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Culturally Diverse Undergraduate Researchers' Academic Outcomes and Perceptions of Their Research Mentoring Relationships

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Abstract

Few studies have empirically investigated the specific factors in mentoring relationships between undergraduate researchers (mentees) and their mentors in the biological and life sciences that account for mentees' positive academic and career outcomes. Using archival evaluation data from more than 400 mentees gathered over a multi-year period (2005–11) from several undergraduate biology research programs at a large, Midwestern research university, we validated existing evaluation measures of the mentored research experience and the mentor-mentee relationship. We used a subset of data from mentees (77% underrepresented racial/ethnic minorities) to test a hypothesized social cognitive career theory model of associations between mentees' academic outcomes and perceptions of their research mentoring relationships. Results from path analysis indicate that perceived mentor effectiveness indirectly predicted post-baccalaureate outcomes via research self-efficacy beliefs. Findings are discussed with implications for developing new and

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refining existing tools to measure this impact, programmatic interventions to increase the success of culturally diverse research mentees and future directions for research.

Keywords

undergraduates; social cognitive career theory; mentored research experience; underrepresented minorities; mentoring

Introduction

Growing the next generation of scientists and engineers is an international concern. Numerous case studies from various countries illustrate the central role of mentoring as a capacity building process toward the career and professional development of emerging researchers (see Bennett, Paina, Ssengooba, Waswa, M'Imunya, 2013; Healy & Jenkins, 2009; Santora, Mason, & Sheahan, 2013). Mentored undergraduate research experiences are high impact learning practices (Graham, Frederick, Byars-Winston, Hunter & Handelsman, 2013) that effectively increase undergraduate student interest and preparedness for science, technology, engineering, and mathematics (STEM) careers (Lopatto, 2004; Russell, Hancock, & McCullough, 2007; President's Council of Advisors on Science and Technology, 2012; Seymour, Hunter, Laursen, & Deantoni, 2004), helping them make informed decisions about considering or actually pursuing graduate degrees and research careers in science (Pacifi & Thomson, 2011). Through hands-on learning experiences, students contribute new knowledge to their discipline under the guidance of a mentor and begin to define their disciplinary identity. An effective research mentoring relationship is central to successful undergraduate research experiences (Laursen, Hunter, Seymour, Thiry, & Melton, 2010). However, little is known about how specific factors in mentoring relationships between undergraduate researchers (mentees) and their mentors affect mentees' post-baccalaureate academic and career pursuits. Studies investigating the academic and career outcomes of undergraduate researchers have tested either the general contribution of research programs or how perceptions of research mentoring they receive is related to their commitment to a science career (e.g., Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; Villarejo, Barlow, Kogan, Veazey, & Sweeney, 2008). Scientific study of research mentoring relationships is needed to determine its mechanisms of impact on undergraduate STEM students' future actions and to subsequently improve mentoring effectiveness.

The work presented here uses the mentored undergraduate research experience as a microcosm to study what culturally diverse mentees in biological sciences perceive as impactful in the mentor-mentee relationship and how perceptions of that relationship relate to their actual post-baccalaureate academic behavior. Archival evaluation data from more than 400 mentees gathered over a multi-year period (2005–11) from several undergraduate biology research programs at a large, Midwestern research university were used to factor analyze existing evaluation measures of the quality of the mentor-mentee relationship for undergraduate research mentees and their mentors. A subset of data from mentees (77% underrepresented racial/ethnic minorities) was used to conduct a path analysis with the study's measures to test a hypothesized model of associations between mentees' academic

outcomes and perceptions of their research mentoring relationships based on social cognitive career theory (SCCT; Lent, Brown, & Hackett, 1994). Results from this study begin to identify the factors in the research mentor-mentee relationship that impact student outcomes and establish a framework in which to develop new and refine existing tools to measure this impact going forward.

Many educational interventions designed to promote STEM research careers lack an explicit theoretical base and fail to capitalize on the extensive literature in the psychology of career development (Byars-Winston, Gutierrez, Topp & Carnes, 2011). SCCT (Lent et al., 1994) is based on Bandura's (1986) social cognitive theory and asserts that an individual's level of motivation and choice of actions related to academic and career outcomes are based more on what they believe they are capable of than on what is objectively the case. This model provides a useful theoretical base for understanding the impact of the research mentoring relationship on a student's motivation for and choice of a research career in biological science. In particular, it allows us to examine the relationship between students' perception of the mentor-mentee relationship and their research-related self-beliefs, as well as the impact of these perceptions on their continuation in a research career pathway.

The primary research question guiding this study was: What is the relationship of mentees' perceptions of their research mentoring relationship to their post-baccalaureate academic outcomes? The long-term goal of this work is to identify causal mechanisms of effective research mentoring relationships and, in turn, advance diverse undergraduate students' post-baccalaureate academic pursuits in biological science, referred to from here on in this paper as *positive outcomes*.

Defining Undergraduate Research Experiences

The types of undergraduate research experience in which students participate can vary. Students may work individually or in a cohort. They may participate during the academic year, while taking courses, or during the summer, when they can commit to doing research full-time. They may be mentored directly by a professor, which is often the case at smaller liberal arts institutions, or by a senior researcher (e.g., a graduate student, postdoctoral fellow, or scientist), which is typically the case at large research universities. The current study uses data from students who participated in biology undergraduate research experiences at a single research university, and focuses on positive outcomes from a subset of those who participated in one of several intensive 10-week summer research programs offered at the university. Each of these mentees engaged in full-time research under the mentorship of a graduate student, postdoctoral fellow or faculty mentor.

Because our goal is to identify critical elements in the research mentoring relationship that affect positive student outcomes, we were not only interested in *what* impacts mentored research experiences have on students but *how* they create the effect that they have. Identification of critical elements in the research mentoring relationship that affect students' positive outcomes will allow for development of interventions that can be targeted to those factors. Accordingly, a novel aspect of this study is our examination of students' research knowledge and skills apart from their perceptions of their research mentors' effectiveness in

order to investigate the impact of these two separate but related components of an undergraduate research experience. In the following sections, we define and describe the benefits of undergraduate research experiences and articulate the theoretical framework for this study.

