UNDERGRADUATE RESEARCH IN SCIENCE: MOTIVATING FACTORS, EXPECTATIONS, AND OUTCOMES OF THE RESEARCH EXPERIENCE

by

LARA BRONGO PACIFICI

(Under the Direction of Norman Thomson)

ABSTRACT

Undergraduate research in science has gained support and popularity over the past decade. Research on the outcomes of undergraduate research in science is abundant and reflects numerous positive gains associated with research experiences. Understanding of the influences that guide students to pursue undergraduate research in science is, however, lacking. Further, while outcomes are well-defined, insight to how outcomes relate to students' expectations of the research experience is deficient. The purpose of this dissertation is to address these areas of vague understanding regarding undergraduate research in science. The first chapter uses exploratory and confirmatory factor analysis to examine factors influencing students' participation in science undergraduate research. The second chapter examines students' expectations of their science research experiences in comparison to the realized outcomes that they report. The third chapter compares and contrasts the influences and expectations of pre-med and non-pre-med students doing undergraduate research in science. Online questionnaires, follow-up interviews, and participant observation were used to collect data. Path analysis and qualitative methods gleaned from Grounded Theory were used for a mixed methods analysis. Accessibility and social influences had the greatest effect on participation in research. Expectations tracked outcomes in most areas, but not in the case of GPA, publishing, and faculty interactions. Attitudes and intrinsic motivation of pre-med students were less than that of non-pre-med students, but their expectations of the research experience did not differ. Implications of this dissertation include the necessity of increased access to undergraduate research programs and possible differentiation of undergraduate research programs to best serve different groups of students.

INDEX WORDS: Undergraduate research, Theory of Planned Behavior, Social Cognitive Theory, Exploratory Factor Analysis, Confirmatory Factor Analysis, Path analysis, Grounded Theory, Undergraduate science education, Pre-med students

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DEDICATION

My dissertation is dedicated to my grandparents – Gerard & Christine (Della Pietra) Beauchamp, Ralph Brongo, and Geraldine (Partridge) McWilliams – who showed me the value of hard work, the power of a good hug, and the importance of family.

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CHAPTER 1

INTRODUCTION

In 1998, the report of the Boyer Commission encouraged research universities to shift away from the research versus teaching dichotomy towards an integration of research and learning (Boyer commission, 1998). The Boyer report suggested increased undergraduate research (UR) experiences for students at research universities as one way to bridge the gap between research and learning. Undergraduate research in science has increased greatly at liberal arts colleges and research universities alike in the years since the Boyer Report (Hu, Kuh, & Gayles, 2007).

Several research studies have examined the benefits, such as increased research skills and understanding of the nature and development of scientific knowledge, gained by students through experiences with undergraduate science research (e.g. Kremmer & Bringle, 1990; Ryder, Leach, & Driver, 1999; Kardash, 2000; Seymour, Hunter, Laursen, & Deantoni, 2004) and have made a strong case for the importance of undergraduate research. For example, Seymour et al. (2004) found that experiences in science research helped undergraduates clarify, refine, and/or confirm students' preexisting choice of career directions, including graduate or professional school. Seymour et al.'s (2004) data encourage educators and scientists to promote UR, but despite these studies, we still lack an understanding of the factors that initiate students' interest in undergraduate research. Similarly, while researchers report that UR can have an effect on choice of career directions, there is little research on the relationship between students' expectations for and outcomes of their research experiences.

My dissertation research first seeks to better understand the particular factors, including attitudes, motivations, and social influences that students use in making decisions to pursue UR in science and their future career and educational decisions. And second, it seeks to illustrate the degree to which expectations of research experiences are met. Third, several avenues exist for UR opportunities at the University of Georgia – some students are paid for research while others earn course credit, some students develop their own research questions while others contribute to set research protocols, some work in the lab while others work in the field. It is quite possible that influences, expectations, and outcomes may vary among the different research experiences. With the understanding gained from these three research foci, undergraduate research experiences could be tailored, promoted, and implemented to best serve more students.

Roadmap

The first chapter of this dissertation presents a model for student influences to do research. The model is tested both to assess how well the model fits with the questionnaire data and also to determine which factors have the greatest influence on students' decisions to do UR in science. Follow-up interview data are analyzed to obtain a multi-dimensional understanding of the deeper explanations behind the constructs indicated by the quantitative data to be influential in students' decisions to do research. This chapter provides a starting point for future research examining UR in different contexts and between different groups of students.

The second chapter focuses only on students who have participated in UR in science to understand how their expectations of the UR experiences compare to the perceived outcomes they experience. Questionnaire data on expectations of UR, collected before a semester of UR in science, is compared to questionnaire data on the outcomes of the UR experience, collected after the semester of research. Interview data provides deeper explanation for the relationships between expectations and outcomes represented by the quantitative data. This chapter provides a different perspective to the several research studies that look only at the outcomes of research. By comparing the outcomes to what the students expect going into the experience, the benefits of research may be interpreted from a student-centered instead of an institutional perspective.

The third chapter goes back to the constructs of the model tested in the first chapter and examines how they compare between pre-med and non-pre-med students. Questionnaire data from pre-med students is compared to that of non-pre-med students is to examine what differences might exist in the influences on research and the expectations of research experiences between the two groups of students. Again, interviews provide a depth of explanation not available in the quantitative data. This chapter presents a deviation from the idea that UR experiences in science serve the same purpose for every student and illustrates one example of how different groups of students may encounter UR experiences.

Together, the three chapters of this dissertation provide a multi-faceted view of students' pursuits of UR experiences in science. The first chapter builds the foundation for the other two chapters, which provide more specific analysis. These three chapters cannot cover the wide array of possible research questions about why different students do research and how they perceive their research experiences, but they do provide interesting conclusions to several aspects that are key in understanding UR in science. Future research can pick up where this dissertation leaves off to further explore UR in different contexts and with different students.

Subjectivities

I have had diverse experiences that have led me to my interest in science education in general and, more specifically, to the study of students doing research. My earlier education was in biological sciences. While pursuing my undergraduate degree, I had the opportunity to participate in several wildlife research studies. I valued these experiences more so than any class I had ever taken. After graduating with my Bachelor of Science degree, I spent a year in California, working as an intern on marine mammal research projects. My early experiences with research encouraged me to pursue a master's degree wherein I could conduct a research study of my own. From the beginning, the research that I did was never a means to an end. I originally took research jobs because I thought they would be interesting and fun. This was, indeed, the case, so I kept on doing research. I was never quite sure where I wanted to end up in my career, so I chose experiences based on what I wanted to do at the time and with little consideration beyond the near future. I figured that as long as I was working and gaining new experiences, it would help me in the long run once I decided what I really wanted to do.

While pursuing my master's degree, I had the opportunity to teach lab sections of undergraduate wildlife biology courses. I discovered that I absolutely love teaching. I found sharing my enthusiasm for science even more rewarding that pursuing my own questions about science. I was not sure how, but I knew that I wanted teaching science to be a part of my life for the duration of my career.

After completing my master's degree, I moved to North Carolina and was serendipitously hired at a high-achieving college-prep charter school. I went from having no formal teacher training to working with some of the most brilliant faculty I had ever met and with students who were every teacher's dream. I loved teaching and learning at Raleigh Charter High School. I learned more about biology through teaching it in a single year than I did in all my years of studying the subject. I also learned from my coworkers what it means to be a great teacher and what it means to be an effective mentor. I did not realize until I came to the University of Georgia and met people who have taught in other public high schools just how fortunate I was in my teaching position.

When it came time for my husband and me to leave Raleigh, I decided to combine my enthusiasm for science research and my love of teaching to pursue a doctorate at the University of Georgia. I looked forward to doing research again; this time with students as the focus of the research. Looking back to when I finished my masters, I was firmly grounded in the post-positivist epistemology (even though I never heard that term until I began my doctorate work). I had read Karl Popper (1935, 1991) several times in different courses and had drilled the process of science in research methods classes and in my own research project. Doing science was very straightforward. In science, there is an answer out there. Use rigorous methods, be completely objective, and eventually you will find the answer. Reconciling the epistemology of science was so simple that I never even thought about it.

Teaching was also very straightforward, but in a round-about way. There were different answers for different situations, but I could always rely on the answer to one question to guide all my decisions: What's the best for my students in this context? I let the needs of the students guide the format and pace of our class. Although I came into the classroom at the beginning of the year knowing more about biology than (most of) the students, we worked together through the year to build their knowledge base and understanding in biology. I did not know the term constructivist while I was teaching, but I was living in a constructivist paradigm just the same. At the same time, I taught students about objectivity and hypothesis testing in science. There was no conflict between the two ways of knowing. As Osborne (1996) states, "the nature of science has no necessary bearing on the nature of teaching and learning science, for the former is a philosophical issue to do with the nature of science while the latter is an educational issue to do with the best way of educating non-scientists about science (p. 67)." When we learned about science, we constructed meanings from our experience but when we did science and when we discussed scientists doing science, we talked about objectivity and approached questions by predicting, testing, and either verifying or supporting.

Now I am doing research in the field of science education studying students doing science research. I have taken a number of courses on qualitative research and I have really enjoyed them. I came to see how qualitative methods are useful for different types of questions and how they often work well within a constructivist framework. I learned more about the methods and I have had opportunities to dabble in constructivist qualitative research in science education. While I value the constructivist perspective and I see its application to educational research, I also see how post-positivist approaches can be appropriate for certain questions. I, therefore, consider myself a pragmatist because I do not identify with one particular paradigm. Pragmatism rejects dualisms such as that between constuctivism and positivism. A pragmatist chooses the appropriate framework based on the question at hand. It is possible that the most fruitful research is that which combines different approaches to data collection and analysis and that draws from multiple theoretical frameworks.

William James, who is known as one of the "Fathers of Pragmatism," said, "The world of concrete personal experiences to which the street belongs is multitudinous beyond imagination, tangled, muddy, painful, and perplexed. The world to which your philosophy professor introduces you is simple, clean and noble. The contradictions of real life are absent from it

(James, 2007, p. 14)." In such a multitudinous world, it is not appropriate to look only through one lens or study by only one approach. In science, researchers will continue to uncover the truths of nature, and in science education, researchers will continue to work with students to construct knowledge of science and how it works. Miller et al. (2008) explain that disciplines have the tendency to become entrenched in a particular epistemology, which results in a narrow focus and could actually hold-back the progress of their work. They suggest that, especially in interdisciplinary research, a pluralistic approach to epistemology can work to integrate different values and can result in a more complete understanding of complex situations. For this pragmatic, pluralistic framework to be successful, however, we must continue to question our methods, consider multiple avenues, and ask whether there may be a better way to approach problems. I agree with James, so in my research I will use multiple approaches to best address my research questions.

My past experience in science research served me well in my dissertation research. My understanding of the process of doing science research was helpful in understanding the expectations of students participating in research. While my prior experiences were useful as I attempted to understand the experiences of undergraduate researchers, they also bring caveats. I had positive experiences in science research as an undergraduate and as a mentee both in my research and teaching, but I do not assume that all undergraduate researchers have similar positive experiences. I imagine that there is a spectrum of possible experiences and reactions to those experiences. Unlike me, some students may come to the experience with very pointed reasons for why they are doing research and what they expect from the experience. While I drew on my own experiences both in teaching and research to help ground my work, I was also conscious of the bias that my personal experiences may introduce into the analysis.

I hope that my dissertation research is helpful to those administrating UR programs, as well as the faculty and students and teachers of the students who consider participating in undergraduate science research. I also hope that it sparks an interest in others to understand more about students' experiences in science research.

CHAPTER 2

LITERATURE REVIEW

Undergraduate research opportunities have increased across the board in American colleges and universities since the Boyer Report (Boyer commission, 1998) in 1998, but research universities have been equally matched, and in some cases surpassed by their private liberal arts counterparts, in their opportunities for undergraduate research (Hu, Kuh, & Gayles, 2007). Students at research universities should have opportunities to take advantage of and participate in the high level research taking place at their institutions.

In order to understand the implications of the increase in UR opportunities and to improve those opportunities to best serve students, faculty, and their institutions, research is needed on the various aspects of UR. In 2004, Seymour, Hunter, Laursen, and Deantoni published, as a part of a research article, an extensive review of the research done on UR prior to 2002. In their review, Seymour et al. (2004) classified 54 research articles published between 1975 and 2002 into two general types of literature: Type 1 had hypothesized benefits both claimed and well-supported and Type 2 had hypothesized benefits that are either simply stated or claimed but not adequately demonstrated (see Appendix A). The vast majority (45 of the 54 articles) fell into the Type 2 classification, and the majority of those (22 of 45) were descriptive accounts of particular UR programs, described either by faculty, administrators, or students. These descriptions do not make reference to research or evaluation.

Of the nine Type 1 articles described by Seymour et al. (2004), four were research-based, which means that the methods and findings of a formal research project were described, and five were evaluations of UR programs, which means that complete information on the evaluation of a specific UR program was described. All four research articles explored the benefits of UR experiences, and found research skills, oral communication skills, understanding of the nature and development of scientific knowledge, and research epistemological development as areas of benefit (Kremmer & Bringle, 1990; Ryder, Leach, & Driver, 1999; Kardash, 2000; and Raukhorst, 2001). In over 25 years of study, only four research articles emerged in the field of UR and they all focused on the same aspect of UR experiences. Seymour et al.'s review draws attention to the need for further comprehensive research on UR and even suggests areas for future inquiry. They point out that, "A limited number of studies discuss students' reasons for wanting to participate in undergraduate research…it is important to learn what motivates students to participate – or not to do so (Seymour et al., 2004 p. 499)." They also discuss the focus of research on benefits saying that, "It may also reflect the traditional unease of academe with the realm of affective, nonintellectual phenomena. Apparent disattention to the powerful impact of these experiences on young people – and their consequences for professional preparation – while focusing on such issues as how many of them choose graduate school is, perhaps, to miss the point (Seymour et al, 2004 p.531)."

Seymour et al. (2004) point out important areas for future research in UR; the question is whether their advice was heeded. Has the literature swayed from being largely descriptive? Has research branched out beyond measuring gains? In this review, I will examine the literature from the seven years since the end of the research examined by Seymour et al. (2004) and assess the progress of research in UR. I will also identify areas that still require further exploration.

Summary of Recent Literature

Following Seymour et al.'s (2004) model of Type 1 and Type 2 literature, I classified 25 journal articles published between 2000 and 2008 that focused on UR. In addition to classifying the articles into Type 1 and Type 2, I classified them by focus of the study and by whether they were research, evaluation, description studies, or reviews (see Table 2.1).

Table 2.1. Classification of journal articles on undergraduate research 2000 – 2008.

Type 1: Hypothesized benefits are both claimed and well-supported		**Type 2: Hypothesized benefits are either simply state or claimed but not adequately demonstrated**	
Author(s)	**Focus**	**Author(s)**	**Focus**
Research		**Evaluation**	
Bauer 2001	Critical thinking, differences by major and gender	Falconer & Holcomb 2008	Phenomenological study of experiences
		Description	
Landrum & Nelson 2002	Analysis of benefits of UR perceived by psych. Educators	Hammick & Acker 1998	Gender differences in UR supervisors
Bauer & Bennett 2003	Alumni perceptions of benefits	Cartwright 2000	Benefits of UR
Seymour et al. 2004	Benefits of UR	Bangura 2003	Description of UR at 2 different institutions
Hu et al. 2007	Comparison of UR experiences at different types of institutions	Lopatto 2003	Essential features of UR
Hunter et al. 2007	Costs and benefits of UR	Millspaugh & Millenbah 2004	How to start/develop UR program
Russell et al. 2007	Benefits of UR	Randall et al. 2004	Two models at different universities
Evaluation		Gafney 2005	Important mentor qualities
Ward et al.	Effectiveness of UR program	Kight et al. 2006	Research communities in biology UR
Nnadozie et al. 2000	Rigor of research and graduate school success	Henderson et al. 2008	Drake Univ.'s UR program
Levis-Fitzgerald et al. 2004	Motivations and benefits	**Review**	
Frantz et al. 2006	Attitudes and confidence	Crow & Brake 2008	Suggestions for assessment
Kinkel & Henke 2006	Academic performance and marketability of URers		
Ishiyama 2007	Expectations & perceptions of UR experience		
Grimberg et al. 2008	Likelihood of attending grad school and pursuing careers in science/engineering		

In the years since Seymour et al.'s (2004) publication, there has been a shift in journal articles from the majority being Type 2 articles pre-2002 to the majority being Type 1 articles post-2002. In the current literature, research articles and rigorous evaluations have a slight majority over those articles without empirical evidence to back their claims; however the single classification with the most publications is still the Type 2 description articles. These articles describe specific programs and offer prescriptive advice on how other institutions might plan or develop their own programs without presenting any data. While their anecdotal descriptions may depict novel programs, without any data it is difficult for other institutions to adopt their prescriptions.

The recent publications on UR show a great increase in the proportion of well-designed, evaluation publications. Each of these articles clearly describes the methodology used in evaluating institution-specific programs. The downfall of most of these evaluations is the small sample size. The majority had a sample size ≤50 (Nnadozie et al, 2000; Levis-Fitzgerald, 2004; Frantz et al., 2006; Kinkle & Henke, 2006; Ishiyama, 2007), and Grimberg et al. (2008) had two phases each with 38 participants. The only evaluation with a large sample size (Ward, n=183) analyzed only one form of data, which were open-ended evaluation letters. Although these evaluations are useful for the improvement of the program being evaluated, the lack of depth and breadth of the data used in these evaluations makes it difficult to apply the claims to situations other than those being specifically evaluated.

The percentage of journal articles that are Type 1 research articles has more than doubled since the Seymour et al. (2004) publication. Most of these are well-designed studies with large samples, detailed methodologies, and control groups. One exception is Landrum and Nelson (2002) who sent a survey to 211 psychology educators and asked what benefits of UR they perceived to be important. While the sample size was large, there was no control group in this study and there was only one type of data.

All but one of the remaining six research articles addresses the benefits of UR. Hu et al. (2007) does not examine benefits but instead assesses the impact of the Boyer report. They found that UR did increase across the country after the 1998 Boyer report, but that even though the Boyer report focuses on research universities, a higher percentage of students at liberal arts colleges and doctoral universities are participating in UR. The five articles that did focus on the benefits of undergraduate research found that benefits of UR include increases in: confidence (Seymour et al., 2004; Russell et al., 2007), understanding of what it means to be a scientist (Bauer & Bennett, 2003, Seymour et al., 2004; Hunter et al., 2007; Russell et al., 2007), critical thinking (Bauer, 2001), research and communication skills (Bauer & Bennett, 2003; Seymour et al., 2004; Hunter et al., 2007), and clarity about future education and careers in science (Bauer & Bennett, 2003; Seymour et al., 2004; Hunter et al., 2007; Russell et al., 2007).

Gaps in the Literature

The recent research on UR has provided a great deal of evidence for the benefits of UR, but the focus of the research studies is largely unchanged from the time of Seymour et al.'s (2004) review. We know how beneficial the experience of UR can be for students, but how do we get more students to do UR? There are very few schools that require UR; in most cases it is a personal choice for students to participate. In Seymour et al.'s (2004) article they suggest that future research should explore the motivations behind students' engagement in UR. Similarly, Russell et al. (2007) highlight the need for getting more elementary and high school students interested in science so that they will pursue UR in the sciences, but these avenues of research have yet to be pursued. Despite the increase in UR research over the past decade, we still know very little about what gets students interested and motivated to do UR.

The research on the benefits of UR categorizes the gains into discrete units such as skills, understanding, and future intent, but at the same time, "Students define undergraduate research as a powerful affective, behavioral, and personal-discovery experience whose dimensions have profound significance for their emergent adult identity and sense of direction (Seymour et al., 2004 p. 531)." This implies that the different dimensions of UR interplay to have an overall effect on the students' experience and their future. There has been no research thus far that has attempted to model these interactions of attitudes, influences, and experiences to understand behaviors.

Many of the recent research articles are interested in future intent of students, such as whether they will go to graduate school in science or whether they will pursue a career in science. None of the existing studies, however, have provided longitudinal information on students through their experiences with research and beyond. Bauer and Bennett (2003) surveyed alumni, but they did not have information from those students while they were participating in UR. It is understandable that there is a lack of longitudinal studies due to the relatively short history of research in UR. But if we really want to understand the implications of UR, long-term, longitudinal data collection will be necessary.

Objectives

This dissertation will address some of the key gaps in the current UR literature. The three main objectives will be to understand the factors that influence students' participation in undergraduate research, to understand how students' expectations compare to the perceived outcomes of their research, and to understand how different groups may experiences UR differently. The first objective relates to the gap in the literature on students' interests in science and motivation to do UR. When someone suggests that we should try to get more students interested in science, it is obviously more easily said than done. How exactly do students get interested in science and motivated to do science research? Students currently participating in UR provide a good sample from which to approach this question. They have already been interested enough and motivated to pursue UR in science. The second objective addresses the fact that most research on outcomes is from the perspective of what institutions see as important in research, and it provides a more student-centered perspective. The third objective expands the understanding of students' experiences by examining how different groups of students experience UR differently.

