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The Impact of Mentoring on Life Science Undergraduate Mentors

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THE IMPACT OF MENTORING ON LIFE SCIENCE
UNDERGRADUATE MENTORS

by

Kari L. Nelson

A DISSERTATION

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Under the Supervision of Professors Julie Thomas and Cory Forbes

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THE IMPACT OF MENTORING ON LIFE SCIENCE
UNDERGRADUATE MENTORS

Kari L. Nelson, PhD

University of Nebraska, 2018

Advisors: Julie Thomas and Cory Forbes

Universities are increasingly encouraging their undergraduates to become mentors to others, yet relatively little research has been done to empirically understand the impact of this work on the mentors themselves. Therefore, the overall goals of this work were: (1) To evaluate the types of studies that have been conducted on the impacts of serving as an undergraduate mentor; (2) To examine the methodological rigor of recent studies and make recommendations for improvement; and (3) To assess if serving as an undergraduate mentor impacted the critical thinking of the mentors, using a valid and reliable instrument, the California Critical Thinking Skills Test (CCTST).

Upon searching the undergraduate mentoring literature published from 2013 through 2016, remarkably only about 6% (27 out of 454) examined the impact of mentoring on the undergraduate mentors themselves. Of these 27 papers, 7% contained only quantitative data, 22% utilized some degree of mixed methods, and about 71% were purely qualitative, primarily mentor self-reported descriptions of their experience. Therefore, I recommend more mentoring research be conducted that incorporates rigorous methods, including the use of more mixed methods and quantitative data collection, utilizing valid and reliable instruments.

Subsequently, I used a quantitative instrument, the CCTST, as a pre/post assessment to examine the impact serving as a mentor had on the critical thinking

abilities of mentors who were undergraduate life science majors when compared to similar non-mentor, life science majors. Prior to serving as a mentor, the mentors and non-mentors showed no significant difference in critical thinking ability ($p = 0.118$). However, after mentoring, mentors demonstrated significantly greater overall critical thinking ability than their non-mentor counterparts ($p = 0.001$). Additionally, in the subscales of analysis, inference, and numeracy, mentors showed significant improvements over non-mentors ($p < 0.001$ for each), suggesting that mentoring, at least in this specific program for this population, does affect critical thinking ability.

Overall, the limited research of the impacts of mentoring on undergraduate mentors that is available is encouraging. However, mentoring programs vary widely and more empirical evidence is needed to better understand these impacts and to maximize the benefits for both the mentors and the mentees.

DEDICATION

To Paul,
who has always supported, encouraged, and believed in me.

To Claire, Emma, and Gretchen,
who are the reasons I push myself to be the best I can be.

To my Parents,
who are the models of hard work, perseverance, and modesty.

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PREFACE

The results presented in Appendix A were published in the *International Journal of STEM Education*.

Nelson, K.L., Sabel J., Forbes, C., Grandgenett N.F., Tapprich W.E., & Cutucache, C.E. 2017. How does teaching life science lessons to middle school students impact undergraduates as measured by reflection and professional growth? *International Journal of STEM Education*, 4(3).

The results presented in Appendix B were published in *The Qualitative Report*.

Nelson, K.L, & Cutucache, C.E. 2017. How do former undergraduate mentors evaluate their mentoring experience 3-years post-mentoring: A phenomenological study. *The Qualitative Report*, 22(7).

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CHAPTER 1

BACKGROUND & THEORETICAL FRAMEWORK

Background

Mentoring Literature

Many reports have shed light on the fact that we, as educators, are not training enough undergraduates (UGs) in the Science, Technology, Engineering, and Math (STEM) fields (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016; The Observatory, 2013). Additionally, for those students who are studying in STEM fields, it is imperative that we provide experiences that better train and prepare our graduates for the workforce (Augustine, Barrett, Cassell, Grasmick, Holliday, Hackson, & Murray, 2010; National Science Board [NSB], 2010), especially due to increasing competition from other countries. This is particularly important as, in 2018 alone, it is forecast that the workforce will need several million new STEM college graduates (Carneval, Smith, & Stoll, 2010; Chen & Soldner, 2013; STEM Connector Report, 2014). Furthermore, these graduates are projected to have higher earning potential on average than their non-STEM counterparts (Langdon, McKittrick, Beede, Khan, & Doms, 2011), so the potential contribution to our overall economy is great.

However, while STEM jobs will be available, there is concern that the experiences we are providing our STEM UG are not making them competitive in the workforce of today (National Academy of Sciences [NAS], National Academy of Engineering [NAE] & Institute of Medicine, 2007; 2010) One of the most cited calls to action to improve UG education comes from the report, *Vision & Change in Undergraduate Biology Education* (American Association for the Advancement of

Science [AAAS], 2011), which has applications to all STEM fields. This report pairs the changing STEM environment of the next century with our growing knowledge of effective education for UGs. *Vision and Change* describes that it is not only necessary for our future graduates to understand and recite core STEM concepts, but also to use so called 21st century skills to translate those concepts into real solutions. The National Research Council ([NRC], 2012), recognized that there are many definitions and descriptions of 21st century skills that are essential for students to acquire for success in their future endeavors. In order to provide a consensus description of these skills and a starting point for research, the NRC committee consulted, “cognitive, developmental, educational, organizational, social psychology and economics literature” (NRC, 2012, p.3), which led to the development of three primary domains of 21st century skills essential for students to develop: Cognitive, intrapersonal, and interpersonal. A summary of the competencies that fall under each of these domains can be seen in Table 1.1.

In order to develop these skills in our students, while also providing disciplinary content education, UG education must evolve, according to these reports and many others (National Association of Colleges and Employers [NACE], 2014; Singer, Nielsen, & Schweingruber, 2012). For example, research suggests that classrooms must shift from being teacher-centered to student-centered. Additionally, most educators agree that promoting active learning in the classroom, rather than purely traditional lecture, can promote deeper, retained understanding of concepts by challenging students to think critically and problem solve (Aguirre, Balsler, Jack, Marley, Miller, Osgood, Pape, Lindstrom, & Romano, 2013; Bruer, 1993; Lambert & McCombs, 1998; Mayer, 2003; Rabe, Hemp, Woollen, & Humiston, 2009; Tiwari, Lai, So, & Yuen, 2006). One

suggested mechanism to shift education to student-centered, active learning is to have students serve as mentors to one another (Bozeman & Feeney, 2007; Budge, 2006; McManus & Russell, 1997). This mentoring may be peer-mentoring, which suggests that the mentors are relatively close in ability or knowledge, or it may be students mentoring younger audiences. Mentoring is well-documented to benefit mentees; however, less is known about how it impacts UG mentors, especially when the UG are mentoring to younger audiences, who would not be considered peers of the mentors (Carpenter, 2015). While involving UGs as mentors likely improves their educational experience, the overarching goal of the work presented here is to gather empirical evidence about the impact of mentoring on the UGs who serve as mentors.

Theoretical Framework & Objectives

The current study will use the Constructivist Learning Theory as the theoretical frame (Bruner, 1960). This learning theory was formally proposed by Bruner but has underpinnings of Vygotsky's Zone of Proximal Development Theory (Vygotsky, 1934/1986), as both emphasize the social nature of learning, using scaffolding or structured interactions that lead to meaningful learning (Bruner & Ratner, 1978; Wood, Bruner, & Ross, 1976). A constructivist approach to learning is student-centered, active and social, where instructors act as facilitators of learning. It involves not only interactions between instructors and learners, but also among learners as they interact with materials/tasks. Students construct their knowledge by being exposed to something new, reflecting upon it, and reconciling it with prior knowledge and experiences. This type of learning encourages learners to: Be challenged beyond their current level of

mastery, link what they know (prior knowledge) to what they are discovering, and be curious about how the world works.

Instructors and mentors can facilitate this process by scaffolding student learning (Wilson & Cole, 1991). Hallmarks of learning tied to this theory involve active techniques to learning and authentic problem solving. Active learning stimulates students by encouraging application of knowledge and skills (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Hake, 1998) and has been associated with higher student outcomes, conceivably because it gives context and purpose to learning, according to Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth (2014). Additionally, constructivist learning encourages students to be metacognitive or to reflect upon their learning (Savery & Duffy, 1995; Myers & Wilson, 2000).