Benefits of Undergraduate Research Experiences in STEM

Students who participate in undergraduate research experiences self-report gains in research skills, writing skills, academic self-confidence, research productivity, and intellectual maturity (see Seymour et al., 2004 for comprehensive review; Laursen et al., 2010; Kardash, 2000; Lopatto, 2004). These experiences challenge students intellectually in a way that the classroom learning experiences do not, and often inspire them to continue engaging in scientific research, and in some cases, to pursue professional degrees and careers in STEM (Nagda, Gregerman, Jonides, Von Hippel & Lerner, 1998; Villarejo, et al. 2008). Consequently, undergraduate research experiences have been employed successfully in the recruitment of students to graduate school, especially underrepresented racial/ethnic minority students (Hathaway et al., 2002; Junge, Quiñones, Kakietek, Teodorescu, & Marsteller, 2010; Nagda et al., 1998). Previous research has shown that the mentoring relationship students received during their undergraduate research experience positively correlates with students' beliefs and behaviors in three general areas.

First, several studies indicate that the research mentoring relationship, assessed by the frequency and quality of mentee-mentor interactions, is associated with students' persistence (Nagda et al., 1998), such that students take more science courses, feel more prepared for, and actually pursue STEM graduate study and careers (Junge et al., 2010). The positive effects of undergraduate research experiences on student STEM persistence are due in part to research mentors who professionally socialize mentees into the research enterprise, expose them to "real research" and advance their understanding of how to "do science" (Laursen et al., 2010). Second, by supporting undergraduates' personal and career development as well as their acquisition of research skills, the research mentoring relationship can positively affect students' perceptions of their own research-related abilities (e.g., self-efficacy), of their science identity (Chemers et al., 2011; Cox, 2000; Dolan & Johnson, 2009; Lopatto, 2007; Paglis, Green, & Bauer, 2006; Thiry & Laursen, 2011) and subsequently their interest in and commitment to research careers (Hunter, Laursen & Seymour, 2007). And third, findings from studies of the mentored research experience indicate that the cultural diversity factors of gender and race/ethnicity can influence how undergraduate researchers experience rapport in their research mentoring relationships, what they value in a mentor, and their science or research-related self-perceptions (Blake-Beard, Bayne, Crosby, & Muller, 2011; Carlone & Johnson, 2007; Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009; Ishiyama, 2007; Johnson, Brown, Carlone, & Cuevas, 2011; Laursen et al., 2010). Taken together, these three areas strongly suggest that the research mentoring relationship greatly impacts culturally diverse students' research and science-related self-perceptions, and ultimately their pursuit of a science career.

There is also evidence that experiences of mentoring and undergraduate research may vary across groups. For example, some research on the salience of cultural factors in research

mentoring relationships with undergraduates indicates that gender and race/ethnicity are relevant in how mentees perceive the experience and what they value in a research mentor (Blake-Beard, Bayne, Crosby, & Muller, 2011; Ishiyama, 2007; Muller, Blake-Beard, Barsion, & Wotipka, 2012). And gender and racial/ethnic differences have been observed across numerous studies in students' learning experiences and how they rate their own math or science-related abilities (e.g., Lent et al., 2005; O'Brien, Martinez & Kopala, 1999; Zeldin, Britner, & Pajares, 2008). Further, the type of higher education institution one attends can impact the undergraduate research experience such that students from small, liberal arts colleges may not have as many opportunities available to them to conduct research, and thus their lack of exposure and experience may influence their research-related skills, knowledge, and self-efficacy beliefs (Laursen et al., 2010). Variables related to individual differences as well as context (i.e., campus type) may be important considerations in investigations of mentees' research mentoring and training experiences.

In order to test the validity of our assumptions, we need theoretically-informed and valid measures to tease apart critical elements in research mentoring that lead to desired behaviors (Poody, 2006). Such measures will allow mentors, directors of undergraduate research programs, and institutions to assess the effectiveness of their efforts in this area and provide the feedback necessary to guide program improvements to enhance positive student outcomes. This study provides evidence for the reliability of measures of mentor effectiveness. Further, this study tested proposed relationships among the undergraduate research experience, research mentoring, students' research-related beliefs, and students' post-baccalaureate academic behavior using the theoretical framework of SCCT (Lent et al., 1994) and examined variability in the relationships as a function of gender, campus type, and race/ethnicity.

Theoretical Framework

We chose to use SCCT (Lent et al., 1994) to examine the impact of the mentor-mentee relationship in undergraduate research experiences because it explicates the interactions among individual (e.g., gender, race) and environmental (e.g., research mentor support) factors that shape cognitive beliefs, which, in turn, inform academic and career outcomes (Bakken, Byars-Winston, & Wang, 2006). We also chose SCCT as a theoretical framework for the present study because it has received empirical support in studies with STEM undergraduates across gender and racial/ethnic groups (Byars-Winston, Estrada, Howard, Davis & Zalapa, 2010; Gainor & Lent, 1998; Lent et al., 2005) (see Figure 1).

Self-efficacy expectations, the central cognitive factor in SCCT, refers to confidence in one's ability to successfully perform a given task. Self-efficacy expectations, along with outcome expectations, are important mediators between person factors (e.g., race, ethnicity, gender), contextual background factors (e.g., academic preparation and opportunity for research), learning experiences (e.g., participating in undergraduate research), and an individual's eventual academic and career behavior. Self-efficacy expectations and outcome expectations foster academic and career interests and goals (e.g., intentions to pursue a specific career path) which, in turn, make it more likely that people will take actions to achieve their goals (e.g., seek entry into STEM graduate programs) (Lent et al., 1994). Finally, SCCT assertions

acknowledge that proximal contextual factors (e.g., social supports and barriers) that are encountered at critical choice junctures later in career development can also facilitate or inhibit interest and goal formation, as well as eventual actions. Overall, findings from existing research suggest that the effects of undergraduate research experiences and research mentors on undergraduate students' commitment to and pursuit of science careers are largely mediated by beliefs about one's science and research abilities (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Chemers et al., 2011; Hurtado et al., 2009).

Within the model of SCCT proposed by Lent et al. (1994), the learning experiences (e.g., undergraduate research) are those direct, vicarious, and persuasive encounters that help shape individuals' sense of their own competence and capabilities (see Figure 2). For example, mastering a specific research skill can bolster an undergraduate student's self-efficacy expectations related to success in graduate education. For undergraduate students to pursue STEM fields, they must be exposed to learning experiences that give rise to robust self-efficacy expectations. According to SCCT assertions (Lent et al., 1994), without these essential learning experiences, interests and goals related to pursuing STEM fields may be stifled, regardless of the student's level of objective talent.

