures, the undergraduate students described doing procedures together with the graduate students; then they would do the procedures with the graduate student close by to answer questions; and, eventually they would do the procedure all on their own. As indicated in an interview with a 4-year university student,

> "*Well at first I interacted with her a lot because she had to show me how to do everything. She would also explain to me more in depth about the research. But once I got going it wasn't on a daily basis it was more like once a week."*

Second, within the TEACHING and LEARNING theme, experiences dealt with the graduate student teaching the student how to design and conduct scientific research. This involved the various aspects of research, including the question/purpose, the design, procedures and techniques, equipment and technology, and data collection and analysis. Also, learning how to problem solve when faced with setbacks or failures related to the research. "Techniques" was one of the subcategories and this involved the graduate student teaching the undergraduates how to do procedures and use the equipment and technology. The other two subcategories were "data" support, and "problem solving". As indicated in a survey of a 4-year university student,

> "*The graduate students helped me perform day-to day task. Often she would teach me procedures or supervise the experiments I was performing. If I had any trouble, she would be the first person I went to for help. She also helped a great deal in data analysis and processing."*

Lastly, within the TEACHING and LEARNING theme, communication was emphasized. Undergraduate students were required to write a research report and present their work at the end of the program. Experiences in this category involved the graduate student editing the final report and the presentation slides. The undergraduate students also mentioned practicing their presentation with the graduate students before presenting their work at the program symposium. The feedback received from the graduate students focused on format and content of the work. As indicated in an interview with a 4-year university student,

> *"Giving her the presentation to go over and her going through it an butchering it. It was eye opening. But it was helpful to learn what you would need to provide, what is useful information is and what is not. She also showed me the ins and outs of preparing and giving a presentation to a more professional environment. And then in terms of writing our report or journal was kind of the same process. She provided feedback on what was important to include and how to write up the parts of the paper. So she was very guiding in terms of the professional expectations at the end of the program"*

Building Relationships

The BUILDING RELATIONSHIPS theme related to the various aspects of the relationship that the graduate students built with the undergraduate students. All eight students indicated having experiences with the graduate students related to this theme. First, within the BUILDING RELATIONSHIP theme, the undergraduate students described receiving encouragement and guidance from the graduate students. The undergraduate students would refer to the graduate students as their mentors or described the graduate students as being helpful and supportive to them in general or with their research. As indicated in an interview with a 4-year university student,

> *"I guess I really liked how she doesn't look down on me. She didn't think like here is this undergrad who doesn't know anything. She thought positively about me and believed that I have the potential to do stuff. That is how I would like to be as a mentor to someone."*

Second, within the BUILDING RELATIONSHIP theme, undergraduate identified collaboration with graduate mentor. The undergraduate students mentioned that the graduate student was readily accessible as they were often working in the laboratory. In addition, the undergraduate students described feeling comfortable and at ease approaching the graduate students for help. At the same time, some undergraduate students described working challenges they had with the graduate student. Some graduate students were outwardly frustrated with the undergraduate students lack of understanding or knowledge related to the research. Also, the graduate students came across as being stressed because they had their own research to focus on and working with the undergraduate was time consuming. Throughout the program, the undergraduate students described how their interactions with the graduate students changed. At the beginning of the summer, the undergraduate students worked closely with the graduate student and then eventually began working independently on their own. The undergraduate students described this shift to be a positive experience for them. As indicated in an interview with a 4-year university student,

> *"Well at first I interacted with her a lot because she had to show me how to do everything. She needed to explain to me more in depth about the research. But once I got going it wasn't on a daily basis, it was more like once a week."*

Lastly, within the BUILDING RELATIONSHIP theme, the undergraduate students described the graduate students more like a leader or a director. Experiences in this category involved the graduate students directing the students to do certain tasks and giving them a schedule to help them structure their research work. In addition, the graduate students were described as providing the undergraduate students with performance expectations and feedback. As indicated in an interview with a 4-year university student, "*He reviewed what I was going to test basically and would check my data every so often."*

Discussion

The findings of this study provide an in-depth understanding of the graduate student role in an undergraduate research program. The role of the graduate student was analyzed at three levels of specificity. From the perspective of the undergraduate students, there were three main themes to the graduate student role - ACADEMICS and CAREERS, TEACHING and LEARNING, and BUILDING RELATIONSHIPS. The ACADEMICS and CAREERS theme related to the graduate students being able to provide undergraduate students with experiences that influenced their understanding of academic programs and careers in the STEM fields. The TEACHING and LEARNING theme related to the approaches used by the graduate students to develop the undergraduates understanding of concepts and skills relevant to the STEM fields. The BUILDING RELATIONSHIPS theme related to the various aspects of the relationship that the graduate students built with the undergraduate students.