While this theory is traditionally applied to the student receiving instruction and not the person delivering the instruction (i.e. in the case of the current study, the mentor), it can also potentially be applied to the learning taking place from the mentor's perspective. As UG mentors facilitate learning, they typically have structure for their interactions (i.e. activities, lessons, or discussion points), and are actively working with their peers or younger audiences. As the mentors work with other students, they often also work with faculty and other mentors to learn how to teach and deliver the information. While the mentors may have mastered specific content, at least to a certain level, being in a pseudo-instructor role requires that mentors construct their own understanding of concepts beyond the level at which they are teaching and reflect upon their delivery of these concepts. Therefore, the Constructivist Learning Theory is likely

not only true for the mentees, but also for mentors who are facilitating the students' learning.

Additionally, this theory directly aligns with what Roscoe & Chi (2007) observed when studying peer teaching, where the peer-teacher achieved academic learning via reflecting upon their own comprehension, connecting new knowledge with prior knowledge, and in constructing and elaborating their own knowledge as they assisted their peers with learning. I am curious to understand and evaluate if, while this mentoring is taking place, UG mentors are also constructing 21st century skills beyond simply academic learning? To answer this overarching question, I have conducted multiple studies on the impacts of serving as an UG mentor, which are organized by chapters and appendices that follow.

Therefore, in the following chapters, I will review the recent literature on mentoring and conduct quantitative research to evaluate:

- (1) The types of studies that have recently been conducted on the impacts of serving as an undergraduate mentor (Chapter 2).
- (2) The methodological rigor of recent studies and how this can be improved upon (Chapters 2 and 4).
- (3) If serving as an undergraduate mentor impacts one important 21st century skill, the critical thinking of the mentors, using a valid and reliable instrument, the California Critical Thinking Skills Test (CCTST) (Chapter 3).

Additionally, Appendices A and B will provide the mentors' self-reflections and evaluations of their mentoring experiences. These appendices are a part of the original study design and fall under the overarching goal to gather empirical evidence

of the impacts of serving as an UG mentor. Specifically, the study in Appendix A utilized a mixed methods approach to better understand the mentors' perspectives of their experience by encouraging self-reflection upon the experience. Additionally, Appendix B utilized a qualitative approach, specifically in the phenomenological tradition, to complete a longitudinal study by interviewing former UG mentors 3 years post-mentoring, to encourage them to evaluate their experiences as mentors using the lens of their current experiences. These two works are presented as appendices because they were published in peer-reviewed, scholarly journals prior to the completion of this entire dissertation. Taken together, it is my hope that the chapters and appendices presented herein will provide more empirical evidence of the impacts mentoring can have on UG mentors.

Table 1.1. NRC (2012) 21st century competencies for success in education, life and work. Each broad domain (bold) was broken down into specific competencies by the NRC as seen in each column, respectively.

| Cognitive | Intrapersonal | Interpersonal |
|--------------------------------|---------------------------|----------------------|
| Critical Thinking | Flexibility | Communication |
| Information (Science) Literacy | Initiative | Collaboration |
| Reasoning & Argument | Metacognition | Responsibility |
| Innovation | Appreciation of Diversity | Conflict Resolution |

CHAPTER 2

A SYSTEMATIC REVIEW OF INTERVENTIONS INVOLVING MENTORING EXPERIENCES FOR UNDERGRADUATES (UGs) AND RECOMMENDATIONS FOR METHODOLOGICAL RIGOR IN FUTURE STUDIES

Introduction

In order to design valuable studies on the impacts of mentoring, it is important to first understand the current literature available on this topic. Upon review of the literature, it is evident that much mentoring program research does not include underlying conceptual/theoretical frameworks or rigorous methodology, both of which are essential for credible study designs (Egbert & Sanden, 2014; Hannafin, Hannafin, Land, & Oliver, 1997).

These concerns were originally addressed in Jacobi (1991), who conducted a review of mentoring research, including perspectives of both mentors and mentees, from papers published between 1980 and 1990. Specifically, the Jacobi review proposed four main theoretical frameworks that apply to mentoring programs: i.) involvement with learning, ii.) academic and social integration, iii.) social support, and iv.) developmental support. However, due to the diversity of mentoring programs (inclusive of students served, curriculum or developmental work, and age groups included) not all mentoring programs or mentoring program studies fall neatly into one of these four categories. Moreover, Jacobi (1991) highlighted the need to deploy improved methodology, in addition to the theoretical frameworks, to more clearly address the research questions.

Subsequently, Nora and Crisp (2007) conducted a review of mentoring literature and suggested four dimensions to bring conceptual integrity to the study of mentoring programs: Education/career goal establishment & evaluation, emotional and

psychological support, academic content knowledge support, and presence of a role model. Nora and Crisp (2007) also detailed the functional roles of the mentors in each study, such as service learning and training of pre-service teachers, among others.

The next mentoring review, conducted by Crisp and Cruz (2009), examined a broad variety of publications related to mentoring, from 1990-2007. The major findings from this review suggested more mentoring studies were being published related to mentoring underserved populations than had previously been published and that most studies published during that time period lacked methodological rigor.

Gershenfeld (2014) conducted the most recent mentoring review (based on studies published from late 2007-2012). Gershenfeld (2014) utilized the Levels of Evidence-Based Intervention Effectiveness (LEBIE) scale to evaluate evidence-based interventions (originally proposed by Jackson (2009)) for methodological rigor. This scale (shown in Table 2.1) was designed to provide a systematic mechanism to evaluate interventions by ranking studies using experimental designs typical of traditional quantitative studies such as “randomization with equivalent control and comparison groups” (Jackson, 2009, p. 1193) amongst others. Gershenfeld also built upon categories, suggested by Nora and Crisp (2007), to evaluate the role of the mentors in each of the studies. Lastly, Gershenfeld identified some “key mentoring components... such as mentor-mentee ratios” (2014, p. 366) to help further describe and categorize mentoring programs. Ultimately, the Gershenfeld review served as a recent investigation that bridged the prior reviews on mentoring in an effort to implement both improved methodology and rigor. Interestingly, in the Gershenfeld review, all of the evaluated manuscripts scored as 3, 4,

or 5 on the LEBIE scale (i.e. low on the scale) due to their lack of randomization with equivalent control & comparison group designs (Gershenfeld, 2014).

Based on this information and my own observations from conducting a systematic review of the literature, I suggest that, while the LEBIE scale certainly is a step in the right direction in terms attempting to evaluate the rigor of mentoring programs/studies, many studies of mentoring employ qualitative or mixed methods techniques, which are not adequately addressed by this scale. Therefore, a novel contribution from this systematic review of current literature will be to make recommendations for improving the methodological rigor of mentoring studies based on the type(s) of methods they employ: Quantitative methods only, qualitative methods only, or mixed methods.

Purpose of the Current Study

Since 2012, to my knowledge, no systematic reviews have been conducted within this area of research, thus warranting this discussion. Therefore, to build upon the previous reviews and advance the field of mentoring research, the purpose of this systematic review of current literature is four-fold:

- (1) To use the LEBIE Scale (Jackson, 2009) to evaluate recent mentoring studies (2013-2016) in terms of methodological rigor.
- (2) To examine the functional roles of the mentors in each study (Nora and Crisp, 2007) and identify key-mentoring components (Gershenfeld, 2014) to provide easy access to overviews of these studies for other mentoring researchers.
- (3) To identify the theoretical frameworks (when provided), methods, and general findings from publications that evaluate the impacts of mentoring on mentors

from 2013-2016, building upon the work of Gershenfeld (2014) and the other previous reviews.

- (4) To make recommendations for rigorous mentoring research going forward.

Methods

In order to evaluate the current mentoring literature, I conducted a systematic review of publications indexed in multiple databases, including ERIC, and several in ESBCO (i.e. Academic Search Complete, Education Source, E-Journals, PsycARTICLES, PsychINFO, Psychology and Behavioral Sciences Collection, and Teacher Reference Center) for a total of 454 hits. Specifically, I searched for scholarly articles in English, published from 2013-2016. I simultaneously searched the terms “mentor and undergraduate” and used only peer-reviewed sources. Duplicates of the resulting search in the different databases were removed. Subsequently, titles and abstracts were reviewed in an effort to determine if any of the findings related to UG mentors. Studies were only included in the current review if they offered insights from the mentors’ perspectives. If studies offered insights from both the mentors’ and mentees’ perspectives, since the focus of this review is the impact of *mentoring on mentors*, only the mentor-specific portions of the studies were included in this review. Additionally, service-learning studies were included in this review when it was determined that the service was some form of mentoring others but were excluded from this review if the service was not specifically related to mentoring. After elimination of the studies that did not include findings from the UG mentors’ perspectives, a total of 27 papers were included in this review.