The undergraduate research experience is a complex learning experience that involves many elements, including learning to perform research techniques, navigating relationships with peer researchers, making connections between classroom and research learning, and developing a research mentoring relationship. Though these elements are inextricably intertwined, for the purposes of this research, we examined the isolated effect of the research mentoring relationship on mentee outcomes. We define research mentoring as a set of strategies that facilitate a developmental process aimed at fostering individual growth and development toward pursuit of STEM research careers. By extension, the research mentoring relationship, a bi-directional relationship between mentors and mentees operating in a socially complex interpersonal exchange, is the vehicle through which those strategies can be enacted.

Therefore, we hypothesized that:

1. Effective research mentoring will positively contribute to mentees' research-related self-efficacy expectations;
2. Research-related self-efficacy expectations will increase actions toward a science career (pursuit of a graduate or professional degree in science or medicine).

Based on existing research discussed in the previous section (Lent et al., 2005; O'Brien, Martinez-Pons & Kopala, 1999), we postulated that there may be gender and racial/ethnic differences in students' learning experiences, both in how they experience their research mentors' effectiveness and ratings of their own research skills and knowledge. A subset of the current data sample provided a unique opportunity to examine these postulations as the majority of the mentees were racial/ethnic minorities working with White mentors. We also postulated that the home institution of the undergraduate researchers may impact perceptions of their research mentors' effectiveness and ratings of their own research skills and knowledge (see Laursen et al., 2010).

To test these hypotheses and assertions, two sets of analyses were carried out. First, because the data were collected using surveys originally designed as evaluation tools of an undergraduate research experience program, we conducted exploratory factor analyses to establish the reliability and factorial validity of items included in the surveys. The surveys included separate sets of items assessing research-related skills, knowledge, self-efficacy, and mentor effectiveness. Second, we used these validated measures in a path analysis to test hypothesized relationships between SCCT factors (person inputs, background contextual factors, learning experiences, self-efficacy) and students' pursuit of a graduate STEM degree, investigating potential variation of relationships by gender, race/ethnicity, and students' home institution (Figure 2). Importantly, this analysis separately examined two components of the undergraduate research experience: mentees' research-related skills and knowledge and their perceptions of mentor effectiveness.

Method

Procedure

This study was approved by the university's human subject review board and used archival data gathered over a six-year period (2005–2011) from several undergraduate biology research programs at a large, Midwestern research university. All participants consented to the research. Two sets of undergraduate student mentees participating in biology undergraduate research were used in this study: mentees who participated in the university's residential 10-week summer research opportunity program and mentees who participated in undergraduate research offered at the same campus during the academic year. All research mentors for both sets of student mentees were from the host institution and were predominantly White. At the conclusion of the research experience, both summer and academic year students completed evaluation surveys from which the data for this study were drawn. The summer research opportunity program participants had a full-time research experience (40 hrs/week) and included primarily underrepresented racial/minority students enrolled at other institutions, whereas the academic year participants varied in the hours per week spent on research, were predominantly White, and were all from the host campus. Because of the greater uniformity in length of the research experience and greater numbers of underrepresented racial/minority participants in the summer research opportunity program, only the summer research opportunity program data set was used for the path analysis; these data allowed for examination of a common undergraduate research experience and for person factors relating to cultural diversity to be tested. However, factor analyses of the survey items were conducted using data from all available students, including the academic year participants, in order to obtain the most accurate results. The average response rate for the summer research participants' completion of the evaluation surveys was 76%. The summer research program data sources included:

1. Student applications to the university's summer research opportunity program containing information on person input factors (gender and race/ethnicity) and background contextual factors (home institution and prior research experience);
2. Evaluation survey responses collected from the undergraduate mentees upon completion of their research experience;

3. Post-baccalaureate outcome data collected annually from summer research opportunity program participants by the program's director.

Summer Research Opportunity Program Participants: Person Inputs and Background Contextual Factors

Descriptive statistics for the summer research opportunity program students for whom demographic factors were reported are shown in Table 1 (data for academic year students available from authors). There were 214 mentee participants with 65% females and 77% identified as underrepresented racial/minority, including Black, Asian/Pacific Islander, Mexican/Chicano/a and Other Hispanic. Participants were from a variety of institution types, including research extensive institutions, liberal arts institutions, and institutions offering only some advanced degrees (intermediate). The sample included relatively equal representation of students who had a prior mentored research experience and those who had not. Consistent with the requirements for admission to the summer research opportunity program, over 96% of the sample had a GPA > 3.0, and over 60% had a GPA > 3.5 on a 4.0 point scale where a top grade is an "A" equal to a 4.0; the majority had completed their third year of college.

Variables

Four sets of item clusters from the undergraduate research evaluation surveys were investigated and validated for this study. Content for the evaluation survey was developed and collated by Dr. Christine Pribbenow (Pfund, Pribbenow, Branchaw, Miller & Handelsman, 2006). Items used in the survey are based on several pre-existing instruments which have been widely used to assess the gains made and outcomes achieved by undergraduates who engage in undergraduate research (Kardash, 2000; Lopatto, 2004; Seymour et al., 2004). The same survey was used across the 2005–2011 period from which the data were drawn, except for the addition of the self-efficacy items beginning in 2007 (see note on Table 3). Summary descriptive data for the four item clusters are presented in the Results section along with the factor analyses.

Research Self-efficacy—This set of 14 items asked mentees' to rate their confidence in various research activities. Examples of item questions include, "I can make important contributions to a research team" and "I can get into graduate or professional (e.g., medical, veterinary) school if I want to." The items were rated on a Likert-type scale ranging from 1 (not confident at all) to 5 (very confident) with higher scores reflecting mentees' greater research confidence.

Research Skills—This set of items directed mentees to assess themselves on 14 skills related to specific research competencies. Item examples include understanding scientific papers, formulating research hypotheses, analyzing data, working collaboratively with others, and presenting information. Items were rated on a Likert-type scale ranging from 1 (no skill) to 5 (very high skill) with higher scores indicating participants' greater perceived research skills.

Research Career Knowledge—This set of items consists of five items that assessed mentees' understanding of various aspects of the research enterprise and science careers such as knowledge of the nature of science and research, career paths of science faculty, and career options in the sciences in general. Items were rated on a Likert-type scale from 1 to 5 such that higher scores indicated greater knowledge.