The research currently being done on UR is improving in quality and rigor and is setting a solid foundation for future work. This dissertation research may be the foundation for longer-term research that can be continued in the future.

CHAPTER 3

UNDERGRADUATE RESEARCH IN SCIENCE: FACTORS INFLUENCING STUDENT PARTICIPATION[1]

[1]Pacifici, L.B., and Thomson, N. To be submitted to *Journal of Research in Science Teaching*

Abstract

Undergraduate research (UR) in science is gaining popularity and support. UR has been shown to produce gains in areas like critical thinking, development of knowledge and skills, and personal-professional gains. With such potential benefits, institutions are interested in increasing the number of students participating in research. The purpose of this chapter is to understand the influences on students' decisions to participate in UR in science, which will help institutions to recruit students into UR and have them experience the associated gains. Drawing from the Theory of Planned Behavior, Social Cognitive Theory, and literature on UR in science, a questionnaire was developed and completed by 154 science majors to measure different influences on students' decisions to do UR in science. Exploratory factor analysis was used to identify six main factors involved in student participation to do research: attitudes, effort, self efficacy, beliefs, social interactions, and intrinsic motivation. The factor analysis and correlation matrix were used to construct a model of the influences on students' decisions to do UR in science. Confirmatory factor analysis was then used to analyze the proposed model. Qualitative data from interviews with a subsample of 18 science majors provided deeper explanations for results from the quantitative analysis. The factor analysis approach performed well in this situation and shows promise for other contexts regarding UR. As more is understood about students' influences to do UR in science, UR programs can be tailored to best serve the purpose of the programs and the expectations of students.

Introduction

In 1998, the report of the Boyer Commission for improving undergraduate education in research universities encouraged a shift away from the research versus teaching dichotomy and toward an integration of research and learning (Boyer Commission, 1998). The Boyer report suggests increased undergraduate research (UR) experiences for students in research universities as one way to bridge the gap between research and teaching. The Boyer report states that, "learning is based on discovery guided by mentoring rather than on the transmission of information" (Boyer Commission, 1998, Part I). UR experiences provide the opportunity for students to experience mentored discovery that they may not experience in their science classes. In 2000, the National Science Foundation (NSF) identified UR as a critical component in its strategic plan for integrating research and education (NSF, 2000). In the years since the Boyer report and NSF's strategic plan, UR opportunities in the sciences have increased in both research universities and their private liberal arts counterparts (Hu, Kuh, & Gayles, 2007). In order to understand the implications of the increase in science UR opportunities and to improve those opportunities to best serve students, faculty, and their institutions, research is needed on the various aspects of UR.

Recent research on science UR has provided compelling evidence for the outcomes associated with UR experiences. Several studies have examined the benefits, such as increased research skills and understanding of the nature and development of scientific knowledge, gained by students through experiences with undergraduate science research (e.g. Kremmer & Bringle, 1990; Ryder, Leach, & Driver, 1999; Kardash, 2000; Seymour, Hunter, Laursen, & Deantoni, 2004) and have made a strong case for the importance of UR. For example, Seymour et al. (2004) found that experiences in science research helped undergraduates clarify, refine, and/or confirm students' preexisting choice of career directions, including graduate or professional schools. Seymour et al.'s (2004) data encourage educators and scientists to promote UR, but despite these studies, we still lack an understanding of the factors that initiate students' interest in pursuing UR.

There are few institutions that require UR; in most cases it is a personal choice for students to participate. Seymour et al. (2004) suggest that future research should explore the motivations behind students' engagement in UR. Similarly, Russell et al. (2007) highlight the need for getting more elementary and high school students interested in science so that they will pursue UR in the sciences, but as yet there is little research in these areas. Despite the increase in UR research participation over the past decade, we still know very little about what influences students to engage in UR.

The purpose of this research is to better understand the factors, such as beliefs, attitudes, self-efficacy, and motivation that influence students to pursue UR in science. Seymour et al. (2004) explain that, "Students define undergraduate research as a powerful affective, behavioral, and personal-discovery experience whose dimensions have profound significance for their emergent adult identity and sense of direction" (Seymour et al., 2004 p. 531). Similarly, there are likely affective, behavioral, and personal factors that interact to lead a student to pursue UR. These different dimensions interplay to have an overall effect on the students' experiences and their futures. It is, therefore, also the purpose of this research to explore how factors interact with each other to impact student decisions about research.

The overarching question addressed by this research is: Why do students participate in undergraduate research in science at the University of Georgia? Sub-questions include:

1. What motivates students to participate in undergraduate science research?

2. Who influences students to pursue or not pursue undergraduate science research?

3. How accessible is undergraduate science research?

4. What level of self-efficacy do students have related to undergraduate science research?

5. How do different the constructs of motivation, social influences, accessibility, and self-efficacy work together to influence students' decisions to do undergraduate science research?

Framework

In order to adequately address the research questions, which seek both to expose students' influences and to provide deeper meaning to explain those influences, this inquiry was approached from a pragmatic and pluralistic perspective. A pragmatic approach was chosen because the research questions do not fit neatly into one particular paradigm, but instead are best approached from multiple perspectives at once. Pragmatism rejects dualisms such as that between constructivism and positivism. A pragmatist chooses the appropriate framework based on the question at hand. It is plausible that the most fruitful research is that which combines different approaches to data collection and analysis and that draws from multiple theoretical frameworks.

William James, one of the "Fathers of Pragmatism," said, "The world of concrete personal experiences to which the street belongs is multitudinous beyond imagination, tangled, muddy, painful, and perplexed. The world to which your philosophy professor introduces you is simple, clean and noble. The contradictions of real life are absent from it (James, 2007, p. 14)." In such a multitudinous world, it is not appropriate to look only through one lens or study by depending on only one approach. In science, researchers will continue to uncover the "truths" of nature, and in science education, researchers will continue to work with students and teachers to construct knowledge of science and how it works. Miller et al. (2008) explain that disciplines have the tendency to become entrenched in a particular epistemology, which results in a narrow focus and could actually hold back the progress of their work. They suggest that, especially in interdisciplinary research, such as that at the intersection of science and education, a pluralistic approach to epistemology can work to integrate different values and can result in a more complete understanding of complex situations. For this pragmatic, pluralistic framework to be successful, however, we must continue to question our methods, consider multiple avenues, and ask whether there may be a better way to approach problems. Johnson and Onwuegbuzie (2004) draw from the pragmatic stance and contend that,

> epistemological and methodological pluralism should be promoted in educational research so that researchers are informed about epistemological and methodological possibilities and, ultimately, so that we are able to conduct more effective research… [A] mixed position allows researchers to mix and match design components that offer the best chance of answering their specific research questions (pg. 15).

The students who do UR in science and their faculty mentors are likely most familiar with a post-positivist paradigm of science research. This research is meant to be accessible to those scientists while also acknowledging the social construction of both science and student learning. The research questions reflect both the pursuit of an answer regarding the nature of influences on student decisions to do research as well as the deeper underlying explanations for why those influences are important. The theoretical framework for this research is consequently pluralistic, drawing from multiple theoretical perspectives and multiple approaches to data collection and analysis.

This research draws from two main theories that relate to the research questions: The Theory of Planned Behavior and Social Cognitive Theory. The following section describes each theory, how it relates to this research, and how the two are integrated in design.

Theory of Planned Behavior

Ajzen (1985, 1991) developed the Theory of Planned Behavior (TPB, see figure 3.1), which aims to understand the affective aspects that influence human behavior. TPB posits that behaviors are largely based on one's intention to perform a behavior and that intentions are influenced by three constructs: (a) "Attitude toward the behavior", (b) "Subjective norms", and (c) "Perceived behavioral control." "Attitude toward the behavior" is a person's positive or negative evaluation toward performing a certain behavior and is influenced by the individual's behavioral beliefs. "Subjective norms" are the social pressures, as perceived by the individual, to either perform or not perform the behavior, and these norms are influenced by the beliefs of influential figures in the individual's life. The "Perceived behavioral control" is the person's perception of one's ability to perform the behavior. The perceived behavioral control is influenced by control beliefs that one has regarding whether or not they are able to carry out the behavior. Depending on the intention, one of the three constructs may play a more or less important role, and in some instances only one or two of the constructs influence an intention (Ajzen, 2005).

TPB offers insight to what factors may be important to students' decisions to do research. The questionnaire, therefore, included items related to one's attitudes toward doing science research, social influences on pursuit of UR in science, effort involved in doing research, self-efficacy toward doing UR in science, and perceived accessibility of research experiences. Past research on UR in science (e.g. Seymour et al., 2004; Hunter et al., 2007) was also used to identify other possibly important factors such as specific motivations to do research and specific accessibility issues.

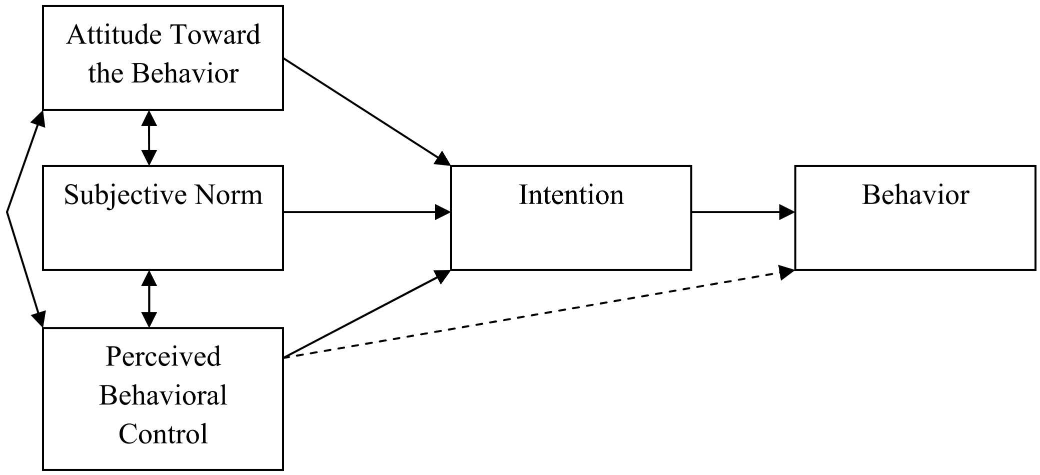

Figure 3.1. Theory of Planned Behavior (Ajzen, 1985, 1991)

Social Cognitive Theory, which provides a constructivist framework for understanding human action, is complimentary to the TPB but provides a slightly different perspective of understanding regarding influences on students participation in UR in science. The model of SCT (Figure 3.2) involves interaction among an individual's thoughts and feelings, the environment, and the individual's actions (Bandura, 1986). SCT, like TPB, incorporates self-efficacy and social persuasion and their effects on actions. SCT recognizes, however, that we are not simply reactive organisms driven by environmental stimuli; we are reflexive organisms. SCT suggests that to analyze actions based solely on scaled quantifiable data may be to miss the point. SCT delves deeper to analyze the thoughts and feelings behind the actions. So while the TPB allows us to estimate quantities related to each of the arrows in the proposed model, SCT provides us a lens with which to examine the meaning behind the arrows.

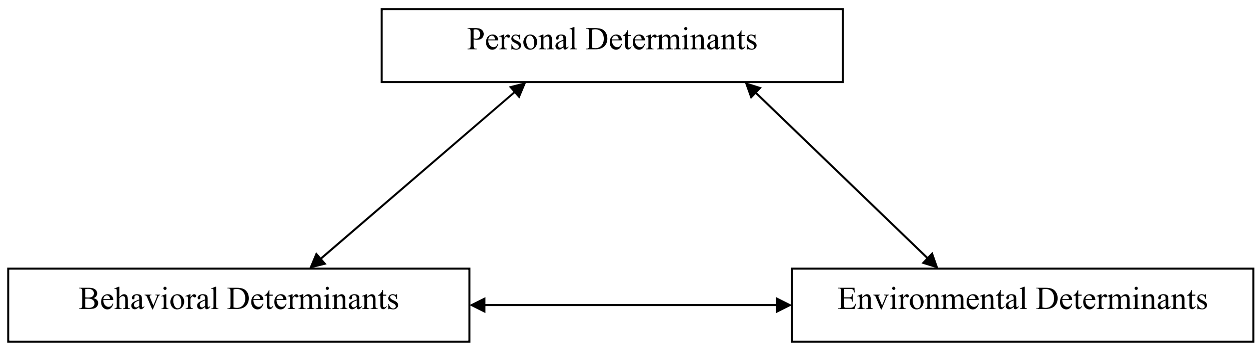

Figure 3.2. Social Cognitive Theory (Bandura, 1986)

Research Design

Approach

Koballa and Glynn (2007) point out that research on science-related attitudes and motivations range from detached statistical analyses to emotional qualitative analyses. This research used a mixed methods approach in an attempt to span and integrate these extremes. The quantitative data provided a basis of information upon which qualitative methods were employed to gather more detailed, individually specific information. The quantitative data allowed for comparisons between students doing UR in science and those not doing UR in science. The qualitative data allowed for a richer understanding of the aspects involved in students decisions regarding doing science research. The quantitative data were collected and initially analyzed first, and then qualitative data were collected and analyzed. The quantitative analysis was used to inform the follow-up interviews, and the data from the interviews helped provide deeper explanation for the quantitative data.

Quantitative >> informs>> Qualitative *Qualitative >> explains>> Quantitative*

This mixed-methods approach allowed for development and complementarity in the analysis. Development is where the findings from one method informs the other method, as is the case with quantitative informing qualitative in this case. Complementarity is when one form of data provides elaboration, enhancement, and clarification of the other form of data, which is what the qualitative data does for the quantitative data in this case (Johnson & Onwuegbuzie, 2004).

Data Collection

Sixteen students participating in science UR completed a pilot questionnaire consisting of open-ended questions related to influences on their participation in UR (Appendix B). Pilot questionnaire responses informed the construction of the research questionnaire. The quantitative data were collected through an online questionnaire. The questionnaire was composed of 45 Likert scale questions (Appendix C). Responses were on a 5-point scaled that ranged from "strongly disagree" (1) to "strongly agree" (5), with 3 being "neutral". Herzog and Bachman (1981) found that response level was significantly greater when the number of questionnaire items was between 35 and 45, compared to having greater than 100 questionnaire items. They also found that the proportion of respondents who responded with the same answer for the entire questionnaire was significantly lower with the shorter questionnaire. The questionnaire length was, therefore, kept in a range that would encourage a high number of high quality responses.

Questionnaire items were organized into seven categories derived from past literature on UR in science (e.g. Seymour et al., 2004; Hunter et al., 2007): Attitudes, beliefs, accessibility, self-efficacy, intrinsic motivation, extrinsic motivation, and social influences. Attitudes and beliefs toward science and research were addressed with ten questions each. Accessibility, self-efficacy, intrinsic motivation, extrinsic motivation, and social influences were addressed with five questions each. Attitudes and beliefs are broader constructs with more factors to be addressed in this research than the more specific constructs of accessibility, self-efficacy, intrinsic motivation, extrinsic motivation, and social influences, which accounts for the greater number of questionnaire items for beliefs and attitudes.

A question asking whether the student has ever participated in UR separated respondents into researchers and non-researchers. Several demographic questions at the end of the questionnaire asked students to identify their gender, major, race, grade point average, and post-graduation intentions. While not integral to the research described in this chapter, these demographic factors may be used in future research to explore possible differences in influences between groups.

An email was sent to all upper-level science majors via their department list serve. Approximately 1700 upper-level undergraduates are science majors at UGA. The list serves utilized included those for the following majors: biochemistry and molecular biology, biology, cell biology, chemistry, ecology, forestry and natural resources, genetics, microbiology, and physics and astronomy. The goal was to achieve 10% participation from the 1700 upper-level science majors. The email that students received included a link that brought them to the survey questionnaire in Survey Monkey (http: //www.surveymonkey.com). The last item on the questionnaire asked students to provide an email address if they were willing to participate in follow-up interviews. Those who provided their email were contacted for interviews. An attempt was made to get 10% participation in follow-up interviews with a similar representation of research and non-research students as was reflected in questionnaire responses.

Interviews took place on the campus of the University of Georgia and lasted an average of thirty minutes. Interview questions were based on the participants' responses to the questionnaire items so were consequently different for each participant (Appendix D). Interview questions addressed the main constructs of the model in general and then asked follow-up questions related to specific factors of the constructs. For example, when a student indicated that they strongly agreed with the statement, “There are barriers for some students to do UR in science,” they were asked to discuss the barriers in their interview. The goal of the interviews was to gain more reflective explanations and clarification for the questionnaire responses. Each interview was digitally recorded then transcribed.

Participants

The questionnaire was completed by 154 upper-level science majors spanning the life-science and physical science disciplines. Of those who completed the questionnaire, 86 had participated in UR and 68 had not participated in UR. Of those who did research, 46 were female and 40 were male, and of those who did not do research, 39 were female and 29 were male.

Kline (2005) suggests that an appropriate sample size for path analysis is 10 to 20 times the number of parameters in the model. In this case, parameters are analogous to constructs, so the model described above contains seven parameters. The sample size of 156 is just over 20 times the number of parameters.

Follow-up interviews were completed with a sub-sample of 18 of the original 154 who completed the questionnaire. Of the 18 participants, 11 had participated in UR and 7 had not participated in UR. Six of the research students were female and five were male. Four of the non-researchers were female and three were male. Three of the research students were biology majors, three were microbiology majors, two were cell biology majors, two were chemistry majors, and one was a genetics major. Two of the non-research students were biology majors, two were microbiology majors, one was a natural resources major, and one was an ecology major. All names used in this study are pseudonyms, and this research is approved by the Institutional Review Board at the University of Georgia (Project number: 2009-10867-0).

Data Analysis and Findings

There were three main phases in the analysis of the questionnaire data: (1) conducting exploratory factor analysis, (2) examining correlations between identified factors, (3) conducting confirmatory factor analysis on a model constructed based on the exploratory factor analysis and correlations. Quantitative analysis was followed by qualitative analysis to provide explanations and deeper understanding of quantitative data.

Exploratory Factor Analysis

Exploratory factor analysis (EFA) was performed using the Statistical Program for the Social Sciences (SPSS), version 17.0 (IBM SPSS, 2008) to examine the relationships between the items of the questionnaire and to identify groupings of items into factors (Costello & Osborne, 2005). Principal components factoring with the Varimax rotation was used to extract factors with an eigenvalue greater than 1.0. Tabachnick and Fidell (2001) cite 0.32 as a good rule of thumb for the minimum loading of an item, so any item that did not achieve a loading greater than 0.32 for any one factor was excluded from analysis. Twenty-three items were thus excluded from analysis, but the mean responses for all questionnaire items are presented in Table 3.1. Six factors emerged from the principal components analysis (Table 3.2). After examining the items that loaded into each factor, the six factors were labeled as: (1) Attitudes, (2) Self-efficacy, (3) Social interactions, (4) Beliefs, (5) Effort, (6) Intrinsic motivation. The reliability of each of the six factors was assessed using a Cronbach alpha test, which provides an internal consistency estimate of reliability of questionnaire items (see Table 3, Cronbach, 1951). A lenient cutoff for exploratory research is a value of 0.60 (Garson, 2010). Anything above 0.60 is acceptable, and below 0.60 is unreliable. All six factors had a Cronbach alpha value >0.60.

Table 3.1. Mean questionnaire item responses.