Three main criteria then guided my literature review. First, I used the LEBIE Scale (Table 2.1) to evaluate these studies in terms of methodological rigor. Second, I used the categories from Nora and Crisp (2007) to determine the functional role of the mentors in each study and key-mentoring components (Table 2.2) (Gershenfeld, 2014) of each study. Third, I identified the theoretical/conceptual frameworks (when present), methods and findings in the publications (Table 2.3). Subsequently, I made recommendations for researchers who are studying the impacts of mentoring on mentors to consider important methodological components specific to the type of study and data (i.e. quantitative, qualitative or mixed methods).

Results and Discussion

The overarching purpose of this review was to build upon the previous reviews that have been conducted in the mentoring field and to promote methodological rigor in this area of research. Upon review of the literature, it is clear that there are limited studies that report findings from the perspectives of UG mentors. Notably, from the original database hits in my search, only about 6% (27 out of 454) of the articles provided this UG mentor perspective. Articles were excluded from the review if they did not include any data from the perspectives of the mentors. Additionally, articles were excluded if the mentors were not students; rather, the mentors in many studies were faculty members who were mentoring UGs or junior faculty. Finally, some articles were excluded that had a service-learning focus, if the service was not related to mentoring but, instead involved for example, environmental or other community services.

LEBIE Scale Findings

Upon further review of the articles that did meet my inclusion criteria (n=27), several interesting trends emerged. To begin, the LEBIE scale was used to evaluate the methodological rigor of the studies, as it has been in past reviews of the mentoring literature (Gershenfeld, 2014). The results from this analysis can be seen in Table 2.1.

Notably, the LEBIE scale was not helpful in distinguishing the Levels of Evidence-Based Intervention Effectiveness in this study, as only one article reviewed ranked *Efficacious* (Level 3) and the remaining 26 articles reviewed ranked *Emerging* (Level 4). This result was due to the fact that only one of the studies in this review involved any type of comparison between control and treatment groups and was quasi-experimental in design. Upon closer review of the LEBIE scale and the mentoring literature, this finding may not be surprising.

Clearly, the LEBIE scale is best-suited for ranking articles that have quantitative methodology, which was uncommon in the literature reviewed for the current paper; nor was quantitative methodology common in the literature from the previous mentoring review in Gershenfeld (2014), whereby all programs scored Level 3, 4, or 5 on the LEBIE scale (moderate to low scores on this scale). Typically, in mentoring program evaluations, there is not an opportunity to design studies that have true randomization with equivalent control and treatment groups, which would be required to score a Level 1 or 2 on the LEBIE scale (high scores on this scale). Additionally, to score a Level 1 or *Superior* on this scale, a sustained effect of the intervention over time must be observed. This type of longitudinal study was not present in any of the articles evaluated for the current review nor the previous review (Gershenfeld, 2014). On a positive note, none of the studies evaluated for the current review scored *Concerning* (Level 5) as none of the

participants in any of the studies were *put at risk*. Overall, while this scale may work well in fields that utilize quantitative and longitudinal studies, it may not be a good fit for the mentoring research field, which currently relies primarily on qualitative methods and secondarily, mixed methods because the categories on the LEIBE scale does not include criteria that are typically utilized in evaluating these types of studies and are typically not randomized trials with control groups.

Key Mentoring Program Components

The second major finding of this review is related to key program components (Table 2.2), which provide basic characteristics of each of the mentoring studies included. Interestingly, in about 19% of the mentoring studies reviewed, service-learning was the key function of the program. Additionally, while most mentoring programs (48%) did not offer any compensation (or did not mention compensation), 22% of the studies reviewed offered payment for mentoring, and 30% explicitly stated that the mentor received college credit. The mentees in these studies varied, but typically included either students in K-12 or fellow UGs. Similarly, the frequency of the mentoring interventions varied widely from program to program and, while the support available for the mentors also varied, in most of the studies, if the mentors received support it was from faculty, graduate TAs, and/or peers (Table 2.2). While it is not surprising that the designs of mentoring programs vary widely, this finding further corroborates the perception that studying mentoring programs is a complex process, which can make it difficult to draw broadly applicable conclusions. Therefore, conducting methodologically rigorous studies should be of the utmost importance.

Theoretical Frameworks, Methods, and Findings

An important change from the previous reviews can be seen in Table 2.3. Specifically, all but four of the reviewed studies included a theoretical or conceptual framework, which is considered essential for well-designed studies by most education researchers. Utilizing theoretical frameworks is especially important in order to construct studies with grounded designs, where the methods and design are connected to established theories in order to lead to conclusions and findings that provide valid and reliable evidence (Hannafin, et al., 1997). This is a notable advancement over the previous mentoring reviews and may be attributed to more awareness of the importance of these frameworks among mentoring program researchers.

Furthermore, among the studies, the number of mentors (sample size), and findings varied widely (Table 2.3). For the studies that provided sample size, the number of mentors in the programs ranged from 4 to 141. Findings of the reviewed studies were overwhelming positive, with some general, common themes emerging related to mentors feeling a sense of personal, career, and academic gains after participating as mentors. Additionally, Table 2.3 summarizes the types of data collected, which relate to the methodology used in these studies. Though a large percentage (85%) of the studies reviewed that included details on methods involved mentor, self-report and specifically, only two included purely quantitative data, which were also self-reported (i.e. Likert-type self-rankings). Interestingly, only six of the studies (about 22%) reviewed incorporated both qualitative and quantitative data which, for the purpose of this review, are considered to have at least some degree of mixed methodology. Therefore, the next part

of this review is focused on these six studies in order to evaluate them in terms of methodological rigor, based on criteria provided by mixed methods experts in previous studies (Coyle, Schulman-Green, Feder, Toraman, Prust, Plano Clark, & Curry, 2016; Creswell, Klassen, Plano Clark, & Smith, 2011; Plano Clark, & Ivankova, 2016; Teddlie & Tashakkori, 2009) and to make recommendations for future studies as this field of research continues to emerge.

Mixed Methods Mentoring Studies

In order for mixed methods studies to be rigorous, there are several characteristics that should, at a minimum, be included (O’Cathain, Murphy, Nicholl, 2008; Plano Clark, & Ivankova, 2016). While scholars debate what constitutes methodologically rigorous mixed methods research and how to assess the quality of the research (Bryman, Becker, & Sempik, 2008), most researchers agree that the following components are essential to include in the description of the mixed methods research study: Explicit statement that mixed methods research is being utilized, rationale for using mixed methods research, analytic logic (independent or dependent), sequencing/timing (concurrent or sequential), integration of quantitative and qualitative data (merging, connecting or building), and priority (quantitative, qualitative or both) (Creswell, 2013; Plano Clark, & Ivankova, 2016) (Table 2.4). All six of the mixed methods studies reviewed here explicitly stated that the methods included both quantitative and qualitative measures, but only three used the terms ‘mixed’ or ‘multi-method’. Furthermore, four included the mode of integration, which was triangulation for all studies reviewed herein. These are important components for inclusion in a mixed methods study and are somewhat encouraging

findings regarding the implementation of mixed methods in mentoring studies. However, beyond these components, none of the six mixed methods papers included in this review explicitly stated information on the analytic logic, sequencing/timing, or priority; therefore, I interpreted this information from these studies (Table 2.4).

All six mixed methods studies presented data collection and analysis information that indicated an independent analytic logic because the collection of one type of data, either quantitative or qualitative, was not influenced by the analysis of the other type of data. Subsequently, this also suggests concurrent sequencing/timing in these studies because the collection and analysis occurred independent of one another. Unfortunately, integration, one of the hallmarks of good quality mixed methods research, according to Creswell et al. (2011) was only clearly present in four of the six mixed methods articles reviewed. While all studies discussed and interpreted the quantitative and qualitative data separately, there was no evidence of merging or combining of the two data sets together in two out of the six mixed methods studies.

Based on the analytic design and timing, some options for integration in these two studies could have been triangulation or complementarity/enhancement of the two data sets. Triangulation is a type of convergent validation where one dataset may support findings or claims made using the other dataset. Complementarity/enhancement can also be a beneficial type of integration because the different datasets (quantitative and qualitative) have offsetting strengths and weaknesses from one another, so taking them together can lead to a stronger argument. Another way integration could be accomplished and presented is by incorporating a joint visual display of the data or findings. Lastly, in terms of priority, three of the six studies had more detail, analysis, and results related to

their qualitative data sets, mostly interviews and open-ended questions on surveys, than they did quantitative data. The three remaining mixed methods studies had an even priority between quantitative and qualitative data because the design, analysis, and interpretation of both data sets were relatively equal.