Mentor Effectiveness—This set of 26 items assessed mentees' perceptions of their mentors' effectiveness in performing various mentoring activities. The items were endorsed on a scale ranging from “my mentor did not do this” to “my mentor did this frequently and was effective” (e.g., encourages independence, discusses career paths in science, supports mentee's interest in project).

The first three clusters of items—Research Self-efficacy, Research Skills, and Research Career Knowledge—all deal with the mentees' self-perceptions of their knowledge or abilities relating to research. In addition, all three were scored with 5-point Likert scales with comparable meaning across the sets of items. There was no a priori hypothesis as to how many separate latent constructs these items were actually measuring. Therefore, the total set of 33 items was included for factor analysis in order to determine evidence-based grouping for the items. The 26 Mentor Effectiveness items were thought to comprise a theoretically different construct from these other three groups and were included in their own separate factor analysis.

Positive Outcomes—This is a composite, categorical variable comprising participants' post-baccalaureate academic status indicated by enrollment in either a science-related doctoral program or in medical school. Data for this variable were gathered via a longitudinal survey hosted by the university's graduate school and administered annually to all former mentee participants in the summer research opportunity program by the program directors. This survey requests that the program alumni update their contact information and indicate their current academic standing or career status. This variable was coded as “1” for participants enrolled in a PhD program or medical school and as “0” if not enrolled in these programs, including those for whom these outcome data were missing (i.e., no response). Longitudinal data were available for 97 alumni, the majority of whom were enrolled in graduate degree programs in biology ($n=74$), and a smaller number enrolled in medical school ($n=23$).

Factor Analyses

We conducted exploratory factor analyses on the four sets of item clusters in the evaluation survey in order to identify groupings of related items and create scales to be used within the SCCT (Lent et al., 1994) framework. Several models were fit in order to determine the factor structure that best described the data, comprised of both summer and academic year research groups. This yielded an effective sample size of 430. Factor analyses were carried out using the Mplus statistical software. An oblique Geomin rotation (the Mplus default) was used to rotate factor solutions with more than one factor. Several criteria were used to determine which factor model to retain. One criterion was to examine the relative drop in the initial eigenvalues of the inter-item correlation matrix. An arbitrary decision was also made to

retain a factor solution only if that solution explained at least 50% of the variance among the items. In addition, the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) fit values were examined (with an acceptance benchmark set of 0.90 or above) along with the Root Mean Square Error of Approximation (RMSEA; benchmark <0.08) and Standardized Root Mean Square Residual (benchmark <0.05). Finally, interpretability of the rotated solutions and model parsimony also played an important role in the decision of how many factors to retain. In Table 2, a summary of the factor analyses and fit indices is presented.

For the 33 items covering the Self-efficacy-Skills-Knowledge survey content, a 2-factor solution was deemed optimal. The 2-factor solution featured the Self-efficacy items loading high on the first factor, and the Skills and Career Knowledge items loading on the second factor. The correlation between the two factors was 0.633 and reliability coefficients were at 0.90 or higher. These results lead to the inclusion of two scales in the path analysis: A “Self-efficacy” scale to assess research-related self-efficacy, and a “Skills/Knowledge” scale that was used as one of the measurements of students’ learning experiences.

The same procedure was used to evaluate the 26 survey items relating to mentees’ ratings of Mentor Effectiveness. For this scale, the item “My mentor seemed so busy that I was afraid to interrupt her/him,” had a near-zero factor loading. In the 2- and 3-factor solutions, where the factor structure involving this item was still unclear, residual variances for this item were 0.87 and 0.60, respectively, and thus the item was removed for subsequent analyses. Other fit indices and the pattern of eigenvalues indicated that a 1-factor solution should otherwise be a good fit. Reliability for this 25-item scale was 0.96 (Table 2).

Results

Path Analysis

A path analysis was conducted to examine the contribution of person factors, background contextual factors, and learning experiences to mentees’ research self-efficacy beliefs and actions operationalized as positive outcomes using the summer research opportunity program sample data. See Table 3 for descriptive statistics of continuous variables. The same fit indices used to evaluate model fit in the factor analyses conducted for measurement validity were used to evaluate the path model goodness of fit: CFI, TLI, and RMSEA. In addition, we report the Weighted Root Mean Residual (WRMR), assuming values less than 0.90 reflect a well-fitting model (Schrieber, Stage, King, Nora, & Barlow, 2006). In addition to these fit indices and following Hu and Bentler’s (1999) suggested combinational rule, a chi-square statistic was used to determine the fit between the observed data and the hypothesized model. The Mean-Variance Weighted Least Squares estimator was used to estimate the model. Of the 214 students in the summer research opportunity program sample, 19 were dropped because of missing data on the predictor variables in the model, leaving a final sample of 195 students for the path analysis.

Figure 3 shows the path diagram for the variables chosen for the model with positive outcomes as the dependent variable. In the model, Home Institution is split into two binary variables, Home Institution Category 2 (intermediate), and Home Institution Category 3 (Liberal Arts). Category 1, research extensive institution, is the reference group, such that a

student with a zero on both Home Institution variables is from a research extensive institution. A score of '1' on either of the mutually exclusive Home Institution variables indicates membership in the respective category. Institution type was also thought to be related to and influence whether the student had a previous mentored research experience. These types of experiences are thought to be more likely if the student is from a research extensive institution. In the model, institution type predicts previous experience rather than predicting any of the scales directly. No additional direct paths were hypothesized to the scales because the relationship between Home Institution and Previous Experience was expected to account for most of the influence of Home Institution on the scales on the model. Based on existing research findings previously cited in the literature section, direct paths were hypothesized from person inputs (gender, underrepresented racial/minority status) to mentor effectiveness and skills/knowledge given that women and underrepresented racial/minority individuals may vary in how they perceive rapport with the research mentor and how they evaluate their own abilities. Finally a based on research previous (see Cox, 2000; Dolan & Johnson, 2009; Thiry & Johnson, 2011), we expected a direct path from mentor effectiveness to mentees' research skills/knowledge.

Overall, the hypothesized model resulted in a non-significant chi-square fit statistic ($\chi^2 = 10.52$, $df = 16$, $p = .84$) and showed excellent fit indices, suggesting that it should not be rejected (CFI = 1.00, TLI = 1.12, WRMR = 0.49, RMSEA = 0.00 [CI: 0.00, 0.04]). See Figure 3 for the final model; standardized path coefficients are in parenthesis.