Beliefs	Research?	N	Mean	Std. Deviation
Science research is important to humanity	Yes	88	4.86	.406
	No	68	4.81	.605
Everyone should experience science research	Yes	88	3.25	1.075
	No	68	3.56	.937
Only people with advanced degrees can do science research*	Yes	88	3.99	.851
	No	68	3.91	.728
The work of scientists has little effect on lives of other people*	Yes	88	4.63	.510
	No	68	4.62	.670
Most problems can be solved with science research	Yes	88	2.92	1.234
	No	68	3.35	1.019
Humans depend on science research in their everyday lives	Yes	88	4.36	.746
	No	68	4.49	.635
Anyone can do science research	Yes	88	2.98	1.061
	No	68	3.09	1.143
Most science is applicable to everyday life	Yes	88	3.85	1.045
	No	68	3.96	.953
Doing science research requires critical thinking	Yes	87	4.48	.776
	No	68	4.43	.676
Science research improves our lives	Yes	87	4.52	.760
	No	68	4.53	.585

Attitudes	Research?	N	Mean	Std. Deviation
I would like to become scientist	Yes	86	3.66	1.484
	No	66	3.42	1.348
I would enjoy working with other people in a research setting	Yes	86	4.08	1.043
	No	66	3.64	1.198
I enjoy my science classes	Yes	86	4.35	.682
	No	66	4.33	.641
Doing science research is boring work*	Yes	86	3.84	.879
	No	66	3.41	1.202
I like interacting with science professors	Yes	86	4.10	.686
	No	65	4.08	.645

I prefer to work alone*	Yes	86	3.41	.925
	No	66	3.23	1.035
I like talking about science with others	Yes	86	4.22	.710
	No	66	4.14	.677
I would be unhappy as a scientist*	Yes	86	3.49	1.509
	No	66	3.56	1.426
Doing science research is exciting	Yes	86	3.95	.810
	No	66	3.62	1.034
I enjoy exploring questions for which there is no clear answer	Yes	84	3.95	.943
	No	66	3.53	1.205

Access and Self Efficacy	**Research?**	**N**	**Mean**	**Std. Deviation**
Any student can participate in undergraduate research in science	Yes	84	3.31	1.172
	No	62	3.34	1.144
The process of finding a research mentor was simple	Yes	83	2.98	1.147
	No	62	2.35	1.319
Information on UR at UGA is easily accessible	Yes	84	3.35	1.207
	No	62	2.81	1.401
Applying to do UR was time consuming*	Yes	83	3.14	1.049
	No	62	2.26	1.342
I am confident in my ability to do UR in science	Yes	84	4.20	.773
	No	62	3.71	.965
I am well-prepared to do UR in science	Yes	84	3.99	.951
	No	62	3.47	1.155
I am capable of conducting UR in science	Yes	82	2.67	1.101
	No	62	2.27	1.270
There are barriers for some students to do UR in science*	Yes	83	1.88	.875
	No	62	1.92	1.060
I was not sure whether my research mentor would want to work with me*	Yes	83	2.90	1.255
	No	62	2.84	1.357
I have knowledge and skills required to do UR	Yes	84	3.93	1.062
	No	62	3.55	1.237

Motivations and Social Factors	Research?	N	Mean	Std. Deviation
Parental influence	Yes	82	2.24	1.282
	No	61	2.85	1.436
Interest in science	Yes	82	4.45	.756
	No	61	2.07	1.181
Desire to go to graduate or professional school	Yes	82	4.37	1.171
	No	61	3.03	1.516
Desire to learn more about science	Yes	82	4.29	.853
	No	61	4.15	1.167
Influence of friends	Yes	82	2.49	1.363
	No	61	3.93	1.250
Exploring the possibility of a future in science research	Yes	82	4.04	1.159
	No	61	4.34	1.031
Influence of academic advisor	Yes	82	2.96	1.418
	No	61	3.38	1.368
Influence of K-12 teacher	Yes	82	2.70	1.463
	No	61	3.46	1.104
Influence of college professor	Yes	82	4.31	.744
	No	61	3.89	.948
I chose UR because enjoy science	Yes	82	4.32	.784
	No	61	3.97	1.048
Earning course credit	Yes	82	4.15	1.111
	No	61	3.85	1.029
Earning money	Yes	82	2.81	1.226
	No	61	2.79	1.022
Getting a good letter of recommendation	Yes	82	4.56	.992
	No	61	4.23	.998
Improving my resume	Yes	82	4.26	.874
	No	61	3.96	1.002
Getting into graduate or professional school	Yes	82	4.29	1.247
	No	61	4.02	1.225

* Negatively worded items were reverse coded (i.e. 1=strongly agree, 2=agree, etc.)

Table 3.2. Exploratory Factor Analysis

Factor	Item	Factor Loading					
		Att.	S.E.	Soc.	Bel.	Eff.	I.M.
Attitudes toward doing science research (Cronbach's α = 0.826)	I would be unhappy in a career as a scientist	0.740					
	Doing science research is exciting	0.737					
	I would enjoy working with other people in a research setting	0.718					
	I would like to become a scientist	0.698					
	Doing science research is boring	0.651					
	I enjoy exploring questions for which there is no clear answer	0.612					
Self-efficacy (Cronbach's α = 0.814)	I have the knowledge and skills required to do research		0.677				
	I am confident in my ability to do undergraduate research in science		0.661				
	I am well-prepared to do undergraduate research in science		0.619				
Social interactions in science (Cronbach's α = 0.692)	I like interacting with science professors			0.735			
	I enjoy my science classes			0.708			
	I like talking about science with others			0.699			
Beliefs about science research (Cronbach's α = 0.697)	Humans depend on science research in their everyday lives				0.836		
	Science research improves our lives				0.825		
	Science research requires critical thinking				0.680		
	Science research is important to humanity				0.375		
Effort required to do science research (Cronbach's α = 0.703)	Information on undergraduate science research at UGA is easily accessible					0.795	
	Applying to do undergraduate research was time consuming					0.712	
	The process of finding a research mentor was simple					0.699	
Intrinsic motivation (Cronbach's α = 0.727)	Desire to learn more about science						0.810
	Exploring the possibility of a future in science						0.696
	Interest in science						0.646

Correlations and model construction

SPSS 17.0 was used to calculate correlation coefficients between each of the identified factors, as well as the questionnaire item “Have you ever done research?” (Table 3.3). A model was then constructed to present a possible explanation of how different factors interact to influence student participation in UR in science. Effort, self-efficacy, and attitudes correlated with whether or not a student had done research, so those three factors were included in the model as direct indicators of participation in research. Their direct relationship with participation in research is indicated in the model with a single-sided arrow (Figure 3.3). All other significant correlations were incorporated in the model as co-variances between factors (Figure 3.3).

Table 3.3. Pearson correlation coefficients for factors influencing participation in research (n=154)

	Attitudes	Effort	Self-efficacy	Social Interactions	Intrinsic Motivation	Beliefs	Research?
Attitudes	--	.216**	.456**	.435**	.477**	.151	.171*
Effort		--	.344**	.028	.087	.151	.325**
Self-efficacy			--	.266**	.175*	.210*	.259**
Social interactions				--	.257**	.138	.038
Intrinsic Motivation					--	.149	.038
Beliefs						--	.024
Research?							--

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

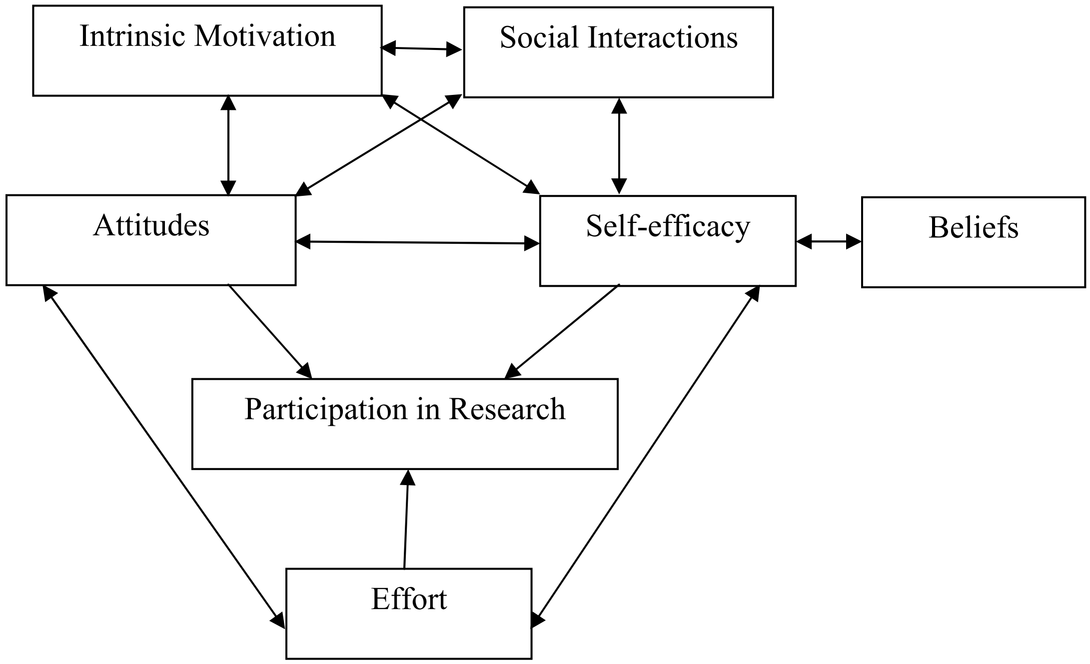

Figure 3.3. Model for influences on student participation in UR in science.

Confirmatory Factor Analysis

The SPSS add-on, AMOS, version 17.0 (IBM SPSS, 2008), which is a Structural Equation Modeling tool, was used to test the hypothesized model. Each arrow in the model represents a hypothesized relationship between the factor at the origin of the arrow and the construct it points to. The model was tested using structural equation modeling (SEM), which refers to a set of related statistical techniques aimed at analyzing models of relationships in which neither independent nor dependent variables are manipulated. Path analysis, a particular SEM technique, was used to test the present model. Path analysis is used to identify a model explaining the relationships in a set of variables rather than simply testing data for any linear relationship. Further, path analysis allows for estimation of the relative importance of paths of influence between variables (Olobatuyi, 2006). A regression weight was estimated for each of the three single-sided arrows in the model (Table 3.4). A path regression weight of 0.25 on an arrow connecting A to B indicates that when A increases by one standard deviation of its mean, B will increase by 0.25 standard deviations of its mean. The regression weights indicate that the factor "Effort" had the strongest relationship with student participation in research. Covariances were estimated for each of the double sided arrows in the model (Table 3.5). The greatest covariance estimates were between attitudes and both self-efficacy and intrinsic motivation.

Several goodness-of-fit indices were employed to determine whether the model fit well with the data. Each index tests a different aspect of fit, so by looking at them together, the overall fit of a model is determined (Kline, 2005). The first goodness of fit test used was the Chi-square statistic, which measures the difference between the sample correlation matrix and the fitted correlation matrix (Olobatuyi, 2006). The lower the Chi-square, the better the model fits the data.

Chi-square values are influenced by the number of variables in a model, so when testing multiple models it is more useful to examine X^2/df. Values less than 3 indicate good fit (Kline, 2005). The X^2/df for this model was 1.44, which indicates a good fit.

The root mean square error of approximation (RMSEA; Steiger & Lind, 1980) includes adjustments for model complexity, so that number of parameters does not necessarily have a profound impact on the fit. The lower the RMSEA, the better the model fits the data. An RMSEA of around 0.05 is considered a good fit, and values greater than 0.10 are unacceptable (Blunch, 2008). The RMSEA measure for this model is 0.052, which again indicates a good fit.

The incremental fit index (IFI) is not as sensitive to sample size as other goodness-of-fit measures. The IFI compares the model to a null model that assumes all variables to be uncorrelated. IFI values range from 0 to 1 with higher values indicated better fit. An IFI value greater than 0.95 is considered a good fit (Hu & Bentler, 1999). The IFI value for this model is 0.976, once again indicating good fit.

The final fit measure was the comparative fit index (CFI; Bentler, 1990), which is similar to the IFI in that it compares the model to a null model with no identified paths, i.e. no relationships. Fit improves as the CFI value approaches 1. CFI values less than 0.9 indicate an unacceptable fit (Olobatuyi, 2006). The CFI value for this model was 0.972, which again indicates a good fit.

Table 3.4. Regression Weights from Confirmatory Factor Analysis

	Estimate	S.E.	P
Effort → Participation in Research	.138	.051	.007
Self Efficacy → Participation in Research	.100	.055	.068
Attitudes → Participation in Research	.017	.050	.737

Table 3.5. Covariances from Confirmatory Factor Analysis

	Estimate	S.E.	P
Effort ←→ Attitudes	.149	.049	.002
Effort ←→ Self-efficacy	.179	.056	.001
Self-efficacy ←→ Attitudes	.318	.062	<.001
Social interactions ←→ Intrinsic motivation	.102	.034	.002
Intrinsic motivation ←→ Attitudes	.342	.059	<.001
Social interactions ←→ Self-efficacy	.096	.035	.006
Social interactions ←→ Attitudes	.194	.040	<.001
Intrinsic motivation ←→ Self-efficacy	.069	.048	.150
Beliefs ←→ Self-efficacy	.070	.029	.015

Qualitative Analysis

Qualitative methods for the analysis of interview data were gleaned from Grounded Theory methods (Strauss & Corbin, 1990). Analysis followed a constant comparative method in which comparisons are made during each stage of analysis. Interview transcripts were coded, line by line, and codes were grouped into categories based on their relatedness and the categories identified in the model. During coding and organization of data, memos were written to elaborate the categories and brainstorm ideas for possible themes tying categories together. For example, if a participant talked about an aspect of their influences to do UR that had not come up in the pilot questionnaire and was not represented in the research questionnaire, a note was made and considered the point in future interviews. If common trends surfaced in interviews, such as the way participants talked about the influence of certain people on their decision to do UR, a note was made and the notes were revisited to help develop rich meaning to describe students' influences. Themes were constructed and used to provide deeper insight to the interpretation of the quantitative data provided by the questionnaires.

Explanations

The greatest direct influence on student participation in research highlighted by the path analysis is effort. Effort items ranked lowest in mean score by both researchers and non-researchers. There were several issues of effort and the associated accessibility of research that came up in discussions with interview participants. The first issue was equity in access to programs for all students. There are two main groups at UGA that provide support, information, and funding for UR. The UGA Center for Undergraduate Research Opportunities (CURO) provides students with information and support in finding a mentor and earning course credit for their research. CURO hosts an annual research symposium where students showcase their research either in an oral or poster presentation. CURO also supports two competitive programs that provide stipends for research participants. The Louis Stokes Alliance for Minority Participation (LSAMP) aims to increase recruitment and retention of minority students in the science, technology, engineering, and math disciplines by supporting students in their pursuit of a baccalaureate degree and in their progression toward graduate school careers. LSAMP provides information, advising, and funding for UR opportunities. For students with access to either CURO or LSAMP, perceived effort required to do UR in science was greatly decreased.

Several interview participants who have participated in research talked about the influence that CURO or LSAMP had on helping them get started with research. Kelly [Microbiology, researcher] said, “Because if I wasn’t in the LSAMP program, I really wouldn’t have known anything about doing undergraduate research.” CURO is housed in the Honors College, and while you do not have to be an honors student to participate in CURO programs, there is a 3.4 grade point average requirement. The mission of LSAMP is to serve underrepresented students. The majority of students at UGA fall beyond the requirements for both CURO and LSAMP. Outside of CURO and LSAMP, students’ other resources for information about research are limited to what their academic department provides, which widely varies. Interview participants perceived a lack of opportunities outside of CURO and LSAMP. Matthew [Chemistry, researcher] said, “I don’t feel like there’s a lot of research opportunities either. I’ve only seen maybe five at the most for people who aren’t in an honors program or something,” and Chris [Biology, researcher] said, “If you can’t do CURO you have to jump through a lot more hoops and do a lot more personal effort to try to get somebody.” Similarly, Tyler [Biology, researcher] explained that,

> The honors program really opens up CURO and everything like that and I feel like it might be tougher for some students because there are a lot of research opportunities out there but it's hard to find where to start and how to get into those.

It's possible for students outside of CURO and LSAMP to do research, but the perception is that it requires more effort. Participants also voiced a need for changes toward more equitable access. Jodi [Microbiology, non-researcher] explained her feelings that, "The university should make undergraduate research seem like it's for everybody instead of people with the highest GPA's or people in the honors program."

Several non-research students talked about other commitments that they had that made it difficult for them to do research. Many of these participants said that they needed to have a job to support them while at UGA. Others spoke of their dedication to service endeavors. Devin [Microbiology, nonresearcher], for instance, said, "I do a lot of volunteer work. I've always done that even before I wanted to go to medical school." Devin worked at medical clinics in Africa, was active in an athletic program for special needs children, and tutored ESOL students after school. While he expressed interest in research and saw great potential value in pursuing UR opportunities, he was not willing to sacrifice his time devoted to service.

Other students spoke of a general lack of time available to participate in research. Science majors often have classes in the mornings and labs in the afternoons. Many faculty research mentors require that students be available for several hours at a time, multiple times per week in order for the mentor to take the student on as a mentee. The class schedule of many science majors prevents such time dedication to research. Several of the non-research participants indicated that they were very interested in research opportunities and hoped that they would be able to do research sometime in their undergraduate career, but had not, as of yet, been able to fit it in their schedule. Lance [Biology, non-researcher] said, “I really have thought about [research], but I’m trying to find some time in my schedule to open it up a little bit. I really would like to do research.”

Another direct effect on participation in UR in science that was highlighted by the quantitative analysis is self-efficacy. One of the main things that students mentioned regarding the confidence they had in being able to do science research was the intimidation they felt toward interacting with faculty. Both research and non-research students talked about being nervous to approach faculty about doing research and fearful that they might not know the appropriate etiquette involved in such interactions. Holly [Biology, researcher] expressed the confusion that she felt and that she expected other students felt saying, “I think a lot of times students are intimidated to talk to their professors and say, ‘Can I do a project with you? How do you start that conversation? How do you go about that?’” Ann [Cell biology and Genetics, researcher] spoke of her intimidation in a similar way saying, “So I had a list of all the labs I was interested in but I hadn’t contacted any of them because I was too scared to give the wrong impression and then they wouldn’t want me in their lab.” Even though Ann had taken the initiative and was intrinsically motivated to look up potential mentors, she lacked the confidence to make actual contact with them.

Many students, even those with a high grade point average, indicated low levels of self-efficacy for doing research when they were deciding whether or not to participate in research. Jodi [Microbiology, non-researcher] earned the highest academic fellowship awarded at UGA.

She had participated in humanities research, but was more interested in science. She planned to participate in science research in the upcoming semester, but was unsure of whether she was prepared for it. She said, “Sometimes it just seems like I can’t talk to [faculty] because I am not smart enough. And just thinking that I need more science classes, more stuff under my belt before I can do [research].” Other students look up to fellows such as Jodi as those students with the most talent, ability, and opportunities. If Jodi has low self-efficacy about participation in science research, it is not surprising that self-efficacy could have a significant impact on the number of students participating in UR in science.

Some of the interview participants had been doing UR in science for multiple semesters before I interviewed them. For those students, their participation in research had a positive effect on their self-efficacy regarding doing science research. They spoke of the increasing autonomy that they earned over time in the research setting and how they became more and comfortable and confident in the research process. Holly [Biology, researcher] explained how doing research affected her self-confidence in doing research and interacting with potentially intimidating research faculty:

> Research has totally affected my confidence in terms of trusting in myself and being able to show myself that I can do research and people can be impressed with it and understand it and I can present it and I have all these abilities that aren’t necessarily reflected in my grades. It has affected my confidence and the way I speak to people. I talked to the head of division of biological and biomedical sciences and I’m like okay, I have to talk to this man. It’s kind of intimidating, but I can do it. And before I would feel overwhelmed but now I’m

> like, no I can do something that’s very challenging and I can work hard. I know that I can work hard. I know my limits and I know my boundaries and that’s really affected the way I do things. I can handle this and I can handle that. I’m no longer intimidated to go to my professor’s office hours or talk to my professor or anything like that.

It is possible that the self-efficacy gained through the research experience, and not necessarily a higher self-efficacy going into the research experience, accounted for the correlation between self-efficacy and participation in research.

Attitudes toward doing science research was the third factor correlated with participation in research. Students discussed their enjoyment of science, their curiosity toward unanswered questions, and the potential of research to allow them to explore those questions. Tyler explained his interest in science research saying,

> The best part about research - I'd say it's the experience towards feeling like a real scientist and doing you know having a problem, going and finding background information, then conducting an experiment to solve that problem. To really like let you know what the basis of science is. What people for thousands of years have been doing. And you don't really get a sense of that in your classes, reading out of books, unless you get that first hand experience then you really know what science is all about.

The idea of doing something new that no one had ever explored before was attractive to some students. Matthew [Chemistry, researcher] said,

> I really have a curiosity; I like figuring things out – like solving problems and stuff. The research aspect is always on the leading edge it's always something new. No one's really broken this ground before wherever research is. I was really drawn to that.

Students also recognized the impact of science research on society. They liked science research because they knew it had the potential to improve humanity. Kelly [Microbiology, researcher] said, "Doing research in science basically enables everybody to have a better life."

Research students spoke about their enjoyment of science beginning early in their educational careers – often times in middle school, and in some cases, as early as elementary school. Many of them indicated that these early experiences were what prompted them to keep pursuing science later in their educational careers. Several students mentioned that while science was the subject they enjoyed the most, it was not their best subject when it came to grades. Chris [Biology, researcher] explains this point saying,

> I liked organic chemistry – it was really tough, but I enjoyed learning about it. I'm taking biochem and genetics now. They're hard, but it's the only thing I like. I do better in my other classes, but just because they're easier. But I don't like them; I just like science. It's all I can stomach doing.