Recommendations

Mixed Methods

Based on the priority in the current literature, and the prevalence of qualitative data in general in the mentoring literature, I would suggest that researchers begin utilizing an exploratory design to further the field of mentoring research and introducing more mixed methods research. In this type of design, the researchers collect, analyze and interpret the qualitative data first and then use what they have learned to develop quantitative data collection measures. This type of design would be well suited to mentoring studies because the intent of this design is often to develop instruments or theories, which are greatly lacking in this field. Furthermore, this may work well in mentoring research because most of the current research is qualitative in nature; therefore, leading with qualitative measures is already well established and familiar. An additional benefit of exploratory mixed methods designs is that they can be used to further understand a larger group of participants than is typical of qualitative research alone; subsequently, this can verify if the qualitative findings that are currently being reported in this field are generalizable to larger populations. Lastly, as more UGs from a variety of fields are being encouraged to serve as mentors, incorporating more mixed methods, which have at least some proportion of quantitative data, into mentoring

research may make researchers who are typically quantitatively focused more accepting of and interested in this research. This is likely especially true for mentoring programs in STEM fields, in which researchers tend to come from a quantitative research background.

While exploratory mixed methods designs certainly have their strengths, they also have their challenges. First, using qualitative findings to develop instruments for gathering quantitative data can be extremely time consuming and difficult, especially when considering the reliability and validity of the instrument. Additionally, this type of sequential design can be problematic in terms of acquiring institutional approval, because the quantitative designs are not known until after the study has started. Even with these limitations, based on the work that has been done, exploratory mixed methods designs seem to be a logical next step in this field.

The overall goal of mixed methods research is to gain a deeper, more complete picture of a phenomenon using and integrating both numerical data and descriptions, in order to more fully understand and assess what is occurring (Creswell, et al., 2011). While this goal of mixed methods research is broadly applicable and is often well suited for understanding a complex phenomenon like mentoring, many researchers in a variety of fields do not know how to accurately conduct this research (Coyle, et al., 2016). Furthermore, in this analysis of literature, only about 26% of studies actually utilized both quantitative and qualitative data, indicating that there is a great opportunity for more mixed methods studies to be conducted in mentoring research.

Longitudinal Studies

Another type of study that should be considered for mentoring research is the longitudinal study. Since one of the most commonly hypothesized benefits of serving as an UG mentor relates to development of career skills, following mentors as they matriculate through their UG degrees and into a career or graduate school could be beneficial for understanding if these gains are actualized. Longitudinal studies are particularly helpful for understanding if an intervention leads to a sustained effect over time; therefore, conducting a longitudinal study could yield interesting insights into a complex phenomenon (Plano Clark, Anderson, Wertz, Zhou, Schumacher, & Miaskowski, 2014) such as mentoring. In the current review, none of the studies evaluated the impact of serving as a mentor over time; therefore, there is great opportunity for this type of study.

Quantitative Studies

A final recommendation for improving the methodological rigor of mentoring studies is to include more quantitative data. Quantitative data were notably lacking in most of the studies. Specifically, there were no quantitative data in about 56% of the studies reviewed, so the use of valid and reliable instruments to gather quantitative data should also be a priority. According to Kruger “quantitative methods allow us to summarize vast sources of information and facilitate comparisons across categories and over time” (2003, p. 18). In other words, quantitative data allow for greater generalization of results, which is important if we eventually want to provide evidence that leads to broad applications. Furthermore, quantitative data are less likely to be

biased, as they tend to incorporate prescribed, repeatable procedures to ensure the results are impartial (Linn, Palmer, Baranger, Gerard, & Stone, 2015; Owen, 2017). In the current review, when quantitative data were included, they nearly always consisted of Likert-type self-rankings or other numerical surveys completed by the mentors themselves. Therefore, there is great opportunity in the mentoring literature to utilize tested, quantitative instruments to better understand the impact of serving as a mentor.

It is important to advance the field of UG mentoring research, as outreach and service-learning programs are becoming increasingly common across college campuses. In order to recommend that UGs become involved in these programs, we need reliable, empirical evidence to understand the impacts of these programs, not only on the mentees, but also the UG mentors.

Limitations and Future Studies

While a thorough review of the currently available literature was conducted, the literature that evaluates the impact of mentoring on UG mentors is minimal, which is a limitation of this review. Additionally, there is great variation in the overall structure of mentoring programs. This makes it difficult to draw broad generalizations about mentoring and the impacts they may have on the UG mentors; therefore, more work needs to be done in order to make valid, broadly applicable recommendations.

There are many opportunities for future studies in the field of mentoring research, especially in terms of describing the experience and potential advantages/ disadvantages from the UG mentors' perspectives. As mixed methods research continues to become increasingly common and better understood, more mentoring programs should

incorporate rigorous mixed methodology, particularly those that explicitly integrate quantitative and qualitative data, as this integration or mixing is the hallmark of quality mixed methods research. Additionally, longitudinal studies would be a beneficial addition to the mentoring literature because a sustained effect over time provides strong evidence that those effects may be directly attributed to the mentoring program. This is especially important in the field of mentoring, where many of the reported gains relate to future potential success (e.g. career and academic gains). Lastly, valid and reliable instruments should be designed and utilized to collect more quantitative data that can be statistically tested for significance. Overall, more empirical evidence should be gathered to determine if serving as a mentor while in an UG program actually provides the benefits many claim it does.

Table 2.1. Levels of evidence-based institutional effectiveness scale (LEBIE).* Count of the articles meeting the criteria of each level from the current review (i.e. 2013 - 2016).

| Evidence-based intervention Level | Study Design | Evidence of Effectiveness | Articles Meeting Criteria |
|--|--|--|----------------------------------|
| Level 1: Superior | ED: Randomization with equivalent control & comparison group | Intervention is superior to an appropriate comparison program. Sustained effect reported at follow-up | 0 |
| Level 2: Effective | ED: Randomization with equivalent control & comparison group | Intervention is proven to be significantly better than a placebo control group, or evidence supporting that the intervention is better than an appropriate comparison intervention | 0 |
| Level 3: Efficacious | QED: non-equivalent control group/non-randomization | Intervention efficacy over the placebo control group, or evidence supporting that the intervention is comparable to or better than an appropriate comparison intervention | 1 |
| Level 4: Emerging | NED: single group (may include pre-/post-test) | Intervention demonstrates some degree of positive change over time | 26 |
| Level 5: Concerning | Any | No evidence of change or change in the opposite direction, putting participants at risk | 0 |

*LEBIE scale taken from Jackson (2009) and later used by Gershenfeld (2014).

ED: Experimental design; QED: Quasi-experimental design; NED: Non-experimental design

Table 2.2. Key mentoring components* in mentoring programs. Numerals used in this table correspond to studies with the same numerals in Table 2.3.