Of all the path estimates, four were significantly different than 0. There was a significant effect of Skills/Career Knowledge score on Previous Mentored Experience, a significant bivariate effect of Mentor Effectiveness score and Skills/Career Knowledge score, and a significant effect of Skills/Career Knowledge score on Self-efficacy score. Finally, there was a positive effect of Self-efficacy scores on Positive Outcomes.

These results indicate that having a previous mentored experience is positively associated with the Skills/Career Knowledge score. Those with a previous mentored experience scored about 3.5 points higher on the Skills/Career Knowledge Scale than those without a previous experience. Further, a student's self-efficacy was directly influenced by her or his sense of their own skills and knowledge, but not by rating of mentor effectiveness. The increase expected in the Self-efficacy score for a one point increase in the Skills/Career Knowledge score is a little over one-third of a point when all else is held equal. Having had a previous mentored research experience produces an expected increase in the Skills/Career Knowledge score of about two points. The model explained 17% of the self-efficacy variance and 4% of the variance in positive outcomes.

Notably, the effect of person input factors was negligible in the model as was the effect of mentees' home institution, indicating that our findings are relevant across race/ethnicity, gender, and campus type for the study's participants. We further examined the person and contextual factors of race/ethnicity, gender, and previous research experience as potential moderators of the effects of the study variables on positive outcomes by introducing appropriate product variables into a regression analysis. Results from multivariate regression analyses did not suggest any meaningful differences in how self-efficacy contributes to

positive outcomes across gender, race/ethnicity, or previous research experiences. Lastly, we examined both mediated and direct effects of the model variables on positive outcomes, testing direct paths from mentor effectiveness to outcomes and from skills/career knowledge to outcomes. Only support for an efficacy-mediated model emerged with no detectable residual effects.

Additional Analysis of Mentor Effectiveness

In order to better understand the elements in the research mentoring relationship that mentees perceive as salient in the undergraduate research experience, we were interested in differences in the study variables with respect to individual items of the Mentor Effectiveness scale. This helped us to understand what specific aspects of mentor effectiveness influenced these variables, in addition to measurements of mentor effectiveness as a whole. Results from bivariate correlations and *t*-tests revealed two items that showed the largest significant correlations with and differences on the self-efficacy and positive outcomes variables (data not shown, $p < 0.05$). Specifically, “*My mentor showed interest in my research project*” and “*My mentor appreciated my contributions*” were associated with higher ratings on research self-efficacy and greater achievement of positive outcomes. Another three items were found to be positively related to self-efficacy, including the mentors’ ability to: 1) offer constructive feedback when necessary, 2) provide the mentee with an overview of how their research fit into an overall research project, and 3) make the mentee feel included in the lab. These results further identified defining features of effective mentoring in an undergraduate research experience.

Discussion

This is the first study to test a model assessing the contribution of mentees’ perceptions of their research mentoring relationships to their post-baccalaureate academic outcomes. The results provided support for three reliable measures to assess research-related skills and career knowledge, self-efficacy, and mentor effectiveness, and supported a hypothesized model of the impact of an undergraduate research experience on post-baccalaureate academic outcomes for culturally diverse undergraduate researchers. We concentrate our discussion on implications of our tested path model and consider future directions for measurement development.

The results generally confirmed the research hypotheses and offer support for using an SCCT-based model (Lent et al., 1994) to examine the impact of research mentoring relationships on undergraduate academic and career outcomes. Consistent with SCCT propositions and existing research regarding the central role of efficacy in predicting future STEM goals and behavior (Adedokun et al., 2013; Byars-Winston et al., 2010; Lent et al., 2005), research self-efficacy mediated the relationship of the model variables with positive outcomes for this study’s participants. Specifically, we found that the research skills and career knowledge were strongly associated with having a previous research experience and with their perceptions of mentor effectiveness. In turn, students’ perceptions of mentor effectiveness, as measured by a multi-item scale, were related to research self-efficacy via the skills and career knowledge gained during the research experience. This latter finding of

a bidirectional path between mentor effectiveness and skills/career knowledge was in contrast to our hypothesized unidirectional path.

The strong bidirectional relationship between mentor effectiveness and research skills/career knowledge suggests that mentees' self-assessment of their skills/knowledge is influenced by their mentor's ability to guide mentees' research understanding and performance; likewise, ratings of their mentor's effectiveness is impacted by mentees' self-assessment of the research skills and knowledge they gained while working with their mentor. A possible explanation is that mentor effectiveness is correlated with the ability of mentors to help their mentee assess her or his abilities, which in turn, helps mentees to have confidence that their own self-assessment is accurate.

Our data indicate that the interaction between mentor effectiveness and research skills/career knowledge is more important to explaining mentees' research self-efficacy than either the independent contribution of mentor effectiveness or the independent contribution of skills/career knowledge. Particularly interesting about these results is that the influence of mentor effectiveness on self-efficacy is only observed through skills/career knowledge. This is a noteworthy point given that much of the existing research on undergraduate research experiences has not examined perceptions of the research mentoring relationship apart from mentees' research skills and knowledge (e.g., Lopatto, 2007).

Consistent with social cognitive theory propositions (Bandura 1986; 1997) that past experiences are associated with future performance, our findings showed that the contribution of mentees' skills/career knowledge to self-efficacy is potentiated by prior research experience. This finding is consistent with research by Paglis et al. (2006) who found that the pre-doctoral research experience of doctoral students in research training programs was positively correlated with adviser mentoring received and research productivity during doctoral study.

It may be that those entering the summer research opportunity program with previous research experience have a better sense of their research skills and more research career knowledge allowing them to better maximize the current research experience. Consequently, they may be more engaged with their research mentors or they may just be savvier at getting their mentors' attention. In addition, mentors who are aware that their mentees had a prior research experience (this information is provided on their summer research opportunity program application) may view them as having more potential to perform and, thus, are more engaged with these mentees (who then self-evaluate their own skills/knowledge more highly).

Taken together, these findings suggest that effective research mentors help their mentees to calibrate assessment of their emerging research skills and career knowledge such that they feel more confident in their research abilities. Research mentor training interventions aimed at improving mentor effectiveness can bolster alignment between mentee self-reported knowledge/skill ratings and the ratings given by their mentors (Pfund et al., 2006). Such alignment is particularly important to attend to given that the research mentoring relationship is a primary element of the undergraduate research experience and given that

undergraduate researchers tend to overrate their research abilities (see Cox & Andriot, 2009).