Research participants also stressed the importance of the impact of science on humanity in their decisions to pursue science and science research. When asked why they would want to pursue a career in science, every participant talked about "helping people" or making a "positive difference" in people's lives. The impact of science was a reason that many of the participants chose to pursue science over other subjects that they enjoyed. Kelly [Microbiology, researcher], for instance, said,

> I realized that I liked history but it's a lot like regurgitation – you learn about world history, and it's going to be the same world history every time. There's really no change. I liked learning about living things – science research enables everybody to have a better life.

So while students may have interest in and earn higher grades in other disciplines, they see science as a career in which they can make a positive difference in society.

Many of the participants who did research felt that having a positive attitude toward research was a necessity. Tori [Chemistry, researcher] said, "Well, you've got to love it if you're going to do it, pretty much. If you don't love it, don't do it. That's pretty important." Ann [Cell biology and Genentics, researcher] felt similarly and said, "I think you have to go into it wanting to do it. You can't just force every science undergrad to do research because not all of them are going to want to do it."

The non-research participants did not necessarily have a "bad" attitude toward science research. None of them talked about science research as something they would never want to do. For most of them, it came back to issues of accessibility, effort, and time. One of the non-researchers had a bit of a different perspective. Devin [Microbiology, non-researcher] had a positive attitude about science research beyond the undergraduate level, but he was skeptical about the "research" opportunities that some students were afforded as undergraduates. He felt that you could get a better experience with research through applied science lab courses. He said,

> I've heard that a lot of the programs here, you basically go in and do one task for an entire semester or 2 semesters. That's part of the reason why I didn't do it. I feel like I would have gotten more out of, being a micro major we can either do research or we can take a lab class, an extra lab class that's actually an intensive lab that we go like 6 hours a week and you actually do a broader variety of things. Let's say you went to one research lab and sometimes you do a pcr for a whole year or you run ELIZA's or something. It's great experience for that one thing, but we get to do both of those and then we get to do sequencing and a variety of different things along with it. So it's less strenuous on that one topic so you don't get as much experience, but there's a broader variety.

So while Devin had a positive attitude toward doing science research, he felt that research-based classes could offer better exposure to the science research than could a semester or two in a single research lab.

Social interactions, while not a direct influence on participation in research, were correlated with both attitudes and self-efficacy, which did directly affect participation. The indirect effect of social interactions was evident in the interviews with students. Many of them talked about the importance of the relationships they forged in the research setting. Most of the research participants worked closely with graduate students or post-doctoral researchers. The undergraduate students valued the guidance that they received from these other lab members both in the specific research context and in the larger future educational and career goals context. Kelly said,

> I made a lot of connections while working in the lab. The grad student I work with has gotten me acclimated in the lab. It's really about the mentoring thing. I asked her about graduate school and she gave me a lot of advice. The relationships that I've built in the lab are ones that I don't think I could have ever made without doing research.

As students learned more about research, they explained that they gained autonomy and independence. Even with the gained independence, interactions in the research setting were still important to them. Thomas [Microbiology, researcher] explained,

> Over time I got a little bit more independent, but she was there pretty frequently or if she was doing something else I could get her attention. I like having someone else to talk to as well as being able to check yourself like – did I do this right? There's a benefit in that. I definitely prefer having people to work with.

Chris [Biology, researcher] valued the type of people he was meeting through research. He said, "Being in the research situation, you meet other like-minded people. So I can meet someone in the lab and make a friendship or connection or something that might help me down the line."

Interview data also supported the idea that social influences, and parents in particular, were influential in their decisions to do research. Several students talked about the influence of teachers or professors, but they did so in terms of the teacher's influence on their enjoyment of and appreciation for science, not as a direct influence on participation in UR. Very few interview participants mentioned peer influence, but almost all talked about the encouragement that they received from their parents. No one indicated that parents had mandated that they do research, but instead students talked about their parents encouraging them without pressure to pursue research if that is what they are interested in. Matthew [Chemistry, researcher] explained that his parents supported him saying that, "They never forced me or wanted me to do it, but they could see that I always had an interest in science more than anything else."

Many of the participants who did research spoke about their parents being scientists. Never in any of the interviews were participants directly asked what their parents did for a living, but many of the participants volunteered the information. Of the ten participants who did research, six of them spoke about one or both of their parents being scientists. Of the eight participants who did not participate in research, only one mentioned having a parent who is a scientist.

While intrinsic motivation was not a direct influence on UR participation, interviewees who did UR reflected the importance of the motivation to learn what it is like to be a science researcher. Researcher participants indicated that their interest and curiosity about futures in science and research were a key reason that they pursued UR experiences. Theresa [Microbiology, researcher] said, "Well, I wanted to learn just how research is, like how it is to be a researcher and some techniques that they do and the way they design experiments, the way they think of what to do next." Sarah [Ecology, non-researcher] has not yet participated in research but aspired to participate in the near future. Her statement below illustrates the desire to gain an understanding of how the process of science is actually carried out in real-world research:

> I just want to see how a scientific question goes from being just a question to getting carried out over years and putting it together and getting it published and moving on to other research. I kind of just want to see how that whole

> process goes. Just you know get involved in it and see if that's maybe what I want to do for a career.

Extrinsic motivations did not emerge as a factor related to student participation in research. This may be because extrinsic influences are seldom the sole motivation behind pursuit of UR in science. Whenever students talked about an extrinsic motivation in their interview, they paired it with an intrinsic motivation. Thomas [Microbiology, researcher] exemplified this point when he said, "Probably one big factor is grad school to show that you've done something like this and won't be new at it. I guess also just for enjoyment – I knew I would enjoy it." Thomas was motivated to do research because it would help him get into graduate school, but he was quick to add that enjoyment played a role, too. Holly [Biology, researcher] explained the balance between extrinsic and intrinsic motivations when she first heard about research experiences saying,

> I was like, oh this is kind of interesting – AND I get paid for this? I think that really helped me because not only would it be interesting experience, I had to consider – how is this going to work out financially. How am I going to live?

Holly and her mother had moved to the United States from Trinidad where the rest of her family still lived. Financing her college education was a major concern, so while Holly was admittedly interested in pursuing research opportunities, she knew it would only work out if she got paid for doing research.

Conclusions and Implications

This study tested the influences on student participation in science UR in one particular instance. When the same analysis is applied in different instances, for instance at a small liberal arts college, different factors may come forward as greater influences. The approach taken in this research is meant as a starting point for similar research in different contexts. The approach is flexible in that it presents an array of possible influences on participation in UR and through both exploratory and confirmatory factor analysis, it is possible to refine those influences to best fit a particular situation. UR programs at other institutions may be interested in applying this approach to their own circumstance and modifying the model to find the best fit for their situation.

There is no one factor that holds the key to students' participation in UR in science, which is evidenced by the covariances involved in the presented model. Multiple factors work together to influence students' decisions about research. In this situation, effort and accessibility issues, such as equity of access to programs, as well as attitudes and self-efficacy directly contribute to undergraduates' decisions to do research. Several additional factors, such as social interactions and motivations have an indirect effect on participation in UR in science. The presence of so many interactions among factors influencing research participation relates back to the theoretical basis for this research. In the TPB, there is covariation among all three factors influencing intention to perform a behavior, and in SCT, each of the factors of the model influences the others.

In a study of undergraduates' motivations for doing UR, Russell (2008) found that the three main motivations were: (a) Wanting hands on experience, (b) Help getting into graduate or professional school, and (c) Learning what it's like to be a researcher. Similar to the results of this study, the motivations discussed in Russell (2008) represent a combination of intrinsic and extrinsic factors. Consideration of both intrinsic and extrinsic factors in their influence on students' decisions to do research is, therefore, necessary to fully understand the factors effecting student decisions. While the data collected and analyzed in this study is specific to the University of Georgia, other institutions might draw insight from the findings to adjust their own recruitment efforts for UR.

For those institutions trying to attract more undergraduates to do research, appealing to students' desire for social interactions may be one effective approach. Most researchers will tell you that their research is highly collaborative, but not all students are aware of the interactive nature of research. Information advertising UR opportunities should also appeal to the positive attributes that students value in science and research. Reminding students of the positive impact that researchers can have on humanity is one way to draw on those positive attributes to attract students to the experience. Providing more information about what researchers do and what impact they can have may help mediate possible differences between students who have scientists in their family and those who do not.

Issues of accessibility of UR are an important consideration for institutions interested in developing their UR opportunities. If the intent is to make UR accessible to all students, then efforts should be made to inform all students about UR. Doing so requires moving beyond programs that target a specific subset of students, such as honors students or underrepresented populations. Taraban (2008) suggests that small changes, such as a campus-wide website to make research opportunities more visible, are the kinds of small steps that will add up to have a significant positive impact. Many institutions, understandably, put minimum requirements on participation in research. If requirements are made, they should be clearly stated and justified so as to minimize marginalization of particular students. Some programs, departments, or institutions take the accessibility issue to the other extreme by mandating research experiences for all students. Research has shown, however, that required research experiences are counterproductive and that the most effective UR experiences are those that are done out of genuine interest (Russell, 2008). The key, then, is a balance between providing access to students who are genuinely interested without forcing students to participate.

Those institutions interested in further developing UR programs should work to increase funding for UR experiences to ensure the longevity and stability of UR. This point is supported by Russell (2008) who found that research mentors perceived financial support to be the major barrier to increasing UR. Further, not only initial funding is important but also the sustainability of programs. Grant funds are short-lived, and even institutional and departmental support is ephemeral in today's economy (Blanton, 2008). Financial support is also needed to provide stipends for students who are interested in research but need to be earning money to support their undergraduate education. Students should not have to choose between a job to support them and UR to open doors to their future.

Similar to combining jobs and UR, another avenue for potential programs may be to combine service and UR. By offering programs integrating service and research, students will not necessarily have to choose one over the other if they are interested in both. Research in the medical and environmental fields often have direct effect on social well-being, so they may be good starting points for programs incorporating research and service.

Previous research has shown that UR experiences lead to increased confidence in research skills, ability to succeed in graduate school, and qualifications for jobs in related fields (Russell, 2008). The results from this study indicate that even students who participate in research may have low self-efficacy when they enter their research experiences but that participation in research may help to increase their self-efficacy. Future research should focus on this gain and the specific mechanisms through which it is achieved.

The affective aspects of students' interest in science and research should not be underestimated. Students' attitudes toward science research affects their educational and career paths, and many students recall early experiences with science as being formative in their overall positive evaluation of science. The majority of students who do UR in science trace their interest back to when they were young children or when they were in high school (Russel, 2008). The science content that is learned in elementary and middle school may not transfer later in life, but the feelings and emotions tied to early experiences with science may persist. In this way, influencing undergraduates to pursue research may begin much earlier than when they begin their undergraduate career. Attracting undergraduate students to science research through enjoyment and interest during K-12 science education may have profound direct and indirect effects on students' pursuit of research in the future.

Considerations and Future Directions

The proposed mixed methods approach was useful in illuminating the influences on students' participation in UR. Construction of the confirmatory model based on exploratory factor analysis was simple and effective, which speaks to the robustness of the approach. Results from both the exploratory and confirmatory factor analysis provided a solid foundation from which deeper examination then took place with the qualitative data. The complimentarity afforded by combining the multiple sources of data presented a holistic picture of students' influences that would not be possible with quantitative or qualitative data alone.

The participants in this study represented a range of science majors, although the majority of them were life sciences majors. Some participants were male, some were female, and they represented a range of ethnicities. Future studies may address similar questions but target certain groups to determine how the model performs in more specific instances, for example, looking specifically at under-represented populations, or examining the influences at work for non-science majors working on research in other fields. There are a growing number of research programs for high school students, and it may be interesting to apply the model to those high school students doing research to see where they map with the model. Examining the differences between certain groups in particular may shed more light on the forces at work in students' decisions to pursue research. Programs involving teacher research experiences should also be examined. While research experiences for high school students and teachers are less prevalent than those for undergraduates, a review of the literature suggests similar gains for all three groups (Sadler, Burgin, McKinney, & Ponjuan, 2009). The more that is understood about influences on participation in science research, the better prepared we are to broaden and enrich the research experience.

Talking with the interview participants sparked curiosity about students' perceptions of the nature of science and how it is possibly affected by research experiences. When interview participants were asked why they liked science, most of them said that they liked science because it is objective, that there is one right answer, and that it is straightforward. When they were then asked if that was what their experience was like in the research lab, the response was always the same – laughter. Students admitted that in the research setting there was never one clear answer, uncertainty was the norm, and subjectivities were unavoidable. It was not possible to ascertain in discussions with them, however, whether they perceived this discrepancy as an insightful experience leading to the revision of their ideas regarding the nature of science or that the it led them to see research as being "different" from science because of the discrepancy. Burnley, Evans, and Jarrett (2002) found that students who choose to do UR are well-prepared to grapple with questions on the nature of science when prompted in journal responses to critically think about their ideas about science. Is the experience of doing research enough to get students thinking about the nature of science or is encouraged and supported meta-cognition, in journal responses for instance, necessary for students to make the connections between the nature of science and their research experiences? This question of the relationship between understanding of the nature of science and UR experiences is intriguing and would benefit from future research.

The influences that play a role in students' decisions regarding UR are, of course, not the last important influences in their career paths. Future research might take a similar approach to explore the constructs that influence students who become career scientists and whether UR plays a role in their decisions. Longitudinal studies spanning from high school or early undergraduate career to years later when those individuals are settled in a permanent job could shed light on both influences involved in pursuing research and also on how undergraduate experiences influence where they end up after their undergraduate career.

Another avenue for future research related to this study, is an exploration of teacher research experiences in science. Science teacher research experiences are growing in number and popularity and have the potential to positively impact teachers' understanding of the nature of science (Varelas, House, & Wenzel, 2005) and to positively influence their students' understanding of the nature of science (Brown & Melear, 2007). While the aims of teacher science research experiences and UR in science are both related to providing a better understanding of what it means to be a scientist while increasing knowledge and skills related to science and research, the motivations for participating in research may be very different in teachers compared to undergraduate science majors. Applying the model described in this study to science teacher research experiences could provide a deeper understanding of the constructs involved in teachers' decisions to participate in research and could, in turn, provide useful information for attracting teachers to science research experiences.

CHAPTER 4

UNDERGRADUATE RESEARCH IN SCIENCE: EXPECTATIONS AND OUTCOMES[1]

[1]Pacifici, L.B., and Thomson, N. To be submitted to *CUR Quarterly*

Abstract

The beneficial outcomes of undergraduate research (UR) in science have been continuously supported in scholarly research. The reported outcomes are often discussed in terms of institutional goals for education. The purpose of this chapter is to examine the outcomes of UR in science in relation to the individual expectations of students participating in UR. A questionnaire on students' expectations of their research experience was completed by 26 undergraduate science majors at the beginning of the semester that they were doing research. They completed a second questionnaire at the end of their semester of research on their perceived outcomes of their experience. Follow-up interviews were conducted with eleven of the participants to gain a deeper understanding of the relationship between students' expectations and outcomes of UR. Increased GPA and help getting into graduate or professional school were the two outcomes for which students reported significantly higher outcomes than expectations. Making faculty connections and publishing research were the two outcomes for which reported expectations were significantly higher than outcomes. These results can be used to help institutions fine tune their UR programs to address student expectations.

Introduction

Undergraduate research (UR) has consistently produced positive outcomes for participating undergraduate students. Several research studies (Kremmer & Bringle, 1990; Ryder, Leach, & Driver, 1999; Kardash, 2000; Bauer & Bennett, 2003; Seymour et al., 2004; Kinkel & Henke, 2006; Russell et al., 2007) have examined the benefits gained by students through experiences in undergraduate science research and have made a strong case for the importance of undergraduate research. Research experiences not only prepare students for the next step in a scientific career, but they also help students hone their skills, knowledge, and understanding related to the process of science research. In addition to understanding the outcomes of UR experiences in science, educators, science faculty, and UR program administrators should also be concerned with the expectations of students entering UR experiences and the degree to which their experiences and the outcomes of their experiences meet their expectations. Understanding not only the outcomes, but also students' expectations of their research experience, will allow colleges and universities to tailor their UR recruiting to accurately represent their program. In doing so, students will have realistic expectations and a clear understanding of the possible outcomes they may gain through the research experience.

Researchers have determined that the benefits of undergraduate research include increases in: confidence (Seymour et al., 2004; Russell et al., 2007), grade point average (Kinkel & Henke, 2006), understanding of what it means to be a scientist (Bauer & Bennett, 2003, Seymour et al., 2004; Hunter et al., 2007; Russell et al., 2007), understanding of aspects of the nature of science (Ryder, Leach, & Driver, 1999), critical thinking and problem solving (Bauer, 2001; Hunter, Laursen, & Seymour, 2008), research and skills (Kremmer & Bringle, 1990; Kardash, 2000; Bauer & Bennett, 2003; Seymour et al., 2004; Hunter et al., 2007), communication skills (Bauer & Bennett, 2003; Seymour et al., 2004; Hunter et al., 2007), and clarity about future education and careers in science (Kremmer & Bringle, 1990; Bauer & Bennett, 2003; Seymour et al., 2004; Hunter et al., 2007; Russell et al., 2007). Bangura (2003) examined expectations of undergraduate research at two different institutions, but the research focused at the expectations of the institution as opposed to the expectations of the students. One of the institutions has high expectations for and is encouraging of UR, while the other does not especially encourage UR. Bangura's (2003) work is useful, especially to institutions looking for models of how to support UR, but their research did not address the expectations of students entering UR in science. As Cartwright (2000) explains, UR provides gains for both students and the university, so we should be concerned, therefore, with the expectations and outcomes of both the students and the university.

More recent studies on undergraduate research have provided further evidence for the benefits of UR. The focus on gains from research experiences is driven by issues of accountability. For programs to maintain or expand subsidization or to gain program accreditation, evidence of gains is necessary. While current research provides clear evidence of personal, professional, and academic gains associated with UR, research is lacking on the relationship between students' expectations for and outcomes of their research experiences. Some may consider any benefits as positive; however, there may be discrepancies between what students expect to gain through research and what gains are actually realized. In some cases, expectations may not be met even though there are certain gains. In other situations, gains may be greater than expectations. In either case, understanding the correspondence between expectations and outcomes of UR is needed to provide useful information to improve UR programs and address students' expectations. If expectations are not being met, students will be dissatisfied with their research experiences, and if outcomes are exceeding expectations then students are unaware of the benefits they may experience through research. Neither of these situations is ideal for programs that are aimed at increasing undergraduate research, so it is critical to gain an understanding of the correspondence between students' expectations and outcomes of UR in science.

This research sought to illustrate the degree to which expectations of research experiences are met for those doing UR at the University of Georgia. The specific research questions were:

1. What are the expectations of students entering undergraduate research experiences in science at the University of Georgia?
2. What are the outcomes of students' undergraduate research experiences in science at the University of Georgia?
3. How do expectations and outcomes of undergraduate research experiences in science at the University of Georgia compare and contrast?

The goal of these questions is to better understand how the gains that undergraduates expect to experience through research compare and contrast to their perceptions of realized gains after their research experiences. With the understanding gained in answering these questions, undergraduate research experiences could be tailored, promoted, and implemented to best serve all students interested in pursuing UR in science.

Methods

Approach

A mixed-methods approach was used to examine undergraduates' expectations and outcomes of their science research experiences. Quantitative analysis of questionnaire data were used to measure and compare students' reported expectations and perceived gains, whereas qualitative analysis of interview data were used to gain a deeper and richer explanation and description of the relationship between students' expectations and outcomes.

Data collection

A pilot questionnaire was administered during the summer of 2009 to 20 undergraduate science majors who were doing research at the time. Pilot questionnaire items were open-ended questions (see Appendix B). Responses from item seven on the pilot questionnaire , *What are* *your expectations for your science research experience?*, were used to construct ten Likert scale questions related to research expectations for the pre-Fall 2009 research questionnaire (see Appendix E). Ten corresponding items relating to the outcomes of the research experience were constructed for the post-Fall 2009 questionnaire. Items were only constructed for expectations noted by multiple respondents to the pilot questionnaire. Outliers were excluded, but a note was made to be aware of these additional expectations during the follow-up interviews. In addition to those ten items, four more items were included to address outcomes identified as important in the literature – critical thinking, problem-solving, self-efficacy, and understanding what it means to be a scientist.

Follow-up interviews were conducted with eleven of the 26 students who completed the questionnaire. Interviews were semi-structured with questions derived from the questionnaire responses. Interviews took place on the campus of the University of Georgia and were about 30 minutes in length. In the interviews, students were asked to clarify their questionnaire answers and more deeply discuss their expectations of the research experience and how their perceived gains corresponded to those expectations (see Appendix D for examples of interview questions).