| Mentors | Mentees | Function | Comp | Frequency | Support |
|---------------------|--------------------|--|--------|--------------------------------|--------------------------|
| 1. UGs | UGs | Assist with a writing-intensive course (Ed Dept) | S | 10x/wk | Faculty & GTA |
| 2. Senior-level UGs | K-12 Youth | Prepare for robotics competition | S | 6 mtgs, each 1-3 hrs in length | Faculty & team coaches |
| 3. UGs | Latino Youth | Service-learning | C | 1-semester | Faculty |
| 4. UGs | At-risk youth | Service-learning | C | 1x/wk for 12 wks | Faculty, therapists |
| 5. Exp UGs | New TAs | Professional development for both pedagogy & content | - | N.S. | Faculty & peers |
| 6. Exp UGs | UGs | Service-learning | N.S. | N.S. | Faculty & GTAs |
| 7. Exp UGs | UGs | Assist with transition to profession | N.S. | N.S. | Faculty |
| 8. UGs | Grades 5-12 youth | Support gifted and talented students | - | Electronic as needed | Faculty & peers |
| 9. Exp UGs | UGs | Generate network of supportive relationships | - | 1.5hr/wk x 14 wks | Faculty, peers |
| 10. Exp UGs | UGs | Understand how peer mentors negotiate their lab roles | - | N.S. | Faculty |
| 11. UGs & P-B | Grades 5-12 youth | Science education outreach | S | 5x | Faculty & peers |
| 12. Exp UGs | HS youth | Assist with transition to profession | N.S. | 4-8x | Faculty & HSTs |
| 13. Exp UGs | UGs | Training in metacognition & mentoring | N.S. | 1 academic year | Faculty |
| 14. Exp UGs | UGs | Peer-mentoring to assist new students | N.S. | N.S. | Faculty |
| 15. UGs | HS youth | Outreach | N.S. | 3 months | Faculty & HSTs |
| 16. UGs | HS youth | Service-learning | C | 24x over a semester | N.S. |
| 17. UGs | UGs | Facilitate 1 st - year student engagement; service-learning | C | N.S. | Faculty & peers |
| 18. UGs | K-12 youth | Training of student teachers | C | 150 hrs/2 years | Faculty |
| 19. UGs | Grades 5-12 youth | Public engagement | - | Weekly | Faculty & teacher |
| 20. UGs | K-12 youth | Science outreach | C | Varied | Faculty |
| 21. UGs | Disabled K-8 youth | Service-learning | C | 6x/session | Faculty & teacher |
| 22. UGs | Grades 5-12 youth | Outreach | N.S. | N.S. | Faculty & teachers |
| 23. Exp UGs | UGs | Part of a class | C | 1 semester | Faculty |
| 24. UGs | UGs | N.S. | N.S. | 1 semester | Faculty & guidance staff |
| 25. UGs | Grades 9-12 youth | Internship | S | Summer | Faculty |
| 26. UGs | UGs | Assist with large enrollment class | - or S | 12hrs/wk | Faculty |
| 27. UGs | UGs | Retention of freshman | S or C | 1x/week | Faculty |

Comp., compensation mechanism; N.S., not specified; - indicates none provided; S, indicates stipend; C, indicates credit for class or toward graduation; GTA, graduate teaching assistant; Exp, Experienced (to imply at least 1-prior year training and only junior or senior standing UGs); HST, high school teacher; P-B, post-baccalaureates; *Adapted from Gershenfeld (2014).

Table 2.3. Frameworks, methods, and findings in empirical undergraduate mentoring studies. Numerals in this table correspond to studies with the same numerals in Table 2.2.

| Author & year | Theoretical/conceptual framework | LEBIE | Methods and N-value | Data collection | Findings |
|---|--|--------------|--|---|---|
| 1) Douglass, Smith, & Smith, 2013 | Zone of Proximal Development (ZPD) (Vygotsky, 1978) and Relational-Cultural Theory (RCT) (Miller & Stiver, 1997) | 4 | MM, quan: Ranking of mentor qualities via Undergraduate Peer Mentor Ranking Survey (UPMRS). qual: Open-ended perception question via Undergraduate Peer Mentors Survey (UPMS) N=12 mentors | SR ranking of mentor characteristics considered important and mentors' perceptions | Mentors rank knowledge of writing process, communication, and trustworthiness as most important skills of mentors. Mentors perceptions were positive and indicated that it gave them experience in being an educator and providing feedback. |
| 2) Yilmaz, Ozcelik, Yilmazer, & Nekovei, 2013 | None except theories specific to engineering concepts | 4 | Qual only: survey results N=20 in year one, N=18 in year two | Undergraduates took a class in conjunction with mentoring. Survey had limited feedback related to mentoring, specifically | Mentors express increased robotics understanding and interest as well as increased interest in engineering. |
| 3) Cushing & Love, 2013 | Cultural responsiveness & critical consciousness | 4 | Qual only: semi-structured focus groups, N=36 | Semi-structured focus groups, SR | Increased cultural responsiveness and awareness. Improved interpersonal and communication skills. |
| 4) Haddock, Weiler, Krafchick, Zimmerman, McLure, & Rudisill, 2013 | Family Systems Framework (Bowen, 1974) | 4 | Qual only: open-ended survey N=141 | Mentor SR | Personal growth and professional development- program positively influenced their civic attitudes and civic engagement. |
| 5) Holmes, Marinuk, Ives, & Warren, 2013 | Peer teaching conceptual framework and pedagogical content knowledge | 4 | Qual only: open-ended surveys, conducted for 7 years N not provided | Mentor SR gains | Experienced TAs mentor younger TAs and show professional development in teaching & management. |

| Author & year | Theoretical/ conceptual framework | LEBIE | Methods and N-value | Data collection | Findings |
|--|---|--------------|---|---|--|
| 6) Karlin, Davis, & Matthew, 2013 | Education for sustainable development | 4 | MM survey, quan: Likert-scale ratings, qual: open-ended questions N=7 | Mentor SR | Positives: in-person interactions, helping students learn, developed leadership & communication skills. |
| 7) Chester, Burton, Xenos, Elgar, & Denny, 2013 | Transition in – transition out model and Psychological literacy (Cranney & Dunn, 2011) | 4 | Quan only: self-rankings N= 34 | Mentor SR | Significant increase in psychological knowledge and understanding. Perceived as a positive experience. |
| 8) Lamb & Aldous, 2014 | Bernstein’s model of pedagogical device (1990) | 4 | Multi-method: Questionnaires (with quan & qual questions), survey, focus group interviews, case study, discourse analysis of emails between mentors and mentees N=12 mentors | Mentor SR and faculty interpretation of emails. | Mentors gained experience with establishing guidelines for communication with mentees and supporting mentees in managing their heavy academic and outside of school loads due to being in a Gifted and Talented program. Electronic communication between mentors and mentees had its limitations. |
| 9) Ward, Thomas, & Disch, 2014 | None for framing the study, but discovered a new framework through study, Theory of “Multidimensional Responsiveness” | 4 | Qual only: grounded theory journal entries, retrospective assessment questions, project director’s observations, N=26 mentors over 2 years | Mentor SR & project directors report | Understand the social-psychological processes at work in the mentoring experience -7 themes of mentor service emerged: guidance, emotional supportiveness, companionship, integrity, insight, demanding accountability, and (overarching or summative finding) multidimensional responsiveness |

| Author & year | Theoretical /conceptual framework | LEBIE | Methods and N-value | Data collection | Findings |
|---|--|--|--|--|---|
| 10) Packard, Marciano, Payne, Bledzki, & Woodard, 2014 | Legitimate peripheral participation (Lave & Wenger, 1991) | 4 | Qual only: nested case studies with purposeful sampling for interviews N=4 mentors | Mentor SR via interviews & outside interviews with faculty & mentees | Mentors establish credibility from prior lab experience and faculty-scaffolded authority. Mentors feel authority when supervision is delegated to them. |
| 11) Tenenbaum, Anderson, Jett, & Yourick, 2014 | Near-peer mentorship model (Jett, Anderson, & Yourick, 2005) | 4 | Qual only: survey with 20 free-response questions N=11 mentors | Mentor SR via open-ended survey questions | Mentors felt that they grew and matured from the mentoring experience, much of which was related to professional skill development. |
| 12) James, 2014 | None provided | 4 (mentees had controls but mentors did not) | MM pre-post Rosenberg Self-Esteem Scale and Self-Efficacy Scale both with Likert rankings. Psychological Literacy Scale, Mentoring Impact (Likert scale and open-ended question). Mentor focus groups N=8 | Mentor SR | Significant increases in valuing intellectual challenge required to use scientific thinking and being insightful & reflective pre- to post-mentoring. Also verbally noted improvements in communication, confidence and teamwork. |
| 13) Washburn & Zevallos, 2014 | Self-reflection (Terrion & Philion, 2008) | 4 | Qual only: SYRAS (Share your recipe for academic success) writing tool N=15 | Mentors' writing reflections evaluated by faculty | The SYRAS exercise provides a structure for mentors to be metacognitive |
| 14) Ruane & Koku, 2014 | Social network analysis (Scott, 2013) | 4 | Qual only: threaded discussion boards on Blackboard N=45 | Faculty used discussion board posts to evaluate density and centrality | Mentors had high levels of influence and prominence in the online sites and impacted relationship development and information sharing. |