The positive correlations observed between three items on the mentor effectiveness scale and the research self-efficacy scale provide insight into some aspects of the research mentoring relationship that account for the positive effect on efficacy beliefs—offering constructive feedback, providing mentees with an overview of how their research fits into the larger research project, and making mentees feel included in the lab. Whereas the first two factors may be obvious foci for a research mentor to attend to with her or his student, making mentees feel included in the lab is especially noteworthy given that the majority of our sample were female and underrepresented racial/minority students. And although no relationships in the path model tested varied by race/ethnicity or gender, research repeatedly documents that underrepresented racial/minority and female students report a lower sense of belonging or “fit” in STEM contexts than do their male and White peers (e.g., Blake-Beard et al., 2011; Carlone & Johnson, 2007; Hurtado et al., 2009). Combined, the three items that emerged as salient from the mentoring effectiveness scale may contribute to a mentee’s feeling of belonging in research settings and previous studies have shown that sense of belonging is associated with underrepresented racial/minority students’ research self-efficacy and academic persistence in science and engineering majors (Foor, Walden & Trytten, 2007; Johnson, 2012; Stolle-McAllister, Santo Domingo, & Carrillo, 2011; Tonso, 1999).

Further analysis revealed detectable differences in positive outcomes on two items from the mentor effectiveness scale: 1) “My mentor showed interest in my research project” and 2) “My mentor appreciated my contributions.” These results suggest that a mentor who helps their mentee to feel that their work is interesting and valued may positively impact that mentee’s persistence in STEM. Lewis (2003) argued that “An aspiring scientist relies on the judgment and invitation of practicing scientists throughout every phase of the educational and career process” (p. 371). Our data further illustrate that developing emerging scientists involves more than increasing their research competencies. It also involves social factors like being recognized as capable scientists and having their scientific contributions be viewed as credible by established members of the scientific community (Carlone & Johnson, 2007; Hurtado et al., 2009).

Recommendations for Practice

Santora et al. (2013) found that both U.S. and international faculty view mentoring relationships as important aspects of their work and even conceptualized mentoring in similar ways, despite different contexts by country. Thus, the findings from the present study may be relevant to informing efforts to enhance the retention and academic success of emerging researchers in the life sciences nationally and abroad. Specifically, the results suggest that mentors be trained to:

1. help mentees become more aware of their own abilities and research understanding (i.e., metacognitive awareness),
2. instill in mentees a sense of belonging in science, and

3. highlight for mentees the value of the mentees' research contributions.

The authors of this paper have experience with a process-based approach to research mentor training based on the published curriculum, *Entering Mentoring* (Handelsman, Pfund, Lauffer, & Pribbenow 2005) which could be leveraged for this purpose. Indeed, implementation of a recent adaptation of *Entering Mentoring* developed for the mentors of early career clinical and translational researchers significantly increased mentors' self-reported mentor competency ratings and also significantly increased their mentees' rating of mentor effectiveness (Pfund et al., 2013; Pfund et al., 2014). Importantly, *Entering Mentoring* includes diversity and inclusion considerations which is especially important given that White research mentors working with underrepresented racial/minority undergraduates may view their mentoring relationships as unaffected by cultural diversity (Prunuske, Wilson, Walls & Clark, 2013).

Limitations and Future Directions for Research

Using a set of existing evaluation measures allowed us to achieve adequate sample size to test our hypothesized model once the measures were evaluated. However, these measures only assessed some of the possible factors influential on positive outcomes, as reflected in the small to moderate amount of variance accounted for in the self-efficacy and positive outcomes variables, respectively, in this study. To be sure, there are unmeasured aspects of research mentoring and the undergraduate research experience that are determinants of post-baccalaureate outcomes which were not captured in the present study, such as science identity and social integration into the science community (Chemers, et al; Estrada, Woodcock, Hernandez & Schultz, 2011), the impact of research peers, personal life events that can redirect academic and career plans, and alignment between mentees' and mentors' ratings and mentees' own skills (Laursen et al., 2010; Pfund et al., 2006). Additional research incorporating other SCCT variables, such as sources of learning information and outcome expectations, will allow for fuller testing of SCCT propositions (Fouad & Guillen, 2006; Lent et al., 1994). Further, the factor analysis results indicated that the research skills and research career knowledge measures used in our study, though conceptually distinct, are similar at the measurement level. We encourage continued attention to the measurement of these constructs in future studies. Lastly, although we did not find any main effects of gender or race/ethnicity, future studies may investigate the effects of intersectionality in the SCCT model we proposed including examination of gender differences within racial/ethnic groups (see Cole & Espinoza, 2008).

There are several directions for further investigating the impact of research mentoring relationships on the academic and career outcomes of culturally diverse undergraduate researchers. First, we will continue the identification of critical elements in the research mentoring relationship that account for the positive effect on students' efficacy beliefs and academic and career outcomes. Whereas the present results examined an omnibus index of the mentoring relationship based on the existing measure (mentor effectiveness), we conceptualize the *mentored research experience* as a type of learning experience that can be operationalized by Bandura's (1997) four sources of learning information (see Figure 2). To assess the contribution of these sources of learning information to student academic and career outcomes, we recently revised the mentee surveys to include SCCT-based measures

of research-related sources of learning, outcome expectations, and goal intentions in science. The revised survey also solicits mentees' ratings of both the importance and effectiveness of mentor cultural competence that will allow for the quantitative examination of the relevance of cultural factors in the research mentoring relationship. Identification of salient sources of efficacy information and the salience of culturally competent mentoring will inform future interventions in research opportunity programs and inform mentor training to better target relevant efficacy sources and to support students' research self-efficacy in culturally responsive ways.

Second, we will modify the extant research mentor training intervention offered at the study site university to target the SCCT-based, empirically-identified factors contributing to positive outcomes for undergraduate researchers previously discussed (e.g., research self-efficacy, valuing mentees' research contributions, belonging in science). We will then test the effectiveness of this adapted intervention on mentee outcomes. We also have plans to incorporate our findings into research mentee training efforts.