Participants

Participants were 26 upper-level science majors at the University of Georgia who participated in science research during the Fall 2009 semester. Each of these participants completed one questionnaire before they began research at the beginning of the semester and another questionnaire at the end of the semester. Participants were initially located through the list serves of each science department. Respondents to the first questionnaire included both researchers and non-researchers. Those respondents who had participated in UR in science were contacted to complete the second questionnaire. Questionnaire participants were 18 females and eight males. Students who completed questionnaires were asked if they were willing to participate in follow-up interviews, and 11 of the original 26 students volunteered for interviews. Of the 11 interview participants, 6 were female and 5 were male.

Data Analysis

SPSS 17.0 (IBM SPSS, 2008) was used to calculate means and standard deviations for the responses to each questionnaire item. Paired, two-tailed, student's t-tests were used to determine the significance of differences between mean expectations and outcomes. The student's t-test is a parametric test that calculates a t-value that is compared to a critical value to determine whether the difference between the two samples is significant. The paired t-test is used when two groups are correlated, such as matched-pairs, repeated measures, or before-after as in this case. A two-tailed test was used because there is no expected directionality to the potential difference between students' expectations and outcomes (Garson, 2008).

Interviews were transcribed, and interview data were analyzed using the constant comparative method (Strauss & Corbin, 1990). Transcript analysis was progressive, meaning that each previously analyzed interview informed the analysis of subsequent interviews. Interview transcriptions were initially coded to categorize and summarize the essence of short segments of data. Initial codes were in the form of gerunds, such as "learning," "earning," "clarifying," and "connecting". After initial coding was complete, the individual codes were chunked together and examined for identify more focused codes. Through this focused coding, subcategories of the initial codes emerged, such as "learning about science," "learning about being a graduate student," "earning money," "earning credit," "clarifying career aspirations," "clarifying what I don't want to do," "connecting with faculty," and "connecting with students." Themes were then constructed that described the essence of what students talked about within each subcategory.

For example, when students talked about “learning about science,” many of them discussed how their research informed their learning in the classroom and vice versa. Therefore, “correspondence between their research and classes” was a theme.

Results

Mean expectations and outcomes for the categories with standard error bars are presented in Figure 4.1. Expectations were greater than outcomes on four items: knowledge gain, peer connections, faculty connections, and publishing, but significant difference only existed between the means for faculty connections and publishing. Outcomes were greater than expectations on four items: skills gain, recommendation letter, GPA increase, and help with graduate or professional school, but a significant difference only existed between the expectations and outcomes for GPA increase and help with graduate or professional school. Means were almost equal for the items enjoyable and clarify career goals. The mean responses for the four additional outcome items are illustrated in Figure 4.2. The mean values from these four additional outcomes range from 4.3 to 4.9, which corresponds to agreement and strong agreement that the noted outcome was achieved. When compared to the mean values of outcomes paired with expectations, the mean values for the additional outcomes are comparable to the five highest values of outcomes from the original list paired with expectations.

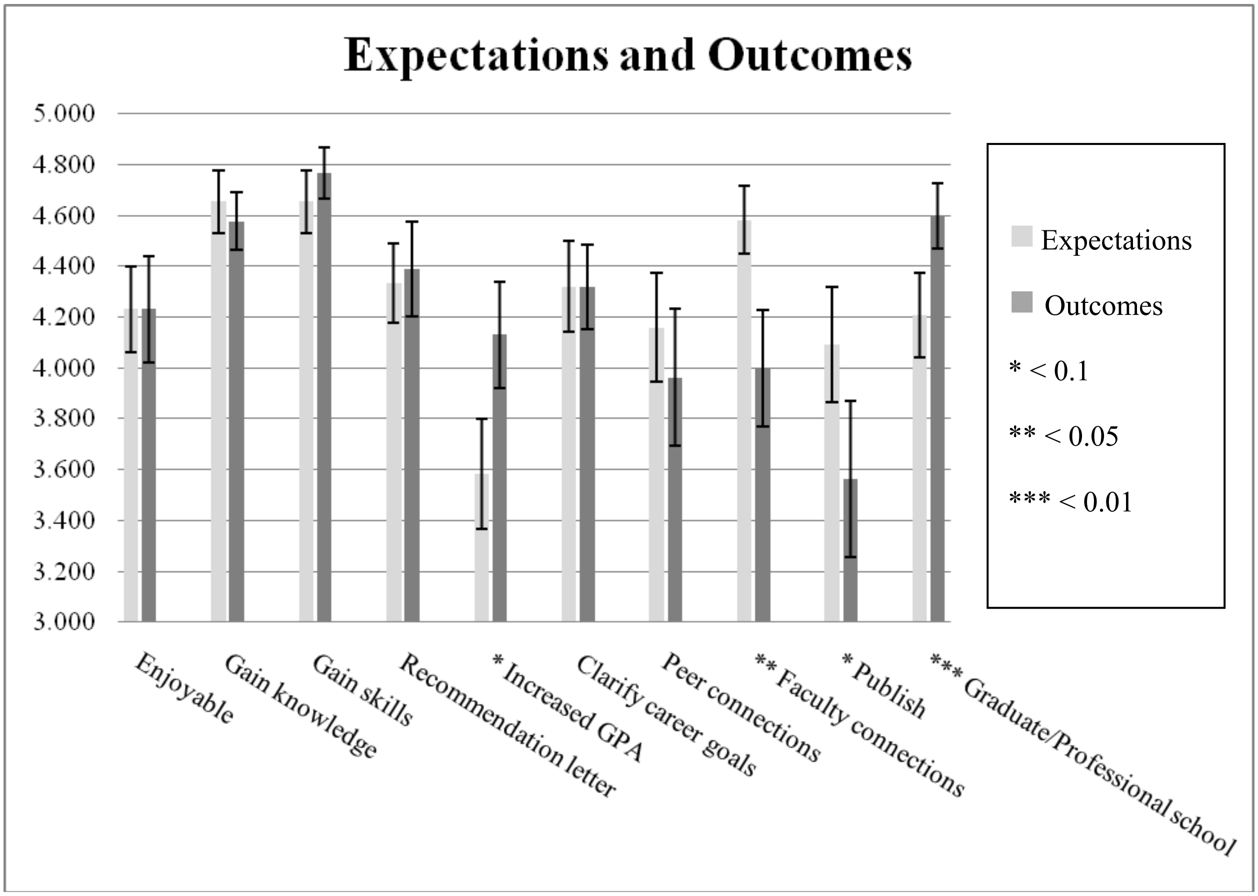

Figure 4.1. Mean Likert Scale Responses and Standard Deviation Bars for Expectations and Outcomes of Undergraduate Research Experiences in Science

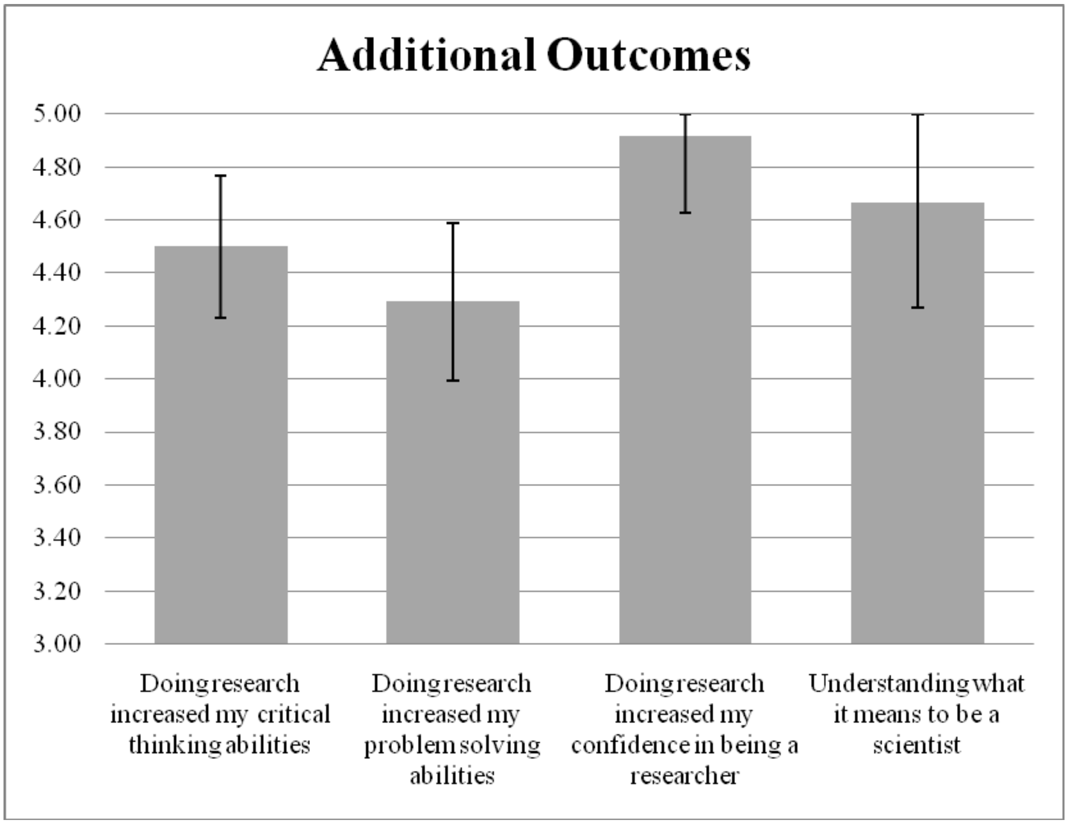

Figure 4.2. Mean Likert Scale Responses for Additional Outcomes of Undergraduate Research Experiences in Science

The quantitative data provides a baseline understanding of the correspondence between students' expectations and outcomes of their UR experiences in science. The following section draws from the qualitative data to elaborate on the categories with "richer" data provided by students in their own words in open discussions. These qualitative data are compliment to the quantitative data already presented.

Enjoyment

Students expectations and outcomes for enjoyment of their research experience were similar. I asked several students about whether all science majors should experience undergraduate research in science and many of them expressed the need for wanting to do it and having to be open to enjoying the experience in order to get anything out of it.

> "Well, you've got to love it if you're going to do it. If you don't love it, don't do it. And a lot of people say that the people you work with is what makes it and so I think definitely try to work with good people and enjoy the people you work with. That's pretty important." – Tori

> "I think you have to go into it wanting to do it. You can't just force every science undergrad to do research because not all of them are going to want to do it. Not all of them, if they don't want to do it, they are not going to do it well. You really have to want to do it or you are not going to have much fun." – Ann

While these students did enjoy the experience, they realized that not everyone would enjoy doing science research and felt the desire to do research and personal enjoyment of the experience were important precursors to a successful experience. The element of enjoyment that students spoke of was internal. Students did not look to their research mentor to make it fun. Those who were excited going into the experience, enjoyed it because it was something they were invested and interested in.

Skills and knowledge

Gaining skills and knowledge were the greatest expectations that students had for their research experiences. The gains in skills and knowledge that students percieved closely alligned with their expectations. Students recognized the knowledge and skill transfer between their research and their classes. Students also had greater confidence in their classes when they had experienced the coursework in their research. Theresa said, “I’m in microbiology lab now, so I know a lot of the techniques already from the research.” Research provided context for what students learned in their science classes, which made it easier to comprehend.

> “The knowledge transfer between my research and classes is amazing. That’s one of the things that I really liked about doing research. I’m taking advanced genetics now and it’s basically all primary literature so when I’m going through it and reading, I actually did a lot of these techniques so I can like see it in my head. Oh, they are going to do this and this. It’s helped a lot with getting the techniques – actually doing it so I can visualize it a lot better. And a lot of the background information that I read for my project transferred over. I took cell bio in the summer. We got to the cell cycle and we were learning all these things and I was like – I do that!” – Ann

Ann, like several other students, was enthusiastic about the correspondence between her research and her classes. Research experience provided students with an advantage going into science courses because of the knowledge and skills gained through research.

> "When I started doing research, it put me ahead in my classes – like when I started taking microbiology, I actually understood okay so this is why we do plate counts and this is how we do a plasmid transfer. It was like the research that I did really helped me in those courses." - Kelly

The applied, hands-on nature of research helped students grasp the deeper meaning of what they were doing and learning in science.

> "I think I learn a lot more in research because in class and in labs you're kind of just following instructions blindly and not really knowing exactly what you're doing. You don't really have an end goal – it's like I just want to get through these two hours then write up the paper. But with research you are doing it and you are forced to learn it and so I think I've learned a lot more this way. It's more practical." – Michael

Students valued the skills and knowledge gained in their research experiences for how it helped them in their science courses. Research experience provided a context to apply class material, which benefited students in both their research and their classes.

GPA

Participants were focused on the need to maintain a high GPA. They saw research as lower-stakes academic activity than classes. They did not so much look to research as a way to increase their GPA, but instead saw it as a beneficial academic experience that would not include the grade-related pressure that exists with traditional science courses. If a grade was attached to their research experience, the grade was based on their performance in the lab and usually on a final research paper explaining what they did through the course of the semester. Research did not involve traditional tests, such as those that account for the majority of grades in science classes. UR students appreciated this distinction between grades in classes and in research.

> "I'm in analytical chemistry this semester, and they really want you to get the right answer. I don't know it's kind of tough. Sometimes I don't know exactly what I'm doing. I don't understand everything. I'm afraid I won't get the right answers so my grade will be bad. So it's kind of like that pressure that makes it not an enjoyable experience." – Julia

Julia's comment also relates back to the previous topic of enjoyment. Her research did not involve the grade-related pressure of classes, which made the research experience more enjoyable to her.

> "I am really self-concious about my GPA. My GPA is low so I worry how I'm going to get into graduate school. I know it's affected me in terms of classes because I think I'm a better researcher than I am in classes. And being able to show myself that I can do research and people can be impressed with it and understand it and I can present it and I have all these abilities that aren't necessarily reflected in my grades. I think that's very easy to do in college – focus on your grades and to build up so much of your self-worth in your grades. And having this other area, I can say okay, well I can do this and it doesn't reflect in my academic ability." – Holly

Holly illustrated the feeling that research provides an alternative to a high GPA to prove one's ability and competence.

When they initially looked into participating in research, some students did not know that you could even get credit for a research experience. For that reason, several students did not expect that research would have an effect on their GPA but ended up benefiting from a boost in their GPA from their research grade.

> "At first I was just interested and wanted to go and see what it was like with Dr. D. I had no idea that I would get class credit for it. I didn't know that it would count as an upper-level biology class toward my major. That was a pleasant surprise to find that I would get four hours of credit for it." - Theresa

Clarifying career goals

Little difference existed between students' expectations and outcomes for how research would help clarify their career goals. Sometimes research experiences lead students to recognize what they might not want to do. Semester-long research experiences provide students an opportunity to try an area of research, and if it is not what they are looking for, they can try something else. In most science graduate programs, once you sign on for a research project, you are committed to it for a number of years. Doing UR for some students relieved the stress of having to choose what area to pursue.

> "To me the best part of doing research is just getting the experience in. It's not like I'm going to go to graduate school and not know what area of research I want to go into. Doing research is how I figured out I don't want ot do anything with plant biology because I liked learning the techniques but I really didn't get why I was doing this. With the cellular biology, I understood what the big picture was, but I wasn't enjoying it as much as I would have liked to. Now that I'm doing research in infectious diseases, I enjoy doing the techniques and I enjoy learning about why I'm doing it. Doing research has the advantage of basically giving me

> the experience and telling me okay, you're doing this and you don't like it, don't do it in graduate school." – Kelly

Kelly's comment relates back again to the notion of enjoyment as an important aspect of the research experience. Kelly used her level of enjoyment to judge whether or not the research she was doing is something that she would like to pursue later in life. Through her varied experiences and opportunities, Kelly finally found what she enjoys doing and what she hopes to continue doing in the future.

Science research careers are not widely publicized in society. Up to and even including their undergraduate careers, most students have little exposure to what it means to be a research scientist. This lack of knowledge makes it difficult for students to recognize whether a career as a research scientist is suitable for them. UR experiences provide the insight that helps students make such decisions.

> "I wanted to see if I really want to do research because most people won't go into school wanting to go into research and that's just kind of a side thing, but I really felt like this is what I really want to do and that gave me a big chance to see if it's the field that I want to go into – this alternative energy – is that it, or do I want to go into something else?" - Matthew

The science-related career with which students identify most is the field of medicine. Seven of the eleven interview participants in this study planned to be a doctor when they entered their undergraduate career. While the reasons they wanted to be doctors varied, for a few of them it was simply because it was the only job that they "knew" about in the field of science.

> "I think the problem with science is that it doesn't get enough exposure. Medicine gets a lot of exposure, so you watch TV and you think you want to be a doctor

and someone asks do you know anything else about science other than being a doctor and it's like – not really. So why do you want to be a doctor? And part of it is just that you never really know what else is out there. You might not know what being a doctor is really like and you need to challenge yourself to say, hey maybe I'd be better at this than being a doctor. So I think that part of the goal of research is to give exposure to something else that's out there." – Holly

Holly used her research experience to learn more about the possibilities of a science career beyond being a medical doctor, and she found that she was actually better suited to doing research. She entered her undergraduate career with plans to be a medical doctor, but after doing research, she decided to pursue a PhD in biostatistics. Kelly had a similar experience where she came into UGA wanting to be a doctor but discovered through her research experience that science research was really what she wanted to do.

> "My ultimate goal was to be a doctor – I really didn't know anything about being a research doctor having a PhD. The only doctor I really knew about was being a medical doctor. When I stared doing research, I was like I could still be a doctor getting my PhD, and I don't have to go through medical school and I'd get to do the thing that I really like." – Kelly

For some students, their experience doing science research at a university helps them decide not only what they want to do in the future, but what they do not want to do.

> "I'd like to maybe work in a company doing research. I don't really want to be a professor; I want to be hands-on still. I see Dr. R, and he never really goes into the lab and does stuff. He writes papers all day and writes books, and tells us what to do, but he never actually does much himself." – Tori

Tori respected her mentor and his research and appreciated the time that she spent interacting with him, but his day-to-day work was undesireable to her. Research helped Tori understand that she was better suited for a research setting rather than that in academia. Ann's experience was similar but what she found was that research was not something that she desired to exclusively pursue in her career.

> "As much as research has been helpful with my academic career, I don't think I could do this for a career. I need more change of scenery instead of being stuck at a lab bench for hours and hours. And I need a little more interaction with more people. I'm pre-med, so I want to go to different rooms and see different people. I was open to research before I got in. I've been pre-med since forever and then I wasn't so sure so I started looking into other things. I was looking into research but I didn't want to make any decisions on that because I've never done it, how do I know, but I was lookinginto things like doing research at St. Judes. I don't think I would be very good at research, though, because you have to be ahead of the game because you want to get published first and things like that. You have so many questions and you have to figure out how you're going to test it. The kind of thinking you have to do – I don't think I'm that great at it, so I don't think research is the career for me." - Ann

Whether students' research experiences showed them exactly what they wanted to do with their future, provided them an example of what they definitely do not want to do, or simply opened their mind to the variety of possibilities for futures in the field of science, UR experiences help students clarify their career goals.

Faculty connections and recommendations

After gains in knowledge and skills, students' highest expectations for their research experiences were for the connections that they would make with faculty. This, however, was also the item with the greatest discrepancy between expectations and outcomes. Students were hopeful going into the UR experience that working side-by-side with faculty would provide them with a strong faculty contact, which may lead to strong future recommendations.

> "I'm kind of a people person, so I really enjoy meeting new people and making connections, so just beyond the fact that I'll maybe get some good recommendations, I'll also get to know some cool people and always have someone I can fall back on or ask some questions. Like Dr. B, everyone he's had under his research has gotten into med school or grad school or whatever they want to do they get in." – Chris

For most students, though, they interacted far less with the faculty mentor than they did with graduate students or post-doctoral researchers. Students were thankful for the interactions and help that they received from graduate students and post-docs, but it is not the same as having a connection with a faculty member who can open doors by writing recommendations and helping students network.

> "[The postdoc] was really helpful. He understood my inexperience being just a student, so he gave me plenty of background information to read just to get me acquainted with everything before we started and even as we were going through he would explain everything so well because a lot of the stuff I had never worked with before like an autoclave. You don't do that in the undergraduate class labs. So he would show me how to do it and make sure I was doing it right, so he was

really helpful. Dr. B would just come in once in a while and check on me and see how my research article was going because that's how I was graded ." - Tyler

Undergraduate researchers were impressed with and respectful of their faculty mentors but rarely spent any time actually interacting with them.

"My research mentor is a really smart, interesting guy, so it's scary to talk to him – he's really brilliant. I was working with a post doc for about a year and a half and then he moved to Australia, so now I'm working with a grad student. I don't see my faculty mentor super-often. Probably like once every two weeks. He'll come into the lab and ask questions sometimes." – Julia

"Dr. R only comes down maybe once or twice a week, but most of the time we only see him at lab meetings. Most of the time he's up in his office if we need help for something, but he doesn't come down to the lab very much and if he does it's like, 'Okay, what have you done since I've been gone?' And if you don't have the news he wants, he just kind of walks away." - Tori

Julia and Tori did not express any real disappointment about the lack of contact with their mentors, but their expectations of the connections that they would make with their mentors was far different from what actually happened.