| Author & year | Theoretical/conceptual framework | LEBIE | Methods and N-value | Data collection | Findings |
|---|---|--|---|---|--|
| 15) Kim, Chacko, Zhao, & Montclare, 2014 | None stated | 4 (mentees had controls but mentors did not) | Not stated | Not stated | Mentors gained teaching and mentoring experience. |
| 16) Walsh, Veri, & Willard, 2015 | Student proximal outcomes (Whitley & Walsh, 2014) | 4 | Qual only: Case study, program observations, mentoring reflections, semi-structured interviews N=8 mentors | Mentor SR on perspectives of the impact of teaching & faculty observations | Themes of personal development, intellectual/career development, and community influence. |
| 17) Murray, 2015 | Experiential Learning Theory (Carver, 1996) | 4 | Qual only: end of semester reflections & faculty observations, N not stated | Mentor SR & faculty interpretation of mentor's actions | Anecdotal findings that faculty have witnessed mentors increasing their "learning and developmental outcomes" in addition to mentors' subsequent involvement in other activities as leaders. |
| 18) Blaszk, 2015 | Theory of the Self (Mead, 1962) | 4 | Qual only: case study interviews N=21 | Observations by faculty and SR from mentors | Promoted dialogue and reflection for the mentors and a greater understanding for the researcher). |
| 19) Grant, Liu, & Gardella, 2015 | Constructivist Theory | 4 | MM, qual: Interviews, observations, physical artifacts; quan: surveys N = 52 | SR learning experiences of mentors and observations by faculty – data were triangulated for integration | Benefits of teamwork, leadership, communication, & STEM concepts. All mentors indicated importance of support from classroom teachers. |

| Author & year | Theoretical/conceptual framework | LEBIE | Methods and N-value | Data collection | Findings |
|---|---|--------------|--|--|---|
| 20) Carpenter, 2015 | Experiential Learning Theory (Carver, 1996) | 4 | Qual only: semi-structured interviews, content analysis N= 11 | Mentor SR gains among various mentoring programs | Career, academic &/or personal gains (such as content knowledge, fun) reported by 4+ mentors. Also, 4 or more mentors felt it helped them understand students, scientific practices, active learning, and the importance of student interest. |
| 21) Santiago, Lee, & Roper, 2015 | Contact Theory Framework (Allport, 1954) | 3 | Quan only: pre- and post-administration of the "Attitudes Toward Disabled Persons Scale" N = 51 experimental & N = 31 control | SR attitude change toward disabled persons after mentoring in a service-learning program | No significant difference in attitudes toward disabled individuals between those that participated in service learning and those who did not. |
| 22) Pluth, Boettcher, Nazin, Greenaway, & Hartle, 2015 | None stated | 4 | Not stated | Not stated | The majority of mentors plan to volunteer in the future and include the experience on their CV. |
| 23) Everhard, 2015 | Socio-constructivist approach | 4 | Qual only: questionnaire at the end of the semester, N=28 | SR quotes used as evidence | Mentors mentioned increased experience finding and using resources, working with others, self-confidence and metacognition. |
| 24) Aderibigbe, Antiado, & Anna, 2015 | Critical constructivist | 4 | MM, quan: survey N=19 qual: focus groups N=8 | SR analyzed by descriptive statistics, frequency, & thematic analysis | Mentors develop personal and professional skills. |

| Author & year | Theoretical /conceptual framework | LEBIE | Methods and N-value | Data collection | Findings |
|---|--|--------------|---|--|---|
| 25) Anderson, Tenenbaum, Ramadorai, & Yourick, 2015 | Career advancement and psychosocial support frameworks | 4 | Qual only: online surveys N=42 | SR survey responses were thematically analyzed | Mentors report gains in communication skills, professional behavior, self-confidence, student management, pedagogy, and career education. |
| 26) de Oliveira, de Franca Carvalho, Cespedes, de Oliveira, & Le Sueur-Maluf, 2015 | Near peer mentoring model was used | 4 | Qual only: open-ended reports N=20 | SR | Teamwork, professional skills, and organizational abilities |
| 27) Cutright & Evans, 2016 | Near peer mentoring model was used | 4 | Qual only: exit survey and interviews N=8 | SR, open-ended exit survey and interview questions | Unique experience, expanded knowledge, time management and communication improved |

*Table originally used in Crisp and Cruz (2009) and adapted by Gershenfeld (2014). MM, mixed methods; quan, quantitative; qual, qualitative; SR, self-report

Table 2.4. Mixed methods research criteria. Mixed methods research statement, rationale, and integration were taken from the studies examined, if present. Analytic logic, timing, and priority were not detailed in any of the studies; rather, these are interpretations from the author of this review.

| Citation | Explicit statement that mixed methods research was used | Rationale for using mixed methods | Integration of data (triangulation or connecting/ building) | Analytic logic (independent or dependent) | Timing (concurrent or sequential) | Priority (quan, qual or both) |
|--|--|--|--|--|--|--------------------------------------|
| Douglass, Smith, & Smith, 2013 | Not explicitly stated, but quan and qual stated | Quan self-rankings used for statistical testing and qual included so mentors could describe experiences & make suggestions for improvement | Not explicitly stated | Independent | Concurrent | Both |
| Karlin, Davis, & Matthew, 2013 | Not explicitly stated, but quan and qual stated | Improvement over other work, which typically incorporates only descriptive case study methods | Triangulation of data, quotes used to back up percentages | Independent | Concurrent | Qual |
| Lamb & Aldous, 2014 | Yes, in the text (multi-method used) in addition to terms quan & qual data | Understanding of mentors' perspectives and experiences | Triangulation | Independent | Concurrent | Qual |
| James, 2014 | Yes, mixed methodology term used | Assessment of impact of program and mentors' perceptions | Not explicitly stated | Independent | Concurrent | Both |
| Grant, Liu, & Gardella, 2015 | Yes, mixed methods term used | Deeper understanding | Triangulation | Independent | Concurrent | Qual |
| Aderibigbe, Antiado, & Anna, 2015 | Not explicitly stated, but quan and qual stated | Better understanding of the peer mentoring process | Triangulation | Independent | Concurrent | Both |

CHAPTER 3

COMPARING CRITICAL THINKING BETWEEN MENTOR & NON-MENTOR LIFE SCIENCE UNDERGRADUATES (UGs) USING THE CALIFORNIA CRITICAL THINKING SKILLS TEST (CCTST)

Introduction

Critical thinking is a skill routinely cited as preferred by employers over basic content understanding (AACU, 2013) and is a core learning objective of science education (Dowd et al., 2018). Moreover, as the employment landscape becomes more competitive, it is imperative that students have the opportunity to have a dynamic, well-rounded professional development experience at the college level. The acquisition of so called “soft skills” such as critical thinking, translate across areas of content expertise, not to exclude the sciences. However, it remains unclear how to train or even enhance critical thinking skills of undergraduate students. On that vein, we studied the intervention of Nebraska Science, Technology, Engineering, and Math 4 U (NE STEM 4U) on the critical thinking skills of undergraduate life science majors.

NE STEM 4U

The NE STEM 4U program provides an opportunity for UG students in STEM majors to voluntarily participate in outreach to students in grades K-8 in Omaha Public Schools (Cutucache et al., 2016). The UG mentors provide STEM lessons in an after-school program one to two times per week for the academic year. NE STEM 4U, as a program, utilizes a 3-fold training platform of teaching, research, and mentorship. For this study, the impact of the teaching and mentoring components on undergraduates’

(UGs) critical thinking abilities were discerned utilizing the well-validated assessment, California Critical Thinking Skills Test.

Importantly, the precise and unique impact of undergraduates (UGs) serving as mentors to youth has widely been ignored, particularly the benefits and challenges for the UG mentors themselves, despite many programs placing mentoring programs under high impact practices (Carpenter, 2015). While some studies examine the effect of serving as a mentor from the UGs' perspectives, the gap in the literature becomes especially pronounced upon review of the methods utilized in published studies, which consist primarily of qualitative, self-reported data (Coyle, Schulman-Green, Feder, Toraman, Prust, Plano Clark, & Curry, 2016; Creswell, Klassen, Plano Clark, & Smith, 2011; Plano Clark, & Ivankova, 2016; Teddlie & Tashakkori, 2009).

While self-reported data are valuable as a good starting point for research or in-depth qualitative understanding of a phenomenon, they can be considered unreliable or biased and are listed as a limitation in many studies (Owen, 2017; Linn, Palmer, Baranger, Gerard, & Stone, 2015). Furthermore, qualitative data may not permit researchers to fully gauge how mentoring impacts specific skills such as critical thinking, which can be difficult to measure empirically (Gellin, 2003). In the rare case that quantitative data are present in a published mentoring study, they typically are not the result of utilization of comprehensively tested instruments (Hannafin, Hannafin, Land, & Oliver, 1997). This suggests that there is abundant opportunity for quantitative data collection and analysis in the mentoring literature, particularly studies that employ valid and reliable instruments. Consequently, we aimed to determine the impact of serving as a mentor on UG mentors majoring in the life sciences, by assessing the impact of

mentoring on critical thinking skills. Critical thinking skills are identified as sought after 21st century learning skills (AAAS, 2011).