Conclusion

Our study contributes to previous literature by illuminating the significant interplay between the research mentoring relationship, as indicated by students' perceptions of their mentors' effectiveness, and students' self-ratings of their research skills, knowledge, and self-efficacy with a sample of predominantly underrepresented racial/minority and female undergraduates. Theoretically- and evidence-based interventions that build the capacity of research mentors to effectively target critical factors in the research mentoring relationship and engage emerging researchers is warranted. Previous interventions have demonstrated the ability to enhance both mentors' and mentees' satisfaction in the research mentoring relationship (Pfund et al., 2006; Pfund et al., 2013; Pfund et al., 2014) and can be enriched by integrating the findings from this study about the importance of affirming mentees' research self-efficacy, mentees' scientific contributions, and mentees' belonging in science. Attending to these factors that affect positive student outcomes for culturally diverse undergraduate researchers may build more effective research mentoring relationships and ultimately help increase the number of students who pursue science and research careers.

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Biographies

Angela Byars-Winston, PhD is an Associate Professor in the University of Wisconsin Department of Medicine in the School of Medicine and Public Health and Director of Research and Evaluation in the UW Center for Women's Health Research. Her research interests include the examination of cultural influences on career development, especially for racial and ethnic minorities and women in the sciences, engineering, and medicine. Specifically, she has focused on testing the validity of theoretical models to explain and predict academic and career outcomes using social cognitive theoretical approaches. Dr. Byars-Winston was awarded a multi-year R01 grant from the National Institutes of Health as Principal Investigator to measure and test critical factors in research training interventions for mentors of ethnically diverse mentees in biological science. She is currently co-leading a renewal of this R01 focused on research mentor cultural diversity awareness. In 2011, she was selected as a Champion of Change by the White House through President Obama's Winning the Future initiative for her research efforts to diversify science fields and is an elected fellow in the American Psychological Association. Dr. Byars-Winston completed a

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Janet Branchaw, PhD is an Assistant Professor of Kinesiology at the University of Wisconsin-Madison and Director of the Wisconsin Institute for Science Education and Community Engagement, a cross-campus unit that develops innovative educational programs in pre-faculty/faculty professional development, undergraduate education, and science outreach engagement. She is the Principal Investigator and Director of the Institute's largest Initiative, Foundations for Success in Undergraduate Biology which provides professional development for and engages faculty to develop and implement novel programs that support the transition to college for first generation, underrepresented minority and low-income biological sciences students. Dr. Branchaw's scholarship and program development expertise is in the area of research mentee and mentor professional development in STEM. She is the Principal Investigator and Director of two undergraduate research programs funded by the National Science Foundation that prepare underrepresented students for graduate education in the biological sciences and careers in research. Through this work she has created training curricula for research mentees (Entering Research) and research mentors (Entering Mentoring) and empirically established the positive impact and effectiveness of these curricula on research mentoring relationships and the persistence of underrepresented minority students in research.

Christine Pfund, PhD is a researcher with the Wisconsin Center for Education Research at the University of Wisconsin-Madison. Dr. Pfund earned her Ph.D. in Cellular and Molecular Biology, followed by post-doctoral research in Plant Pathology, both at University of Wisconsin-Madison. From 2003–2013, Dr. Pfund served as the Associate Director of the Delta Program in Research, Teaching and Learning helping to train future faculty to become better more effective teachers. She is now conducting research with several programs across the UW campus including the Institute for Clinical and Translational Research and the Center for Women's Health Research. Her work focuses on developing, implementing, documenting, and studying a seminar to train research mentors across science, technology, engineering, mathematics and medicine. She has co-authored a manual for facilitators of this seminar, Entering Mentoring, and co-authored several papers documenting the effectiveness of this approach. Currently, Dr. Pfund is co-leading two studies focused on the impact of training on both mentors and mentees and understanding specific factors in mentoring relationships that account for positive student outcomes and is serving as Principal Investigator and director of the Mentor Training Core within the National Research Mentoring Network (NRMN).

Patrice Leverett, MS is a doctoral candidate in the Department of Educational Psychology at the University of Wisconsin-Madison and the UW Center of Women's Health Research. Her research seeks to develop and enhance interventions and training mechanisms to improve long term educational and career outcomes for students of color. Concurrently, Ms. Leverett is examining treatment acceptability of behavior interventions for students across the educational pipeline, in hopes of improving academic outcomes and opening pathways to

higher education. She also serves as a member of the American Psychological Association Graduate Student Committee as the Mentoring Co-Chair for Division 45.

Joseph Newton's is a graduate of the Department of Education Psychology at the University of Wisconsin-Madison. His research focuses on the study of extreme response style, the tendency of individuals to pick the most extreme categories on Likert-type scales, irrespective of the level of the trait being measured. Using a multidimensional IRT model, it is possible to separate the effects of response styles from traits of interest. In his research, he studies the various ways in which the presence of response styles can affect the outcomes of survey research.

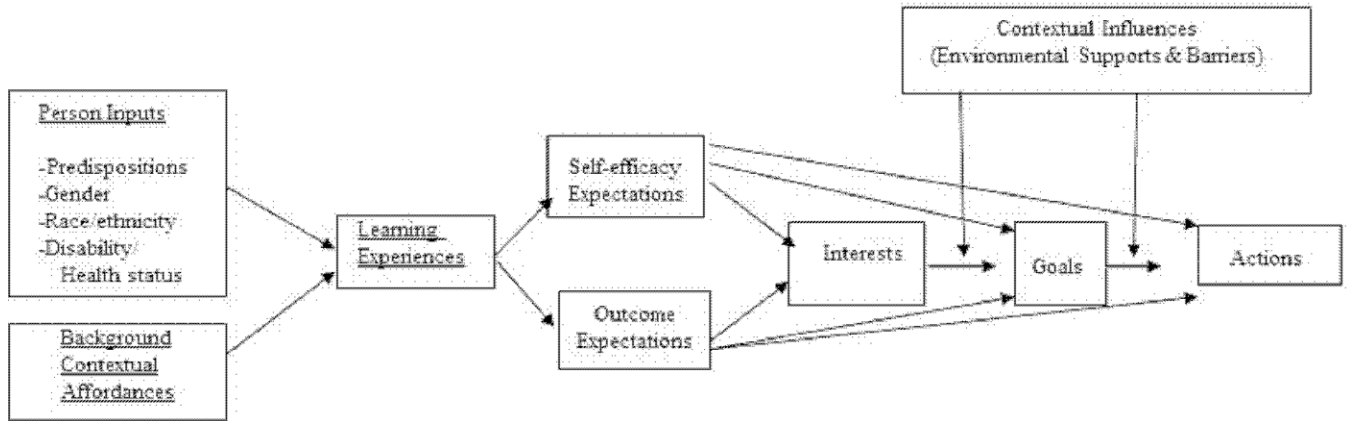


Figure 1.
Original SCCT Model (Lent et al., 1994)