Publications

Going into research, many students had high hopes of publishing their work. For a few students, publications were a possibility, at least in the near future.

"We have like three or four publications in the works. They just kind of exploded; all these things happened at once. We've definitely talked about whether I'd get to be an author, and they said that I would. So that gives me a motivation to get in

> there and do a lot of work. Getting a publication would be pretty awesome." – Matthew

For several other students, however, it became evident that the amount of research necessary to write a publication would take them several semesters to accomplish. Logistical constraints, such as time, credit hours, and other responsibilities and interests prevented many of them from continuing in research to the extent that would result in a publication.

Getting into graduate or professional school

Help getting into graduate or professional school was the seventh highest expectation of undergraduates for their research experience, but it was the second highest outcome reported. Some students went into their research experience for the express purpose of padding their resume to help get into graduate or professional school.

> "Getting into medical school is what made me know that I had to do [research]. I kind of wanted to do it, but that's what made me know I had to do it because if I wasn't going to medical school, I could probably find something else to do. My [academic] advisor told me that research helps with medical school a lot, and on the MCG website, some of their stuff they look at talks about research." – Chris

Others pursued the experience for alternate reasons and found the strengthening of their resume to be an added benefit. Several participants initially entered research to help them decide wether research was something that they wanted to pursue in the future. They found that not only did research help them decide whether science was part of their future plans, but it also provided more opportunity for them to pursue science and research is they desired.

Problem solving and critical thinking

Several students predicted that their gains in critical thinking and problem solving skills would stay with them in their careers to a greater extent than the content-specific knowledge and skills that they gained.

> "As far as later on in life – I'll use the critical thinking and problem solving skills, which is what you need as a doctor, but as far as how to take stuff out of a test tube and put it on a petri dish, I don't plan on using that in the future." – Chris

Some of the students felt that the specific content that they learned through their research may possibly help them in certain classes in graduate or medical school, but the majority of students felt strongly about the more general effect of the gains in problem solving and critical thinking skills, which they felt would be invaluable later in their careers.

Confidence in doing research

Before participation in science research, most students have low self-efficacy in doing science research (see Chapter 1). After completion of a semester of research, however, most students expressed gains in confidence in their ability to do science research.

> "Another reason for doing research is to increase your confidence and your knowledge of yourself. Research really challenges you because no one has ever done this before so you aren't working toward some real solution. It's about seeing how far you can explore this problem, and it's really limited by your imagination and your capability." – Holly

Increase in confidence to do research was the greatest gain reported by participants.

Being a scientist

After a semester of working side-by-side with graduate students and research scientists, students gain an understanding of what it is like to be a research scientist in “real life.” This understanding includes an appreciation for the process, commitment, and time involved in being a successful scientist.

> “I’ve gained better insight to what scientists go through. A piece of information that’s in my textbook – how many researchers and how many experiments it took to be able to put that statement in a book and be accepted just all the huge range that science has on everyday life. My research has helped me appreciate that a lot.” - Tyler

Beyond an understanding of what it is like to be a research scientist, some students gained an even broader understanding and appreciation for what it means to have a career and be a part of a community of practice.

> “Before this, I’ve never really been put in the position where I didn’t know exactly what I was doing and didn’t really have a plan like I’m going to do this, this, and this so nothing goes wrong. So I had a lot of times I would go to sleep at night and I would go through everything I did in the lab that day and I’d be like I did this wrong, I did this wrong, I did this wrong. When I do something wrong, I have to go tell the post-doc the next day and I am dreading it because I don’t want to hear what she has to say about it. I wasn’t a trouble maker when I was younger, so I’ve never been reprimanded a lot, so it’s been a learning experience to admit that I’ve been doing things wrong. It’s made me more realistic I guess because this is a little more real world. This is the most real world that I’ve ever been in.

> Twenty years of my life, everything that I've been perfect at or good at only affected me or certain people. Research is something much bigger, so it's made me more realistic about my expectations that I keep having to tell myself that I made a mistake but it's not that big of a deal. It's taught me I have to admit to things because you could get away with not admitting that you do things wrong but now I've also learned that people need to know if you do something wrong for the bigger research project, so I've gotten better at admitting that." – Ann

The growth that Ann experienced through doing research helped her grasp what it means not only to be a scientist, but more importantly, what it means to be a responsible, contributing member of society. Her quote speaks to the significant gains in maturity that are possible when students are given responsibility and autonomy in their research experiences.

Discussion

Both the questionnaire responses and the interviews were students' self-reported perceptions of their expectations and outcomes of doing UR. Self-reported data assumes that the participant is self-aware and can effectively communicate their thoughts, emotions, and experiences. There is no real way to ensure that students' responses are a true representation of their thoughts, feelings, and experiences, but allowing students multiple avenues to express themselves hopefully provided ample opportunities. The combination of the questionnaire and the interviews helped address this assumption by eliciting information from students in multiple ways. Some students may have conveyed their thoughts, emotions, and experiences more effectively through either the questionnaire or the interview, and some likely needed both to provide a comprehensive understanding. As a researcher, it was extremely valuable to have both sources of data to complement each other and provide holistic insight.

The scope of this research is limited because it spans just one semester at one institution with a limited number of students and UR experiences. Longer-term research could provide an even deeper understanding of the paths students take on their way to possibly becoming a scientist. Hopefully this work can serve as a springboard for future longitudinal studies on long-term outcomes of UR.

Funding sources and accreditation agencies are mainly focused on “the bottom line,” or the specific measurable gains that are experienced through participation in UR. Institutions invest great amounts of time, energy, and money into funding and sustaining programs for undergraduate research, so it is important for them to receive positive feedback and outcomes consistent with their goals in order to continue support of the programs. Focusing solely on outcomes, however, downplays the importance of certain other aspects of students’ experiences with research. This research suggests that some of students’ expectations of research are not met while others are exceeded by their actual research experience. When expectations are different from outcomes, it may have an effect on which students pursue research and whether they decide to pursue research in the future. Understanding both the outcomes of research experiences and the expectations that students have going into research experiences are, therefore, necessary to wholly understand how to initiate and sustain quality UR programs.

Significant disparities existed where expectations exceeded outcomes in the areas of faculty connections and publications. After participating in research, students realized that demands on faculty members’ time is great and that graduate students or post-doctoral fellows are often more helpful and more accessible. While most students still felt like they would receive a positive recommendation from their faculty mentor, the personal connection that they expected was not realized. Hunter, Laursen, & Seymour (2008) explain the importance of the development of collegial relationships with faculty as an outcome of UR. Sixteen percent of students in their study indicated that establishing collegial relationships with faculty was an important outcome of their research experience. We do not know, however, what percentage of students in their study expected establishing collegial relationships going into the UR experience.

The results of this chapter suggest that fewer students develop connections with their faculty mentor than expect to. So while it is true that some students benefit from the relationships they develop with their mentors, others' expectations are not met. This discrepancy should be more of a concern than a point of pride for program administrators.

Upon entering the research experience, many students had hopes of publishing their research, but by the end of the semester realized that publishing is rarely possible in the span of a single semester. This may indicate that undergraduates have unrealistic expectations of both their relationship with the faculty mentor and the possibility of publishing their research. Another way to look at it is as a learning experience. Through these unmet expectations, undergraduates learned more about what it is like to be a research scientist. One has to work to climb the career ladder beginning as a graduate student, then a post-doctoral researcher, then junior faculty, and finally tenured faculty. And, as a scientist, it takes great time and effort to get research published. The gained understanding of this reality was evident when students explained that their mentor was rarely in the lab because he/she was usually busy writing for publication.

Significant disparities existed where outcomes exceeded expectations in the areas of the effect of research experiences on GPA and in helping with graduate or professional school. With the data collected in this study, it is impossible to know whether the increased GPAs were due to the grades students received for their research credits or due to the increased knowledge that they brought into their other classes. Future research may seek to elucidate the root of increased GPAs linked to UR experiences in science. Regardless, institutions and undergraduate research programs could capitalize on these lesser known benefits to recruit more students into research experiences. The effect of future trajectory as far as going to graduate or professional school is often a main focus of research on the benefits of research. The results of this study suggest, however, that students are not fully aware of this benefit when they enter their research experiences. While it is understood by researchers and probably many faculty mentors to be one of the most important benefits of doing UR in science, students may need to be informed more explicitly of this potential gain. Colleges and universities may want to amend recruitment documents to clarify this potential gain.

The purpose of the multitude of research studies on the benefits of UR in science is to work towards common agreement as to what constitutes "success" in UR research programs (Hunter et al., 2008). By looking only at outcomes, the "success" measured is only taking into account the institutional definition of success. My research also considers students' perceptions of success based on how their expectations track with the outcomes of their experience. The institutional definition of success may be the "final word" when it comes to sustaining support and funding for programs, however if students do not deem their experiences as successful, it could lead to fewer and fewer students pursuing research opportunities. Blanton (2008) sites sustainability as the greatest challenge for undergraduate research programs. While institutional support is imperative to sustainability, so is student interest and involvement.

Landrum & Nelson (2002) suggest that evaluations of benefits of UR should be used to provide potential undergraduate research students with examples of the benefits they are likely to gain as the result of participating in UR. Perhaps if this was done more effectively, students would have more realistic expectations of the programs they are entering.

The results of this research are based on a relatively small number of students at a single institution. The results are certainly not generalizable, without caution or caveats, to all students doing UR in science at all institutions. My results do support, however, the examination of not only the outcomes, but also the expectations of UR in science to assess the overall “success” of UR programs. It is my hope that future assessments of UR programs include student expectations and their relationship to perceived outcomes.

CHAPTER 5

UNDERGRADUATE SCIENCE RESEARCH: A COMPARISON OF INFLUENCES AND EXPERIENCES BETWEEN PRE-MED AND NON-PRE-MED STUDENTS[1]

[1]Pacifici, L.B., and Thomson, N. To be submitted to *Cell Biology Education*

Abstract

Most students participating in undergraduate research (UR) in science plan to attend either medical school or graduate school. The purpose of this chapter is to examine possible differences between pre-med students and non-pre-med students in their influences to do research and their expectations of research. Questionnaire responses from 55 pre-med students and 80 non-pre-med students were analyzed. There were no differences in the expectations of research between the two groups, but attitudes toward science and intrinsic motivation to learn more about science were significantly higher for non-pre-med students. Follow up interviews with 18 of the students and a case study with one pre-med student provided explanation for the observed differences. Pre-med students, while not motivated to learn more about science, were highly motivated to help people, which is why most of them want to be doctors. They viewed research as a way to help them on the road to becoming a doctor and as an opportunity to make sure that research is not a career path that they are interested in. Non-pre-med students wanted to do research to learn more about a specific area of science and to gain experience that will be helpful in their graduate school research. The difference in the reasons students want to do UR may be used to tailor UR experiences for students who plan to go to graduate school and those who plan to go to medical school.

Introduction

There are few academic ventures with the competitive reputation of medical school admissions. Since 2002, the number of medical school applicants has increased by over 30%, while the number of medical school matriculants has increased by only 11.5% (AAMC, 2009). Entrance to medical school has consequently become increasingly competitive over the past decade. Along with clinical and volunteer experiences, research experience is recommended for those interested in attending medical school (Rockler-Gladen, 2007; Freedman, 2009).

Several of the top research and primary care medical schools (US News, 2009) mention research experiences in their admissions guidelines, and the vast majority of those schools offer summer research programs for undergraduate students with possible interest in medical school. Harvard medical school, for instance, evaluates applicants based not only on grade point average and MCAT scores, but also on extra-curricular activities, research, and service experiences (Harvard, 2010). Johns Hopkins' medical school website tells potential applicants that, "The ability to conduct, evaluate, and understand research will be critical as medicine advances," and eighty percent of their medical students do research during their medical school experience (Johns Hopkins, 2010). Stanford University's School of Medicine highlights its strong commitment to student research explaining that, "Investigative experience sharpens critical reasoning. Students who are educated in a research environment are stimulated to seek a deeper understanding of disease and develop their ability to analyze scientific literature, making them valued members of any medical field, whether it be academic medicine, community-based practice, health care policy or emerging technologies (Stanford University, 2010)." Undergraduate research (UR) is, therefore, one experience that many students pursue to prepare them for medical school and to set themselves apart in the application process.

In chapter one, the constructs influencing undergraduate students' decisions to do science research were examined. Most universities do not differentiate research experiences for those pursuing medical school and those pursuing other endeavors. The majority of students, doing UR in science, plan to continue their education upon completion of their bachelor's degree (Bauer & Bennett, 2003). The obvious choices for further education in the sciences are pursuit of a master's or doctorate degree in science or the pursuit of a medical doctor degree. The pursuit of a medical degree is quite different in nature than the pursuit of a science graduate degree. The influences on pre-med and non-pre-med students' decisions to do research may also be quite different. The purpose of this chapter is to compare influences on research decisions and expectations of undergraduate science researchers who are planning to go to medical school and those who are not.

The research questions addressed in this chapter are:

1. How do the influences to do undergraduate research compare between pre-med and non-pre-med students?
2. How do the expectations of undergraduates doing research in science compare between pre-med and non-pre-med students?
3. How do pre-med and non-pre-med students explain their experiences in research?

The goal of this chapter is to gain an understanding of the possible differences between aspiring medical students and their non-pre-med counterparts in regards to their influences and expectations of their research experiences. With that understanding, UR programs may be able to tailor their recruitment efforts and their research opportunities to best suit students with different future goals.

Methods

Approach

Similar to chapter one, a mixed methods approach was taken to address the research questions. Quantitative analysis was used to examine the differences in means between questionnaire responses from pre-med and non-pre-med students. Follow-up interviews with both pre-med and non-pre-med undergraduate researchers provided depth of understanding to further explain the quantitative results.

In chapter one, a model for influences on students' decisions to pursue science research was proposed and tested using path analysis. Ideally, the same model would be used to examine the influence of the different constructs between pre-med and non-pre-med students. However, when the total sample (n=154) was divided into pre-med (n=55) and non-pre-med (n=80; 19 did not respond), neither group had a large enough sample size to reliably run the path analysis. The following analysis of differences between the pre-med and non-pre-med groups is a preliminary analysis that can be followed up in the future with the path analysis of the models using a larger sample.

Questionnaire

The quantitative data were collected through an online questionnaire. A pilot questionnaire was administered during the summer of 2009 to 20 undergraduate science majors who were doing research at the time. Pilot questionnaire items were open-ended questions (see Appendix B). Responses from the pilot questionnaire were used to construct ten Likert scale questions for the actual research questionnaire. The questionnaire was composed of 45 Likert scale questions (Appendix C) for non-research participants and 55 Likert scale questions for research participants. The ten additional questions related to the students' expectations of their research experience. Ten questions per construct kept the overall questionnaire to a manageable length, while providing adequate information for analysis. All participants answered questions related to their attitudes and beliefs about science research, as well as on accessibility, self-efficacy, and motivation related to doing UR in science. Several demographic questions at the end of the questionnaire asked students to identify their gender, major, race, grade point average, and post-graduation intentions. Their post-graduation intentions were used to separate participants into pre-med and non-pre-med groups.

An email was sent to all upper-level science majors via their department list serve. Approximately 1700 upper-level undergraduates are science majors at UGA. The list serves utilized included those for the following majors: biochemistry and molecular biology, biology, cell biology, chemistry, ecology, forestry and natural resources, genetics, microbiology, and physics and astronomy. The goal was to achieve 10% participation from the 1700 upper-level science majors. The email that students received included a link that brought them to the survey questionnaire in Survey Monkey (http: //www.surveymonkey.com). The last item on the questionnaire asked students to provide an email address if they were willing to participate in follow-up interviews. Those who provided their email were contacted for interviews. An attempt was made to get 10% participation in follow-up interviews with a similar representation of research and non-research students as was reflected in questionnaire responses. The questionnaire was completed by 154 upper-level science majors spanning the life-science and physical science disciplines, which is 9.1% participation. While this is slightly less than 10%, the sample size was satisfactory to address the research questions.

Reliability

Questionnaire items were tested for reliability using Cronbach's alpha, which measures the internal consistency reliability coefficient. A lenient cutoff for exploratory research is a value of 0.60 (Garson, 2010). Anything above 0.60 is acceptable, and below 0.60 is unreliable. Beliefs, attitudes, social influences, intrinsic motivation, self-efficacy, and accessibility (see Chapter 1 for definitions of constructs) were found to be reliable above the 0.60 level. The Cronbach's alpha for items related to extrinsic motivations was 0.343, which indicates that those items are not reliable when analyzed as a group. The items related to expectations of research were not tested for reliability as a construct because the responses to individual expectation items were of more interest than a combined expectations mean. Each expectations item was analyzed individually to compare the means between pre-med and non-pre med science majors.

Mean Comparisons

The Statistical Program for the Social Sciences (SPSS), version 17.0 (IBM SPSS, 2008) was used to compute mean comparisons. Mean responses between pre-med and non-pre-med students were compared for each of the following constructs related to science research: beliefs, attitudes, social influences, intrinsic motivation, extrinsic motivation, self-efficacy, and accessibility. All participants (n=154) completed questionnaire items for those seven constructs. Those respondents who were participating in research (n=80) also completed questionnaire items related to their expectations of their research experience. Mean expectations were compared between pre-med and non-pre-med students. Independent sample, two-tailed, student's t-tests were used to determine the significance of differences between mean expectations and outcomes. The student's t-test is a parametric test that calculates a t-value that is compared to a critical value to determine whether the difference between the two samples is significant. The independent sample t-test is used when two groups are independent of each other (i.e. not correlated), as in the case of pre-med and non-pre-med UR students. They have no effect on each other, so they are considered independent. A two-tailed test was used because there is no expected directionality to the potential difference between students' expectations and outcomes (Garson, 2008).

Interviews

Follow-up interviews were conducted with 11 of the participants who participated in UR in science to look at differences and similarities between the way they talked about their influences, expectations, and research experiences. Five of the 11 interview participants were pre-med science majors and six were non-pre-med science majors. Interviews took place on the campus of the University of Georgia and lasted an average of thirty minutes. Interview questions were based on the participants' responses to the questionnaire items so were consequently different for each participant (Appendix D). Interview questions addressed the seven constructs of interest: beliefs, attitudes, social influences, intrinsic motivation, extrinsic motivation, self-efficacy, and accessibility, as well as expectations of research for those participating in research. The goal of the interviews was to gain more reflective explanations and clarification for the questionnaire responses. Each interview was digitally recorded then transcribed.

Qualitative methods for the analysis of interview data were gleaned from Grounded Theory methods (Strauss & Corbin, 1990). Analysis followed a constant comparative method in which comparisons are made during each stage of analysis. Interview transcripts were coded, line by line, and codes were grouped into categories based on their relatedness and the categories identified in the model. Initial coding involved labeling sections according to which construct of the model the participant was talking about: beliefs, attitudes, intrinsic motivation, extrinsic motivation, social influences, access, and self-efficacy. The data within each of those initial codes was then examined to determine subcategories of each over-arching code. For example, subcategories within the intrinsic motivation code included "learning about science," "wanting to make a difference," "gaining skills," and "gaining knowledge". During coding and organization of data, memos were written to elaborate the categories and brainstorm ideas for possible themes to explain the data within subcategories. For instance, within the subcategory "wanting to make a difference," there were obvious differences between the way that pre-med and non-pre-med students talked about how they wanted to make a positive difference in the world. When common trends like this surfaced in interviews, a note was made and the notes were revisited to help develop rich meaning to describe students' influences. The themes developed from the analysis of the subcategories were then compared back to the quantitative data. Where similarities existed, the qualitative data were used to provide further evidence and explanation to the quantitative data. Where discrepancies existed, the data were revisited to search for meaning that may explain the differences.

Case Study

A semester-long case study was carried out with one pre-med science major, Chris, who was doing undergraduate research for the first time. The purpose of the case study was to gain both depth and breadth of understanding of a student's influences and experiences as one first begins research and how those influences and experiences may evolve over the course of the first semester of research. Three half-hour interviews and five one to two hour in-laboratory observations comprised the case study. Each interview was digitally recorded and transcribed.

Observations of Chris were guided by the following questions: How does a pre-med student behave in a science laboratory research setting? How does a pre-med student doing science research feel that the research experience relates to his future goals? To what extent does a pre-med student become invested in the work in a science research laboratory? To what extent does a pre-med student relate to the other individuals in the lab? Without observations of other students doing research, the case-study data cannot be used to compare pre-med and non-pre-med students, but the level of interaction with Chris allowed for great depth of understanding of his experience in research, how it evolved over the course of a semester, and how he views research in relation to his life and his future goals.