Critical Thinking

Critical thinking is delineated by a wide variety of definitions. One of the most cited comes from the Delphi Report, in which 46 critical thinking experts across many disciplines came together to define critical thinking as, “purposeful, self-regulatory judgment, which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which judgment is based” (Facione, 1990, p. 2). It is the Delphi Report that provides the foundation for the design of the California Critical Thinking Skills Test (CCTST), which has been used worldwide to measure critical thinking for over 25 years (Insight Assessment, 2017). The test is consistently updated based upon input from experts in fields such as assessment, psychometrics, measurement, statistics, and decision sciences, among others (Insight Assessment, 2017).

The CCTST is typically administered as a pre/post intervention test to provide a comprehensive view of a student’s critical thinking ability. It does this by generating an overall critical thinking score in addition to eight subscale scores: analysis, interpretation, inference, evaluation, explanation, induction, deduction, and numeracy. A detailed description of each subscale score is available in Table 1. According to the test designers, the sub-scores are not intended to represent completely independent factors, however, because many of the sub-scores are not inherently discrete units, they work

together to represent the overall critical thinking ability of the student (Insight Assessment, 2017).

The questions used in the CCTST to measure reasoning skills come from a question pool that has been tested for over two decades by international measurement experts (Insight Assessment, 2017). This test is unique because it is the only instrument that measures both cognitive and metacognitive skills, which is recommended in the Delphi Report (Facione, 1990), and has been extensively evaluated for validity and reliability. A commonly cited definition of validity was provided by Eisenhart and Howe (1992, p. 1) as, “the trustworthiness of inferences drawn from data.” In other words, how well does an instrument measure what it is thought to measure? Reliability is generally defined as, “the degree to which an assessment tool produces stable and consistent results” (AERA, 1985).

Notably, many sources report on the robust validity of the CCTST (O’Hare & McGuinness, 2015; Sorensen & Yankech, 2008; Williams, Glasnapp, Tilliss, Osborn, Wilkins, Mitchell, Kershbaum, & Schmidt, 2003). Reliability tests for the eight subscales resulted in Cronbach’s alpha values ranging from 0.71 to 0.80 and a Cronbach’s alpha of over 0.9 for the overall instrument (Facione & Facione, 1997), which are indicative scores for a strong instrument (Miller and Salkind, 2002). Additionally, the test has been utilized internationally across a wide variety of audiences, including education research, science, nursing, psychology, and engineering fields, among others (Insight Assessment, 2017).

Research Question and Study Design

In this study, we focused on the UG mentoring component of Nebraska Science, Technology, Engineering, and Math 4U (NE STEM 4U) in which UGs volunteer to mentor K-8 students several times per week, to understand whether UG mentors demonstrated gains in critical thinking after at least two semesters of mentoring to middle school students, when compared to non-mentor UGs, using the CCTST. All of the individuals representing both groups (mentors and non-mentors) were life science majors at the University of Nebraska at Omaha (UNO), who took similar courses during their matriculation; therefore, the two groups are normalized except for their mentoring experience. The non-mentor life science UGs served as a control group and took the CCTST at the same time periods as the mentors. Utilizing these two groups, this study was informed by the following research questions:

- 1) Does serving as a mentor impact the critical thinking of UG mentors compared to non-mentor life science UGs, as indicated by pre/post-CCTSTs?
- 2) Are there specific subscales of the CCTST that indicate significant differences between mentor and non-mentor life science UGs?

Methods

This quasi-experimental pre/post-test study utilized quantitative data from the CCTST to test the hypothesis that mentoring positively influenced the critical thinking of mentors (n = 11) in the NE STEM 4U program at the University of Nebraska at Omaha (UNO) when compared to non-mentor life science UGs (n = 26). Informed consent was collected from all voluntary participants in accord with IRB regulations (IRB# 548-12-

EX). Overall, this study took place over two academic years, with the same groups (NE STEM 4U mentor life science majors and non-mentor life science majors, respectively) and phases (quantitative pre/post) but different students each year. The students who participated in this study were selected via convenience sampling and were offered a gift card if they completed both the pre- and post-CCTST.

Both mentor and non-mentor life science UGs took the CCTST at the beginning and end of the academic year (i.e. after two semesters of mentoring and coursework or two semesters of coursework only, respectively). The CCTST is a, roughly, 50-minute, electronic assessment that provides an overall critical thinking score in addition to eight subscale scores: analysis, interpretation, inference, evaluation, explanation, induction, deduction (an optional test), and numeracy. See Table 3.1 for a detailed definition of each measure provided by Insight Assessment (2017).

Analysis Procedures

All statistical tests were completed using Minitab 18 ® Statistical Software (Minitab Inc.) Prior to data collection, we estimated the sample size required to detect an effect using a power level of 80% and statistical significance cutoff of $p \leq 0.05$ for this study. After data were collected, we tested them for normality using the Anderson-Darling test, which indicated the data were normally distributed. Subsequently, we calculated descriptive statistics and gain scores (i.e., difference between post- and pre-test scores) using propensity score matched populations. Specifically, student groups were normalized for prior coursework, year in college, and prior experience in NE STEM 4U (if applicable). Means of pre/post-tests were used for comparison via two-sample *t*-tests. Because we conducted multiple *t*-tests on this data set, we calculated a Bonferroni

correction, to adjust for the increased probability of false-positive results with increasing number of tests (Armstrong, 2014). Then, similar to a study by Walstad and Wagner (2016), who suggest results of pre/post-tests should be disaggregated for further analysis beyond *t*-tests and means, results of individual students' tests were also taken into account by categorizing them as positive, retained, or negative if students' scores improved from pre- to post-test, remained the same, or decreased, respectively. To compare these groups we used a chi-square test. However, the expected values for the retained group were below five, thus violating an assumption of the chi-square test, the retained and negative categories were combined. This retained/negative category was then compared to the number of positively (improved) scoring students via chi-square analysis and 95% CI testing.

Results

At the begin of the academic year, neither the overall score nor any of the subscores of the CCTST test differed between life science students who were NE STEM 4U mentors or non-mentors (Tables 3.2 and 3.3) indicating that both groups were starting at a common level of critical thinking ability. However, at the end of the academic year the mentors (on average) scored significantly higher in their overall scores than non-mentors on post-tests (Table 3.2 and 3.3). In particular, mentors scored higher in the subscale scores analysis, inference, and numeracy (Table 3.3). The average gain scores of NE STEM 4U mentors were at least two points greater than any non-mentor gains for the overall score and all components of the CCTST (Figure 3.1). However, only gains in the

overall score and the subscores analysis, inference, and numeracy were significantly different between mentors and non-mentors (Figure 3.1).

The disaggregation of both the mentors and non-mentors into those who improved their overall score (positive learning) and those who maintained or decreased their overall score (retained/negative learning) indicated that an equal number of non-mentors improved and retained/reduced their score from pre- to post-test, while significantly more mentors increased their score than retained or reduced their score.

Discussion

The overarching objective of this study was to determine if participation in the NE STEM 4U intervention (i.e. the professional development program for undergraduate and graduate STEM majors) lead to significantly improved gains in critical thinking skills. Specifically, we had two research questions (1) does serving as a mentor impact critical thinking skills (compared with non-mentors), and (2) are there specific subscales of the CCTST that indicate significant differences between mentor and non-mentor? Overall, we report herein the data collected using the CCTST as the metric of critical thinking skills gains.

The descriptive statistics for this study are presented in Table 3.2. The overall findings of this research suggest that serving as a mentor in NE STEM 4U led to measurable gains in critical thinking when compared to non-mentors. The first evidence gathered that supports this conclusion is based on gain scores (Figure 3.1). Interestingly, in the overall scale and all subscales, mentors had average gain scores of two or more over non-mentors, which according to Facione, Winterhalter, Kelly, & Morante (2013, p.

76) indicate a “strong effect.” After calculating gain scores inclusive of 95% CIs, mentors have stronger gains over non-mentors in all categories, mentors have statistically significant gains over non-mentors in the overall CCTST score, in addition to the analysis, inference, and numeracy subscale scores (Figure 3.1).