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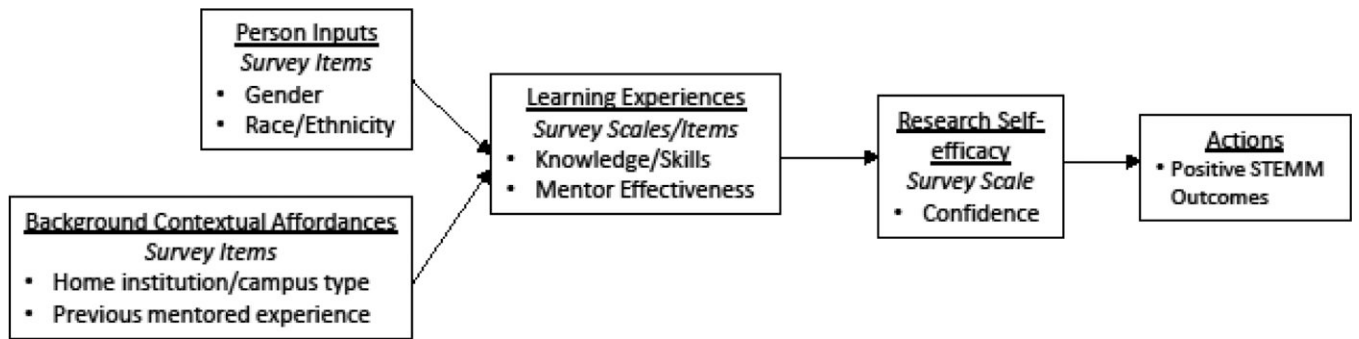


Figure 2.
Adapted SCCT Model for This Study

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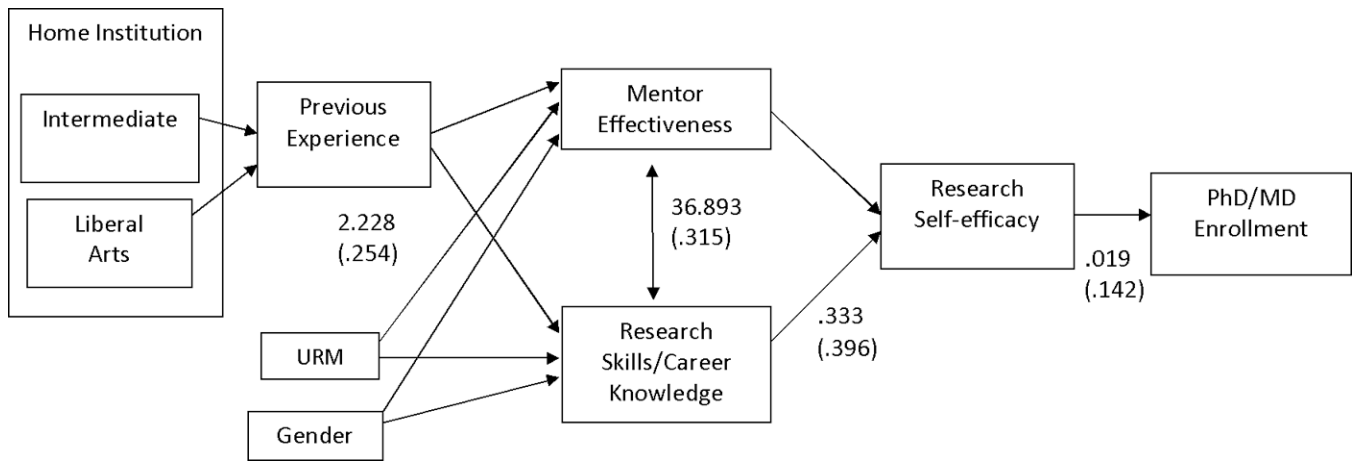


Figure 3.
 Path Model Tested in the Study
 Effects indicate that a one unit change in predictor variable results in a conditional change in dependent variable equal to the size of the effect in dependent variable units. Standardized effects are in parentheses.

Table 1

Summer Research Opportunity Program Participant Descriptive Data for Categorical Variables of Interest

| | | | | |
|-------------------------------|---|--------------------------------------|-----|-------|
| Person Input Factors | Gender | Female | 137 | 64.6% |
| | | Male | 75 | 35.4% |
| | Underrepresented Racial/Minority Status | Non-underrepresented Racial/Minority | 48 | 23.3% |
| | | Underrepresented Racial/Minority | 158 | 76.7% |
| Background Contextual Factors | Previous Mentored Research Experience | No | 103 | 53.1% |
| | | Yes | 91 | 46.9% |
| | Home Institution Category | Research Extensive | 84 | 40.4% |
| | | Intermediate | 48 | 23.1% |
| | | Liberal Arts | 76 | 36.5% |

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Table 2

Summary of Factor Analyses for Scales

| Scale | Factor Model Fit | Reliability |
|--------------------------------|---|---|
| Self-efficacy-Skills-Knowledge | Decision: 2 factors Percent variance explained by 2 factor solution: 55% CFI, TLI: 0.912, 0.899 RMSEA, RMSR: 0.088, 0.066 | Self-efficacy Scale: Cronbach's α : 0.897 Guttman's λ -2: 0.900 Knowledge/Skills Scale: Cronbach's α : 0.939 Guttman's λ -2: 0.941 |
| Mentor Effectiveness | Decision: 1 factor Percent variance explained by 1 factor solution: 71% CFI, TLI: 0.981, 0.979 RMSEA, RMSR: 0.067, 0.051 | Cronbach's α : 0.958 Guttman's λ -2: 0.960 |

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Table 3

Descriptive Statistics for Variables Treated As Continuous

| | N | Min | Max | Mean | Std. Dev. | Skewness | Kurtosis |
|----------------------------|----------|------------|------------|-------------|------------------|-----------------|-----------------|
| Self-efficacy Scale | 170 | 14 | 70 | 60.12 | 7.56 | -2.09 | 9.59 |
| Skills/Knowledge Scale | 214 | 48 | 95 | 76.67 | 9.02 | -0.21 | 0.09 |
| Mentor Effectiveness Scale | 214 | 29 | 104 | 89.64 | 13.81 | -1.59 | 2.67 |

Note: Self-efficacy items did not exist on the research program evaluation surveys used prior to summer 2007, therefore smaller sample sizes for this variable.