Field notes were taken by hand during the observation and were digitally transcribed immediately following the observation. The field notes were coded using gerunds to describe what Chris was doing. Some examples include: calculating, pipetting, interacting, and reading. The data related to each code was then examined to identify themes that described Chris's behaviors in the lab. For example, whenever Chris spoke with someone else in the lab, there was always some degree of humor involved. Joking and kidding was an ever-present aspect of his interactions with other lab members. The themes constructed from observation data were then compared to the data from interviews. In many cases, the observation data agreed with interview data and was useful in providing greater detail and explanation that cannot be gathered in interviews. In other cases, the observation data contradicted interview data. In these cases, the interview and observation data were further examined to draw meaning from the nature of the disagreement.

Results

Mean Comparisons

Results from the mean comparisons between pre-med and non-pre-med students responses to items related to beliefs, attitudes, social influences, intrinsic motivation, self-efficacy, and accessibility are illustrated in Table 5.1. Results from the mean comparisons of individual items of research expectations are illustrated in Table 5.2.

Table 5.1. Mean comparison of factors influencing participation in research between pre-med and non-pre-med science majors as measured by independent samples t-tests.

Construct	**Pre-Med Mean**	**Non-Pre-Med Mean**	**Difference**
Beliefs	4.04	3.94	0.10
Attitudes	3.72	3.99	0.27*
Social Influences	2.84	2.86	0.02
Intrinsic Motivation	3.93	4.43	0.50**
Self Efficacy	3.67	3.64	0.03
Accessibility	2.78	2.78	0.00

*$p<0.05$ **$p<0.01$

Table 5.2. Mean comparison of individual items related to expectations of research experiences between pre-med and non-pre-med undergraduate researchers.

Doing UR will…	Non-Pre-Med			Pre-Med			Difference*
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	
Be enjoyable	4.26	0.785	44	3.96	0.889	32	0.30
Help me gain knowledge	4.79	0.409	44	4.64	0.569	32	0.15
Help me gain skills	4.71	0.506	45	4.60	0.577	31	0.11
Obtain a letter of recommendation	4.41	0.686	42	4.33	0.637	31	0.08
Increase my grade point average	3.61	1.153	41	3.74	1.137	30	-0.13
Help me clarify career goals	4.41	0.715	44	3.88	1.054	33	0.53
Help me make peer connections	4.30	0.878	42	3.84	0.898	33	0.46
Help me make faculty connections	4.42	0.732	41	4.13	0.626	32	0.19
Allow me to publish my research	3.88	0.907	40	3.33	1.111	29	0.55
Help me in applying for grad/prof school+	4.04	1.061	45	4.22	0.843	32	-0.19

+ Medical, veterinary, dental, pharmacy, nursing
*None were significantly different at p<.05

There was little difference between mean responses for the constructs of beliefs, social influences, self efficacy, and accessibility. Mean responses on attitudes and intrinsic motivation constructs of non-pre-med students were significantly higher than those of pre-med students. There were no significant differences in expectations of pre-med and non-pre-med undergraduate researchers.

Explanations

The non-pre-med interview participants talked more, in general, about "liking science" than did the pre-med participants, which reinforces the difference in attitudes toward science research found in the questionnaire results. Five of the six non-pre-med participants went into detail about their fascination with science or their curiosity to continue learning more about science. Holly, for instance, explains how her interest in science goes back at least as far as high school:

> I took AP biology in high school and I really liked biology and I liked genetics even more because I thought it was really cool how genes work and I've always been interested in the fact that we speak and we have feelings and we have emotions and those things all translate into atoms and molecules. I always wonder how all these little things can create such a big effect and how does it all work? So I've always been interested in those kinds of things.

Julia talked about her interest in science in terms of her research:

> It's just fascinating. Especially parasites because they started so early on in the evolutionary scale and they can just, you can take it on to everything. They started off at the very beginning. They are just great to work with and interesting for evolutionary purposes.

When the non-pre-med students talked about why they decided to pursue science and science research, their affinity for the subject and its content was apparent across the board. With the pre-med students there was less continuity.

One of the pre-med participants, Theresa, remembered liking science from an early age, but she never talked about what science content she was interested in or what really captivated her about science. Instead she remembered watching “Bill Nye the Science Guy” and “The Magic Schoolbus” and enjoying those programs. Others of the pre-med students were ambivalent about their interest in science. Michael, for example, did not enjoy science classes in high school at all, but as he went through college he realized that he appreciated the objective nature of science. Chris was interested in biology but professed a general hatred for chemistry. Ann was similarly ambivalent saying, “I’m not a fan of every part of science. I’m in physics now. I don’t like physics. There are certain areas in science that I’m just not a fan of, but I do like science.”

Overall, the non-pre-med researchers went into greater depth in describing their research projects than did the pre-med researchers. Thomas, one of the non-pre-med researchers, went into detail explaining his research on, “larval mosquito proteins and their interaction with an auxin created by the Bt toxin.” He explained how he was working with the addition of other peptides to determine whether toxicity would increase or decrease. Thomas appeared to have a strong grasp on the content of his research and how the day-to-day work that he accomplished contributed to the project as a whole. When another non-pre-med researcher, Holly, was asked about her research, she first gave a short response noting transcription factors and the cell cycle. When asked in a follow-up question if her research was considered cancer research, she responded:

> Um, kind of. It's easy to think oh, cell cycle – cancer. But it is related to transcription factors. They already know that transcription factors affect the cell cycle, but this one is a minor transcription factor so we were changing it to see the effect on the time that cells go through certain phases of the cell cycle. So if you inhibited it, we predicted that it would be phosphorylated by this kinase and we stop it from being phosphorylated and see what happens to the cell cycle.

When most of the pre-med participants were asked about their research, they responded in a more general way, giving a surface explanation of their research and what they do. When Michael, a pre-med researcher, was asked about his research project he explained that they were, "looking at the effects of exercise on cognitive function," but he did not elaborate when asked follow-up questions. Similarly, Tyler, another pre-med researcher, described his research as, "analyzing the intercellular proteins of fungi," and he did not provide additional information in follow-up questions. One exception was pre-med researcher, Ann, who went into detail about her research with the model organism, *C. elegans*, and a particular gene that has a human homologue that functions in cell cycle regulation. Ann talked more overall than most of the other participants, and it was late in her interview when she finally provided detailed explanation of her work.

In the first interview with the case study participant, Chris, he was very brief when explaining his research. He basically said that it was about, "fungus on tomatoes," and that was the extent of it. As the semester progressed, Chris expounded more on the specifics of his research. The details of his research were never the first thing that he mentioned. He was more likely to make comments about social interactions with others in the lab or about his goals for medical school, but it was not because he did not understand his research or that there was a lack of depth in his work. Quite the contrary, in the last three observations of Chris working in the lab, he explained every step of his culturing and testing of different strains of fungi and how it related to his mentor's larger research goals. He demonstrated strong command of the research language, and both he and his mentor were confident with his knowledge and skills related to his work. Talking about the intricacies of his research was not of utmost importance to Chris when describing his research experiences, but when prompted, he was able to thoroughly explain and demonstrate any step in his research project. He also understood the "big picture" of his research and how it fit with his faculty mentor's overall research goals.

Non-pre-med students expressed more intrinsic motivation in wanting to learn about science and wanting to satisfy their curiosity about science. Julia was a non-pre-med researcher studying parasites. When asked why she did research, Julia had the following exchange with the interviewer:

> Julia: Well a lot of people do the kind of research I do because they grow up in malaria endemic areas and they want to find a cure for malaria, but I'm one of those people who just wants to do it because it's fascinating.
>
> Interviewer: That's a really interesting perspective. So you're not like, 'I hope I cure…,'
>
> Julia: Well, it would be really cool [laughter], but that's not my ultimate goal. I guess it's just to understand how it all works.

For her it was about the fascination with science, not necessarily about the glory of finding a cure.

The pre-med students did not lack intrinsic motivation as can be interpreted from the questionnaire data. They were less intrinsically motivated to learn about science than were the non-pre-med students, but they were highly motivated to do something with their life that would help other people. Helping people is what all of them talked about when asked why they wanted to go to medical school, and doing UR in science was something they saw as helping them reach that end. Ann said:

> I want to be a doctor just to – it's pretty cliché – help people. I started tutoring last year in a Latino community and a lot of them aren't very well off. When I saw them I was like, it would be really good if I came back and was a doctor and I could help people like them. I'm not in it for the money, so I could sacrifice my time and help these people who actually need it.

Several of the pre-med students said that while they were relatively certain that they wanted to go to medical school, they saw research as an opportunity to see what it would be like to have a career as a science researcher. Theresa explained that she was not completely sure whether she wanted to be a science researcher or a doctor before having her experience in research. After her research experience, she said, "I want to go to medical school because I don't like research – it's too tedious and I just don't have the qualities of a science researcher." She went on to explain that she felt she could have a greater positive impact as a doctor saying,

> There's like an 80% guarantee that you'll find the right answer in time if you're a doctor. You'll see the results immediately. You'll see the people you're helping. Especially in India – I'm definitely planning to go back to India after I graduate.

Similarly, Ann used research to rule out the possibility of doing science research as a career as opposed to being a doctor

> Ann: I was on the fence about going into research or going to med school, so I really needed to figure it out.

> Interviewer: And after just a few months, you feel like it's helped you make that decision?
>
> Ann: Yeah [laughter]. I feel like I knew probably after my first month that research wasn't for me. It's not that I hate it or anything; I just don't think that I could do this for another 50 years.

Conversely, Kelly and Holly were non-pre-med students who thought they might pursue medical school until they started doing research and realized the possibilities for careers in science beyond being a doctor.

The most basic difference setting apart those who wanted to pursue medicine and those who wanted to pursue careers in research was the focus of their intrinsic motivations. For those who had curiosity and deep interest in learning more about science, they pursued science research, while those who were more interested in social interactions and having a positive effect on the lives of humans, pursued medicine. The importance of this social aspect was apparent in both interviews and observations of the case study participant, Chris. In his first interview, which was before he had started his research, Chris talked about what he expected to get out of his experience:

> I'm kind of a people person, so I really enjoy meeting new people and making connections, so just beyond the fact that I'll maybe get some good recommendations, I'll also get to know some cool people and always have someone I can fall back on or ask some questions.

From the outset, social interactions were one of the most important aspects of Chris's experience. The importance of relationships continued to surface in observations and in the other two interviews with Chris. In the lab, Chris was the first to greet anyone who entered the lab. Other undergraduate researchers in the lab would sometimes work quietly by themselves, but Chris would always approach them and ask them how they were doing. In his final interview, he said that he felt like his lab group was a family. Chris explained that while science research was not what he wanted to do for his career, that he would maintain the friendships that he made – with other undergraduates, graduate students, post-doctoral researchers, and his faculty mentor – for the rest of his life.

Discussion

Both pre-med and non-pre-med students saw undergraduate research as a means to an end, but the end was different between the two groups. In general, pre-med students used undergraduate research as a way to help them get into medical school and as a way to help them clarify their decision to go to medical school. Non-pre-med students wanted to learn more about science and research, and wanted to see what it would be like to be a science graduate student or have a career as a science researcher. These different ends translated into the way students described their influences to do research and their experiences in research.

The pre-med students interviewed here indicated that their decisions to pursue medicine as a career were less about their interest in science and more about their interest in helping people. Each of the pre-med participants discussed their desire for human interaction in their career. Undergraduate research experiences are touted as acculturating students to a community of practice of scientists. The community of practice represented by most UR programs, though, is that of research scientists, not of clinicians or practitioners. Pre-med students are encouraged to participate in research but the notion that they may not identify with the experience the way that science majors intending to pursue graduate school or careers in science research may identify with the research experience is not explored.

Hunter, Laursen, and Seymour (2006) looked at gains in a number of different categories related to UR experiences. One of those categories was "Becoming a scientist," which included gains in behaviors and attitudes necessary to becoming a science researcher. Hunter et al. (2006) interviewed faculty and students about their perceptions of gains after the UR experience, and more faculty responses included gains in "Becoming a scientist," than did student responses. The authors suggest that students realize that they are making gains in knowledge and skills but do not recognize that those gains translate to acquired professional habits. It may also be that some students simply do not identify as scientists or as wanting to be a scientist, so they don't think specifically about gains in "Becoming a scientist." Several of the pre-med interview participants indicated on their questionnaire that they were not interested in a career as a scientist. When each of them was asked in the interview to explain their answer, all of them responded the same way. They said that they were not thinking of a doctor as a scientist. Students see doctors and scientists as completely different entities, and most will likely identify more closely with one or the other. If the ultimate goal of UR is not necessarily to make career science researchers out of all students participating, then perhaps the objectives of UR experiences should include the application of the research experience to the field that the students do wish to pursue.

The social dimensions of science are often unnoticed by students participating in UR (Ryder, Leach, & Driver, 1998). While most students doing UR do interact, depend on, and help others in their research setting each time the work on the research, they fail to recognize that the social interactions are indeed a component of the nature of science. If UR programs incorporated a focus on the social nature of science and encouraged students to discuss or reflect on how social interactions are critical to progress in science research, then perhaps UR students would have an overall better understanding of the nature of science and the pre-med students, in particular, may feel like there is less of a difference between the careers of scientists and doctors. This could possibly be accomplished through lab meetings or through the use of blogs where students reflect on their experiences in the lab and other lab members can comment on the posts.

Trosset, Lopatto, and Elgin (2008) describe course-embedded undergraduate research experiences and compare the perceived gains of the research courses with those of summer undergraduate research apprenticeships. The course-embedded UR experiences covered specific topics, such as genomics and eukaryotic microbes, and they were found to have similar trends in perceived gains as the summer UR experiences. Certain areas, such as working independently, were scored as higher gains in the summer UR group, but in other areas – especially those that the course was designed to highlight, such as understanding the research process and skill in scientific writing, were higher in the course-embedded research experiences. Course-embedded research experiences could be designed to address the interests of pre-med students while providing them authentic experiences in research. Courses focused on clinical health research or drug development research may be of practical interest to pre-med students and may provide a community of practice that they can identify with more closely than some other research experiences. Further, course-embedded research experiences directed specifically toward pre-med students could focus on particular gains or skills that are of interest to medical students, such as collaboration, critical thinking and problem solving.

Russell (2008) analyzed extensive questionnaire data related to UR experiences and found no patterns of differences between research characteristics and outcomes among different demographic groups determined by race or gender. While demographic distinctions may not separate students in their influences and experiences in UR, their academic major or future intentions may set them apart from each other. Future research should utilize larger samples of students to gain greater insight to the differences in what influences pre-med and non-pre-med students to do UR and how the different groups of students actually experience the UR opportunities they are afforded.

CHAPTER 6

CONCLUSION

Mixed methods provided a broad perspective and combined views through different lenses of epistemology and methodology. Some see such mixing of methods as violating the basic premise of certain epistemologies, but it can also be seen as breaking the boundaries of narrow perspectives. Without being tied to a particular way of knowing or way of analyzing, the research is free to construct meaning by whatever means are appropriate to the situation. None of the conclusions drawn in this dissertation would have been the same had only one type of data been collected. The combination of quantitative and qualitative analysis allowed for dimensionality that would not be possible with only one or the other. Moving from larger samples with the quantitative data to smaller samples in the qualitative data allowed for analysis at different levels of scale.

The purpose of this dissertation was to gain a better understanding of the factors that influence students to pursue UR in science, how their experiences track with their expectations of research, and how different groups of students consider UR experiences. The combination of analyses from the three main content chapters addressed this purpose and provided thought-provoking insight that can be used both to improve existing and new UR programs and to serve as a springboard for future research. Each chapter contributed a different aspect adding to the overall increased understanding of UR experiences in science.

The purpose of chapter 1 was to establish a model to explain the influences most important in students' decisions to do undergraduate science research. The exploratory factor analysis provided a basis to construct a model for student influences, which performed well in model testing. This approach may be a useful starting point for others interested in examining influences involved in UR in different situations. The adaptability of the approach makes it easy to apply to various circumstances. Chapter 1 also sought to explain which influences were most important in the particular instance of UR in science at the University of Georgia. In this instance, social interactions, self-efficacy, and accessibility issues emerged as important factors in determining whether students participated in research. Qualitative data provided deeper explanation to the complicated interactions among factors playing a role in students' decisions. I hope UR program administrators at UGA find the analyses of this chapter useful for recruiting students to do research and retaining students in the field of science.

Chapter 2 addressed the most popular research focus of UR – outcomes – but did it in a different way from the bulk of the existing research. Instead of examining outcomes from the institutional perspective of anticipated benefits of research experiences, chapter 2 first addressed students' expectations of research and then compared their perceived outcomes to those expectations. While the student-reported outcomes were similar to those cited in other research, there were some areas where student expectations were significantly different from their perceived outcomes. The increase in GPA and help getting into graduate and professional school were outcomes that students experienced but did not expect. Grades and getting into post-baccalaureate programs are very important to many students. If more students were aware of these potential benefits then perhaps more would pursue UR in science. Conversely, many students' expectations for making faculty connections and having their research published were not met. It is the responsibility of the institution, specific UR programs, and research mentors to make clear to students what is reasonable to expect from their experience. Very few students publish their work, especially if doing research for less than several semesters. The majority of UR students work more closely with graduate students or post-doctoral researchers than their faculty mentors. These facts do not necessarily decrease the positive impact of UR, but if students are not aware of them, they may be disappointed by their experience.

Chapter 3 drew from both previous chapters to compare the influences and expectations of students doing research who planned to go to medical school and those who did not plan to go to medical school. While expectations of the research experience did not vary between the two groups, attitudes toward science and motivation to learn more about science and research were significantly higher in the non-pre-med group. Qualitative data clarified that pre-med students were not completely unmotivated but that helping people was a much larger motivation that was learning about science. Many pre-med students approach UR for very different reasons that non-pre-med-students. The differing reasons for pursuit of research cannot be classified as right or wrong, but they should be recognized as differences that could impact the outcome of research experiences.

The three chapters tie together to provide insight that can hopefully improve UR experiences in science. The main findings from this dissertation can be summed up as:

- Specific aspects, including accessibility of research programs and funding, as well as appealing to students' social needs can be focused on to increase student participation and retention in research.
- There are many benefits of UR, but there are areas where students are not getting what they are expecting from the experience.
- The influences to do research are not the same for all students, and particular groups may have specific differences.

- Overall, student experiences with UR are multi-faceted and dynamic.
- Institutions should look at these multiple aspects, and perhaps others depending on the context, to gain a holistic view of UR and how to make UR programs most effective.

There are countless unanswered questions remaining related to UR in science. I am finishing this dissertation with many more questions than I had when I entered the research. I am now curious about the roles of mentors and how different approaches to mentoring may lead to different outcomes from the research experience. I also wonder about how research experiences influence students' conceptions of the nature of science. Hopefully this dissertation will spark conversations about UR in science and lead to further examination of the important questions. This work will be a starting point for me to continue my research on undergraduate science research. I hope to do longitudinal analysis of students who participate in UR to ascertain how their research experience impacts them beyond their undergraduate years. I also hope to extend my focus to look at teacher participation in science research as a way to improve their teaching efficacy. Undergraduate research in science has the potential to transform individual students into scientists and to open doors that will determine students' successful futures. Continued research on the various aspects of research experiences is critical for continuous development and improvement in UR programs.

REFERENCES

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl and J Beckman (Eds.), *Action-Control: From Cognition to Behavior (pp. 11-39). Heidelberg: Springer.*

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50,* 179-211.

Ajzen, I. (2005). *Attitudes, personality, and behavior*. New York, NY: Open University Press

Association of American Medical Colleges. (2009). U.S. Medical School Applicants and Students 1982-83 to 2009-2010. Retrieved February 25, 2010 from http://www.aamc.org/data/facts/charts1982to2010.pdf.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.

Bangura, A.K. (2003). Metaphors of expectations for undergraduate research: A tale of two universities. Presentation at the Annual Ann Ferren Teaching Conference, Washington, D.C.

Bauer, K.W. (2001). The effect of participation in undergraduate research on critical thinking and reflective judgment. AIR 2001 Annual Forum Paper, Long Beach, CA.

Bauer, K.W., & Bennett, J.S. (2003). Alumni perceptions used to assess undergraduate research experience. *The Journal of Higher Education, 74,* 210-230.

Bentler, P.M. (1990). Comparative fit indexes in structural models, *Psychological Bulletin, 107,* 238-246.

Blanton, R.L. (2008). A brief history of undergraduate research, with consideration of its alternative futures. In R. Taraban & R.L. Blanton (Eds.), *Creating effective undergraduate research programs in science: The transformation from student to scientist*. New York, NY: Teachers College Press.

Blunch, N.J. (2008). *Introduction to structural equation modeling using SPSS and AMOS.* Thousand Oaks, CA: Sage.

Boyer Commission on Educating Undergraduates in the Research University (1998). *Reinventing undergraduate education: A blueprint for America's research universities.* New York: Author.