Interviews with the students helped identify general aspects of the graduate student role and could lead to division of the themes into categories for further analusis. The ACADEMICS and CAREERS theme could be divided into three general categories – *undergraduate paths*, *laboratory careers*, and *graduate school*. The TEACHING and LEARNING theme could be divided into three general categories – *teaching approaches*, *research*, and *communication*. The

BUILDING RELATIONSHIPS could be divided into three general categories - *mentoring*, *collaborative*, and *supervisory*. In future studies we plan on providing a more sophisticated and structured analysis of these categories. This analysis would could be used to gauge the importance of certain aspects of the graduate students role.

The findings of this study are aligned with previous studies that examined the student benefits of being involved in undergraduate research experiences. From this study, the three main themes ACADEMICS and CAREERS, TEACHING and LEARNING, and BUILIDNG RELATIONSHIPS of the graduate student role align with the previously reported professional, intellectual, and personal undergraduate student benefits, respectively [4-7,17]. However, it is critical to keep in mind that most of these previous studies on undergraduate student benefits were conducted at liberal art colleges with faculty members providing the one-on-one mentoring to the undergraduate students. Whereas, this study focused specifically on undergraduate students who were assigned graduate students by the faculty members whose laboratories they were working in at a research university.

The responses of the eight undergraduate students indicated various approaches used by the graduate students to teach them knowledge and skills relevant to their research project. The graduate students were described as engaging the undergraduates in discussion and answering questions they had about their research. In addition, the graduate students demonstrated how to do procedures and, if necessary, would use scaffolding to make complex procedure more manageable to understand and eventually do on their own. Furthermore, the graduate students reportedly provided the undergraduate students with additional resources to help them understand the purpose and relevancy of their research project. Despite that the findings provide insight into the type of approaches used by the graduate student mentors they provide no measurement of their effectiveness. In the context of undergraduate research, no studies have been found to exist in the literature that examine the effectiveness of pedagogical approaches used in undergraduate research programs. Therefore, it is critical that future research studies are conducted to examine the effectiveness of pedagogical approaches used by both graduate students and faculty.

Gaining research experiences and communicating research findings has been reported as an undergraduate student benefit in previous studies on undergraduate research. In general, research is the primary responsibility of graduate students and just one of many demanding responsibilities of faculty. Typically, graduate students spend the majority of their time working in the laboratory. As for the eight students who were assigned a graduate student, most of them mentioned that their graduate student mentor was consistently in the laboratory. In this study, the undergraduate students frequently described the graduate students being available to help them locate materials and use equipment, collect and analyze data, and problem solve setbacks or failures.

Comparatively, help from the faculty members was described by the undergraduate students to be more infrequent and tended to occur at the weekly lab meetings. Something that the undergraduate students mentioned about their faculty mentors, and not the graduate students, was that they were able to clearly provide an overview of their research agenda and how their particular project fit in to that agenda. Previous research that examined the interactions of the

undergraduate-graduate-faculty triad also reported similar findings [13,14]. Specifically, undergraduate students in this previous studies mentioned that they kept the "big picture" questions and discussions about the direction of their research projects for meetings with the faculty mentors. The findings of this study and previous research suggest that there are some responsibilities that graduate students and faculty can share but others that can only be provided by either the graduate student or the faculty. Further research is needed to better define the appropriate roles and responsibilities of graduate student and faculty mentors in undergraduate research program.

Preparing more graduate students to be the primary mentor to undergraduate students in undergraduate research programs is of particular importance, especially as new programs are being developed and existing programs are being expanded at academic institutions across the U.S [1,2]. As mentioned, in the introduction, it is impractical to think that faculty members can be the primary mentors to the increasing numbers of undergraduates seeking out research opportunities. However, the findings of this study do suggest that it remains essential that faculty members continue to provide mentorship to the undergraduate students. To understand the type and level of mentorship provided by both the graduate students and faculty requires further research on the mentor role in undergraduate research program.

These findings have the potential to influence existing and future undergraduate research experiences in many ways. First, calling on graduate students to provide one-on-one mentoring will expand the capacity of institutions to offer more research experiences to undergraduate students. Second, this study defined the graduate student role at three levels of specificity. In general, graduate students do not have much prior mentoring experience and, furthermore, mentoring is not a typical component of graduate programs. The development of mentoring skills is essential for graduate students, especially for those who plan on pursuing a faculty career. The various aspects of the graduate student role defined in this study is useful information for graduate students to know about prior to providing one-on-one mentoring to undergraduate students. Third, mentoring program for graduate students have been developed, however, they would benefit from integrating these findings into their curriculum. Therefore, academic institutions that are expanding or developing undergraduate research experiences should also consider implementing programs to prepare graduate students to take on the role and responsibilities that come along with providing one-on-one mentoring to undergraduate students in research.

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