Brown, S.L., & Melear, C. (2007). Preservice teachers' research experiences in scientists' laboratories. *Journal of Science Teacher Education, 18,* 573-597.

Burnley, P.C., Evans, W., & Jarrett, O.S. (2002). A comparison of approaches and instruments for evaluating a geological sciences research experiences program. *Journal of Geoscience Education, 50,* 15-24.

Cartwright, H.M. (2000). Igniting students: Do large-scale undergraduate research projects enthuse or defuse? http://ptcl.chem.ox.ac.ak/~hmc/papers/confchem2000/cartwrightconfchem2000.html.

Collins, A., Brown, J.S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator,15,* 6-11, 38-46.

Costello, A.B., & Osborne, J.W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10,* 1-8. Retrived May 12, 2010 from http://pareonline.net/pdf/v10n7.pdf

Cronbach L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16,*297-333.

Crow, M. & Brake, D. (2008). The impact of undergraduate experiences on students: An overview of literature. *Council on Undergraduate Research Quarterly, 28,* 43-50.

Falconer, J. & Holcomb, D. (2008). Understanding undergraduate research experiences from the student perspective: a phenomenological study of a summer student research program. *College Student Journal, 42,* 869-878.

Frantz, K.J., DeHaan, R.L., Demetrilopoulos, M.K., & Carruth, L.L. (2006). Routes to research for novice undergraduate neuroscientists. *CBE – Life Sciences Education, 5,* 175-187.

Freedman, J. (2009) Getting into medical school: Help for parents. *The Student Doctor Network*, October 4, 2009. Retrieved February 25, 2010 from http://www.studentdoctor.net/2009/10/getting-into-medical-school-help-for-parents/

Gafney,L . (2005). The role of the research mentor/teacher. *Journal of College Science Teaching, 34* , 52-56.

Garson, G.D. (2008). Student's t-test of difference of means. North Carolina State Statnotes. Retrieved April 6, 2010 from http://faculty.chass.ncsu.edu/garson/PA765/ttest.htm

Garson, G.D. (2010). *Reliability Analysis.* Retrieved February 2, 2010 from http://faculty.chass.ncsu.edu/garson/PA765/reliab.htm

Gates, P. (2006). Going beyond belief systems: Exploring a model for the social influence on mathematics teacher beliefs. *Educational Studies in Mathematics, 63,* 347-369.

Grimberg, S.J., Langen, T.A., Compeau, L.D., Powers, S.E. (2008). A theme-based seminar on environmental sustainability improves participant satisfaction in an undergraduate summer research program. *Journal of Engineering Education, 97,* 96-103.

Hammick & Acker, . (1998). Undergraduate research supervision: a gender analysis. *Studies in Higher Education, 23,* 335-347.

Harvard. (2010). Harvard Medical School admissions. Retrieved on February 24, 2010 from http://hms.harvard.edu/admissions/default.asp?page=application.

Henderson,L., Buising, C., Wall, P. (2008). Teaching undergraduate research: The one-room schoolhouse model. *Biochemistry and Molecular Biology Education, 36,* 28-33.

Herzog, A.R., & Bachman, J.G. (1981). Effects of questionnaire length on response quality. *The Public Opinion Quarterly, 45,* 549-559.

Hill, N.E., & Taylor, L.C. (2004). Parental school involvement and children's academic achievement: pragmatics and issues. *Current Directions in Psychological Science, 13,* 161-164.

Hu, L., & Bentler, P.M. (1995). Evaluating model fit, pages 76-99 in *Structural equation modeling: Concepts, issues, and applications,* edited by Rick H. Hoyle. Thousand Oaks, CA: Sage.

Hu, S., Kuh, G.D., & Gayles, J.G. (2007). Engaging undergraduate students in research activities: Are research universities doing a better job? *Innovations in Higher Education, 32,* 167-177.

Hunter, A., Laursen, S.L., Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education, 91,* 36-74.

Hunter, A., Laursen, S.L., Seymour, E. (2008). Benefits of participating in undergraduate research in science: Comparing faculty and student perceptions. In R. Taraban & R.L. Blanton (Eds.), *Creating effective undergraduate research programs in science: The transformation from student to scientist*. New York, NY: Teachers College Press.

IBM SPSS (2008). *SPSSBase 17.0 for Windows.* Chicago, IL: IBM SPSS.

Ishiyama, J. (2007). Expectations and perceptions of undergraduate research mentoring: Comparing first generation, low income white/Caucasian and African American students. *College Student Journal, 41*, 540-549.

James, W. (2007). *Pragmatism*. Sioux Falls: Nuvision.

Johns Hopkins (2010). Johns Hopkins Medical School admissions. Retrieved on February 24 from http://www.hopkinsmedicine.org/admissions/research.html.

Johnson, R.B., & Onwuegbuzie, A.J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*, 14-26.

Kardash, C.M. (2000). Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92,* 191-201.

Kight, S., Gaynor, J.J., Adams, S.D. (2006). Undergraduate research communities: A powerful approach to research training. *Journal of College Science Teaching, 35,* 34-39.

Kinkel, D.H., & Henke, S.E. (2006). Impact of undergraduate research on academic performance, educational planning, and career development. *Journal of Natural resources & Life Sciences Education, 35,* 194-201.

Kline, R.B. (2005). *Principles and practice of structural equation modeling (2nd edition)*. New York, NY: Guilford Press.

Koballa, T.R., & Glynn, S.M. (2007). Attitudinal and motivational constructs in science learning. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp.75-102). Mahwah, NJ: Lawrence Erlbaum.

Kremmer, J.F., & Bringle, R.G. (1990). The effects of an intensive research experience on the careers of talented undergraduates. *Journal of research and Development in Education, 24*, 1-5.

Landrum, R.E., & Nelson, L.R. (2002). The undergraduate research assistantship: An analysis of benefits. *Teaching of Psychology, 29,* 15-19.

Levis-Fitzgerald, M., Denson, N., & Kerfeld, C.A . (2004). "Hands-on" undergraduate research opportunities in the life sciences: Preparing the next generation of biological researchers. Presentation at the annual meeting of the association for the study of higher education.

Lopatto, D. (2003). The essential features of undergraduate research. *Council on Undergraduate Research Quarterly, 23,* 139-142.

McDill, E.L., & Coleman, J. (1965). Family and peer influences in college plans of high school students. *Sociology of Education, 38,* 112-126.

Miller, T. R., Baird, T. D., Littlefield, C. M. , Kofinas, G. , Chapin, F. ,III, & Redman, C. L. (2008). Epistemological pluralism: Reorganizing interdisciplinary research. *Ecology and Society*, 13, 46-55. [online] URL: http://www.ecologyandsociety.org/vol13/iss2/art46/

Millspaugh, J.J., & Millenbah, K.F. (2004). Value and structure of research experiences for undergraduate wildlife students. *Wildlife Society Bulletin, 32,* 1185-1194.

National Science Foundation (NSF). (2000). NSF GPRA Strategic Plan, FY 2001-2006. NSF Publication 0104. Washington, DC. Retrieved on January 17, 2010, from http://www.nsf.gov/pubs/2001/nsf0104/start.htm .

Nnadozie , E., Ishiyama, J., & Chon, J. (2000). Undergraduate research internships and graduate school success. *Journal of College Student Development, 42,* 145-156.

Olobatuyi, M.E. (2006). *A user's guide to path analysis*. Lanham, MA: University Press.

Randall, D.C., Wilbur, F.H., & Burkholder, T.J. (2004). Two models for an effective undergraduate research experiences in physiology and other natural sciences. *Advancement in Physiological Education, 28,* 68-72.

Rauckhorst, W.H. (2001). Measuring the impact of the undergraduate research experience on student intellectual development. Paper presented at Project Kaleidoscope Summer Institute, Snowbird, UT.

Rockler-Gladen, N. (2007). How to get into medical school. Retrieved on February 24, 2010 from http://college-degrees-programs.suite101.com/article.cfm/how_to_get_into_medical_school.

Russell, S.H. (2008). Undergraduate research opportunities: Facilitating and encouraging the transition from student to scientist. In R. Taraban & R.L. Blanton (Eds.), *Creating effective undergraduate research programs in science: The transformation from student to scientist*. New York, NY: Teachers College Press.

Russell, S.H., Hancock, M.P., & McCullough, J.M. (2007). Benefits of Research Experiences. *Science, 316,* 548-549.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching, 36,* 331-346.

Sadler, T.D., Burgin, S., McKinney, L., & Ponjuan, L. (2009). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching, 47,* 235-256.

Schultz, P.W., & Oskamp, S. (1996). Effort as a moderator of the attitude-behavior relationship: General environmental concern and recycling. *Social Psychology Quarterly, 59,* 375-383.

Seymour, E., Hunter, A., Laursen, S.L., Deantoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education, 88,* 493-534.

Stanford. (2010). Opportunities for student research. Accessed online at http://med.stanford.edu/student_research/ on February 24, 2010.

Steiger, J.H., & Lind, J.C. (1980). Statistically based tests for the number of common factors, *Paper presented at the annual meeting of the Psychometric Society,* Iowa City, IA.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

Tabachnick, B.G., & Fidell, L.S. (2001). *Using Multivariate Statistics, Fourth Edition*. Needham Heights, MA: Allyn & Bacon.

Taraban, R. (2008). What is undergraduate research, and why should we support it? In R. Taraban & R.L. Blanton (Eds.), *Creating effective undergraduate research programs in science: The transformation from student to scientist*. New York, NY: Teachers College Press.

U.S. News and World Report. (2009). Best medical schools. Accessed on line at http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-medical-schools on February 24, 2010.

Varelas, M., House, R., & Wenzel, S. (2005). Beginning teachers immersed into science: Scientist and science teacher identities. *Science Education, 89*, 492-516.

Ward, C., Bauer, K., Bennet, J. Content analysis of undergraduate student research evaluations. http://www.udel.edu/raire/Content.pdf. Accessed January 22, 2009.

APPENDIX A

FROM SEYMOUR ET AL. (2004) TYPOLOGY OF THE LITERATURE IN SUPPORT OF HYPOTHESIZED BENEFITS TO STUDENTS PARTICIPATING IN UNDERGRADUATE RESEARCH, ACCORDING TO PURPOSE AND QUALITY

Type 1: Hypothesized benefits are both claimed and well-supported
Research
(*1*) Kremmer and Bringle (1990)
(*2*) Kardash (2000)
(*3*) Ryder, Leach, and Driver (1999)
(*4*) Rauckhorst (2001, July)
Evaluation
(*5*) Alexander, Foertsch, and Daffinrud (1998, July)
(*6*) Nagda et al. (1998)
(*7*) Foertsch, Alexander, and Penberthy (1997, June)
(*8*) Alexander et al. (1996, June)
(*9*) Fitzsimmons et al. (1990, March)
Type 2: Hypothesized benefits are either simply stated, or claimed but not adequately demonstrated
Evaluation
(*10*) Mabrouk and Peters (2000)
(*11*) Gates et al. (1998)
(*12*) McCurdy, Buckner, and Baughman (1998, Dec.)
(*13*) Humphreys (1997)
(*14*) Sabatini (1997)
(*15*) O'Clock and Rooney (1996)
(*16*) Spencer and Yoder (1995)
(*17*) Zydney et al. (2002)
(*18*) Morley, Havick, and May (1998, July)
Descriptive accounts
(*19*) Chaplin, Manske, and Cruise (1998)
(*20*) Dunn and Phillips (1998)
(*21*) Kitto (1998)
(*22*) Madler (1998)
(*23*) Costa (1997)
(*24*) Manduca (1997)
(*25*) Nikolova Eddins and Williams (1997)
(*26*) Nikolova Eddins et al. (1997)

(*27*) Dukes, Kubinec, and Nations (1996)
(*28*) Voight (1996 Nov.)
(*29*) Weal and Clarke (1996, Aug.)
(*30*) Krochalk and Hope (1995)
(*31*) Byrd et al. (1994)
(*32*) Holme (1994)
(*33*) Fletcher (1993)
(*34*) De La Garza, Anderson, and Lee (1991)
(*35*) Sanzone (1977)
(*36*) Shellito et al. (2001)
(*37*) Orthlieb and Fewster (1994)
(*38*) Christman (1991)
(*39*) Dean (1991)
(*40*) Jones (1991)
(*41*) Halstead (1997b)
(*42*) Kurland and Rawicz (1995)
(*43*) Strassburger (1995)
(*44*) Gueldner et al. (1993)
(*45*) Seago (1992)
(*46*) Schamel and Ayres (1992)
(*47*) Bunnett (1984)
(*48*) Powers and Black (1976)
(*49*) Parsons and Bentley (1975)
(*50*) Powers and Black (1975)
(*51*) Stevens and Reingold (2000)

Histories and reviews

(*52*) Schulz (1998)
(*53*) Halstead (1997a)
(*54*) Schowen (1998)

APPENDIX B

PILOT QUESTIONNAIRE

1. What are the advantages of doing undergraduate research in science?

2. What are the disadvantages of doing undergraduate research in science?

3. What people influenced you most in your decision to do undergraduate research in science?

4. What specifically motivated you to do undergraduate research in science?

5. What barriers are there to doing undergraduate research in science?

6. What factors helped you be able to do undergraduate research in science?

7. What are your expectations for your science research experience?

8. What are your plans for participating in science research in the future?

APPENDIX C

SURVEY INSTRUMENT

1. Beliefs about science research – Please indicate your level of agreement with each of the following statements.

	strongly disagree	disagree	neutral	agree	strongly agree
Science research is important to humanity	O	O	O	O	O
Everyone should experience science research	O	O	O	O	O
Only people with advanced degrees can do science research	O	O	O	O	O
The work of scientists has little effect on the lives of other people	O	O	O	O	O
Most problems can be solved with science research	O	O	O	O	O
Humans depend on science research in their everyday lives	O	O	O	O	O
Anyone can do science research	O	O	O	O	O
Most science is applicable to everyday life	O	O	O	O	O
Doing science research requires critical thinking	O	O	O	O	O
Science research improves our lives	O	O	O	O	O

2. Attitudes about science research – Please indicate your level of agreement with each of the following statements.

	strongly disagree	disagree	neutral	agree	strongly agree
I would like to become a scientist	O	O	O	O	O
I would enjoy working with other people in a research setting	O	O	O	O	O
I enjoy my science classes	O	O	O	O	O
Doing science research is boring work	O	O	O	O	O
I like interacting with science professors	O	O	O	O	O
I prefer to work alone	O	O	O	O	O
I like talking about science with others	O	O	O	O	O
I would be unhappy in a career as a scientist	O	O	O	O	O
Doing science research is exciting	O	O	O	O	O
I enjoy exploring questions for which there is no clear answer	O	O	O	O	O

3. Accessibility and Self Efficacy – Please indicate your level of agreement with each of the following statements.

	strongly disagree	disagree	neutral	agree	strongly agree
Any student can participate in undergraduate research in science	O	O	O	O	O
The process of finding a research mentor was simple	O	O	O	O	O
Information on undergraduate science research at UGA is easily accessible	O	O	O	O	O
Applying to do undergraduate research was time consuming	O	O	O	O	O
I am confident in my ability to do undergraduate research in science	O	O	O	O	O
I am well-prepared to do undergraduate research in science	O	O	O	O	O
I am capable of conducting undergraduate research in science	O	O	O	O	O
There are barriers for some students to do undergraduate research in science	O	O	O	O	O
I was not sure whether my research mentor would want to work with me	O	O	O	O	O
I have the knowledge and skills required to do research	O	O	O	O	O

4. Motivations and Social Factors – Please indicate the extent to which you agree with each of the following factors influencing your decisions regarding participation in undergraduate research in science.

	strongly disagree	disagree	neutral	agree	strongly agree
Parental influence	O	O	O	O	O
Interest in science	O	O	O	O	O
Desire to go to graduate school or professional school (med, vet, dental, pharmacy)	O	O	O	O	O
Desire to learn more about science	O	O	O	O	O
Influence of friends	O	O	O	O	O
Exploring the possibility of a future in science research	O	O	O	O	O
Influence of academic advisor	O	O	O	O	O
Influence of K-12 teacher	O	O	O	O	O
Influence of college professor	O	O	O	O	O
Enjoyment of science	O	O	O	O	O
Earning course credit*	O	O	O	O	O
Earning money*	O	O	O	O	O
Getting a good letter of recommendation*	O	O	O	O	O
Improving my resume*	O	O	O	O	O
Getting into graduate or professional school*	O	O	O	O	O

*Not included in quantitative analysis

5. Demographic Information
    a. Are you female or male?______________________
    b. Have you ever done undergraduate research in science? If so, please explain the context and duration of your research.
        i. No ____
        ii. Yes ____
    c. What is your academic major?_______________________________
    d. Which of the following describe your race (you may choose more than one)?
        i. Black
        ii. White
        iii. Asian or Pacific Islander
        iv. Latino or Hispanic
        v. Native American
        vi. Other (please specify)___________________________________
    e. What is your GPA?
        i. Less than 2.5
        ii. 2.5 – 2.99
        iii. 3.0 – 3.49
        iv. 3.5 – 4.0

f. What do you plan to do after graduating from UGA?

   i. Graduate school – science
   ii. Graduate school – non-science
   iii. Medical school
   iv. Veterinary school
   v. Pharmacy school
   vi. Dental school
   vii. Nursing school
   viii. Job – science-related
   ix. Job – not science-related
   x. Not sure
   xi. Other (please specify) ______________________________________

g. If you are willing, please provide your email address for possible follow-up interviews. You may discontinue your participation in this study at any time.

   ____

APPENDIX D

INTERVIEW SCRIPT AND PROTOCOL

Thank you for agreeing to participate in this interview. These are consent forms that explain the research and how the data will be used. They also explain that all of your responses will be confidential and that you may withdraw from the study at any time. If you agree to participate, you will sign both forms and you will keep one and I will keep one. Do you have any questions about the consent forms?

After forms have been signed: Thank you. Now I'm going to ask you some questions about your experiences and your responses to the questionnaire. Are you ready?

Interview Questions for researchers

1. Why did you decide to do undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain your response?

1. In your questionnaire you indicated … about your beliefs toward science and research. Can you explain that response?
2. In your questionnaire you indicated … about your attitudes toward science and research. Can you explain that response?
3. How did people in your life influence your pursuit of undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain?

4. How did your intrinsic motivation – learning more about science, pursuing an enjoyment or interest of science, understanding whether your future plans include science research – influence your pursuit of undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain?

5. How did your extrinsic motivation – earning credit, earning money, getting a recommendation letter, getting into graduate or professional school – influence your pursuit of undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain?

6. How did your self confidence in your ability to do research influence your pursuit of undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain?

7. How did you're the accessibility of information and opportunities influence your pursuit of undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain?

8. How did your intrinsic motivation – learning more about science, pursuing an enjoyment or interest of science, understanding whether your future plans include science research – influence your pursuit of undergraduate research in science?

   Follow up question(s): In your survey, you indicated that… Can you explain your response?

Thank you very much for your participation in this interview. Your responses will provide valuable data to help understand students' attitudes and decisions about science research. If you have any questions or concerns about your participation in this research, please feel free to contact me at any time.

APPENDIX E

EXPECTATIONS AND OUTCOMES QUESTIONNAIRE

1. Expectations of science research – Please indicate your level of agreement with each of the following statements.

	strongly disagree	disagree	neutral	agree	strongly agree
My research experience will be enjoyable	O	O	O	O	O
I will gain knowledge through my research experience	O	O	O	O	O
I will gain skills through my research experience	O	O	O	O	O
I will receive a good recommendation letter as a result of my research	O	O	O	O	O
My research experience will boost my GPA	O	O	O	O	O
Research will help me clarify my career goals	O	O	O	O	O
I will make peer connections through my research	O	O	O	O	O
I will make faculty connections through my research	O	O	O	O	O
I will publish my research	O	O	O	O	O
Research will help me in applying for graduate or professional schools.	O	O	O	O	O

2. Outcomes of science research – Please indicate your level of agreement with each of the following statements.

	strongly disagree	disagree	neutral	agree	strongly agree
My research experience was enjoyable	O	O	O	O	O
I gained knowledge through my research experience	O	O	O	O	O
I gained skills through my research experience	O	O	O	O	O
I received a good recommendation letter as a result of my research	O	O	O	O	O
My research experience boosted my GPA	O	O	O	O	O
Research helped me clarify my career goals	O	O	O	O	O
I made peer connections through my research	O	O	O	O	O
I made faculty connections through my research	O	O	O	O	O
I published or plan to publish my research	O	O	O	O	O
Research helped me in applying for graduate or professional schools.	O	O	O	O	O
Doing research increased my critical thinking abilities	O	O	O	O	O
Doing research increased my problem-solving abilities	O	O	O	O	O
Doing research increased my confidence in being a researcher	O	O	O	O	O
Through my experience doing research I became a scientist	O	O	O	O	O