Next, to further corroborate this finding, two-sample *t*-tests were conducted using the mean scores for mentors and non-mentors overall as well as for each of the subscales (Table 3.3) with a Bonferroni correction to mitigate the potential problem of multiple comparisons (Dunn, 1961). Notably, mentors’ and non-mentors’ pre-test scores were not significantly different for any of the measures, indicating that both groups were starting at a common level of critical thinking ability (Table 3.3). However, the mentors, on average, scored significantly higher in their overall scores than non-mentors on post-tests ($p = 0.001$). This further supports the assertion that serving as a mentor in NE STEM 4U led to measurable gains in overall critical thinking and also substantiates the gain score findings.

To support our second research question, we examined subscale scores from post-tests. Specifically, analysis ($p < 0.001$), inference ($p < 0.001$), and numeracy ($p < 0.001$), were significantly different between mentors and non-mentors as well (Table 3.3). Interestingly, previous studies (Golbeck, Ahlers-Schmidt, Paschal, & Dismuke, 2005; Madison, 2002) and the summaries of these skills, listed in Table 3.1, indicate a degree of relatedness between these subscale measures. Specifically, these three scales (analysis, inference, and numeracy) all relate to mathematical skill or quantitative literacy (Madison, 2002). Abilities in analysis and inference are also considered to indicate a

higher level of quantitative literacy than basic numeracy or basic computational ability (Golbeck, et al., 2005).

While it is not completely clear why UGs who mentor K-8 youth would show significant gains in measures related to math specifically, the fact that mentors did display these gains post-mentoring is important, as studies indicate math skill is a strong predictor of future success (Trapmann, Hell, Weigand, & Schuler, 2007). Trapmann et al. (2007) found that math grades were good predictors of future success for math, engineering, and natural science majors. Interestingly, Trapmann et al. (2007) found that, for engineering students, math grades were better predictors of academic success than an aptitude test specific to engineering. While the current study involved life science majors and not engineering students, it is interesting to note that mentoring significantly improved critical thinking abilities overall and those related to math skills, which, according to previous studies, seem to be strongly indicative of future success.

The additional subscales of induction, deduction, and interpretation were also close to being significantly improved, on average ($p = 0.004$, $p = 0.008$, and $p = 0.003$, respectively), in mentors over non-mentors; however, with the Bonferroni correction, which indicated that the values were significantly different only if uncorrected $p \leq 0.002$, these gains were not significant. Because of these borderline values, more work should be done with a larger sample size to see if serving as a mentor leads to gains in these areas of critical thinking as well.

While the disaggregated data provide some clarity and additional support for the impacts of mentoring on critical thinking, they also provide opportunities for further study. For example, it would be beneficial if we knew the response to each question, as

we could further disaggregate the data to understand whether retained scores meant the test taker had the correct answer and maintained the correct answer or whether he/she had the wrong answer and retained the wrong answer (Smith & Wagner, 2017; Walstad & Wagner, 2016). Clearly, answering correctly on both pre- and post-tests is more desirable. Having this information could also permit us to further investigate the likelihood of guessing, as studied in Smith & Wagner (2017).

Overall the findings in this study provide evidence that mentoring in NE STEM 4U improved critical thinking of the mentors when compared to non-mentor life science UGs, but more work needs to be done to further understand and corroborate these findings. For example, the findings of this study would be more robust if we had: A larger sample size, additional mentoring programs outside of NE STEM 4U, and a broader variety of STEM majors from different universities included. However, these preliminary findings do strongly suggest that serving as an undergraduate mentor improves critical thinking. Therefore, encouraging UGs to serve as mentors may be a way to fulfill the 21st century skill development that many researchers say courses and other experiences are not meeting (NACE, 2014; Singer et al., 2012). In addition to improving overall critical thinking, serving as an UG mentor significantly improved quantitative skills such as analysis, inference, and numeracy, which are known to be strong indicators of future success for undergraduates in academics and their future careers (Trapmann et al., 2007). Overall, this quantitative study supports the findings of a previous qualitative study, wherein former UG mentors self-reported that they felt their experience improved their critical thinking (Nelson & Cutucache, 2017). More studies

such as these should be conducted to provide strong empirical evidence of the impact serving as a mentor has on UG mentors.

Table 3.1. CCTST scores (overall plus eight subscales) utilized for this study (summarized from Insight Assessment, 2017).

| Score | Description |
|-----------------------|---|
| Overall | How well does student use reason to inform judgment? |
| Analysis | Students identify how arguments are formed based on assumptions, reasons, and claims. Students also glean information from tables, figures, and documents. |
| Interpretation | Students resolve the precise meaning and significance of text or tables and figures; may involve clarifying, categorizing or determining significance. |
| Inference | Students draw probable conclusions based on reason and evidence. |
| Evaluation | Students determine the credibility of sources and claims. |
| Explanation | Students describe/articulate evidence, reasons, methods, rationale and conclusions. |
| Induction | Students draw inferences about what is likely true as a basis for action. |
| Deduction | Students make precise, rigorously logical decisions based on specific contexts. |
| Numeracy | Students interpret figures and tables that present data quantitatively. They make judgments based on analysis and evaluation of mathematical/statistical information. |

Table 3.2. Descriptive statistics for NE STEM 4U mentor and non-mentor life science majors who participated in this study.

| | N | Mean Overall Pre-Test Score \pm SE | Mean Overall Post-Test Score \pm SE |
|---------------------------|----------|--|---|
| NE STEM 4U Mentors | 11 | 78.55 \pm 2.87 | 82.27 \pm 1.76 |
| Non-mentors | 26 | 73.19 \pm 1.52 | 73.73 \pm 1.51 |

Table 3.3. P-values of two-sample *t*-tests comparing NE STEM 4U mentors to non-mentors. After Bonferroni correction, values were significant (as indicated by the *) if uncorrected $p \leq 0.002$. In the pre-test, mentors and non-mentors were not significantly different in any of the measures. However, in four of the measures (overall, analysis, inference, and numeracy), NE STEM 4U mentors scored significantly higher than non-mentors on post-tests.

| | Overall | Analysis | Inference | Evaluation | Induction | Deduction | Interpretation | Explanation | Numeracy |
|-------------|---------|----------|-----------|------------|-----------|-----------|----------------|-------------|----------|
| Pre | 0.118 | 0.125 | 0.041 | 0.210 | 0.126 | 0.140 | 0.046 | 0.455 | 0.055 |
| Post | 0.001* | <0.001* | <0.001* | 0.081 | 0.004 | 0.008 | 0.003 | 0.056 | <0.001* |

Figure 3.1 Average Gain Scores for Participants

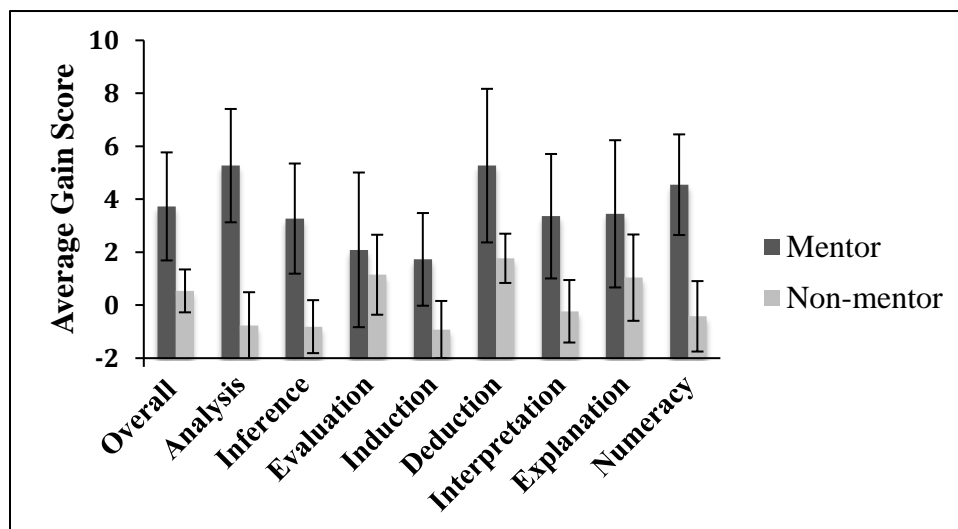


Figure 3.1. Summary of average gain scores for participants with 95% CI bars shown. Average gain scores were calculated for the overall score and eight subscale scores for both NE STEM 4U mentors and non-mentor life science majors. Notably, average mentor gains were at least two points greater than any non-mentor gains for all components of the CCTST. However, based on CI overlap, the scores that appear to be significantly different between mentors and non-mentors are: Overall, analysis, inference, and numeracy.

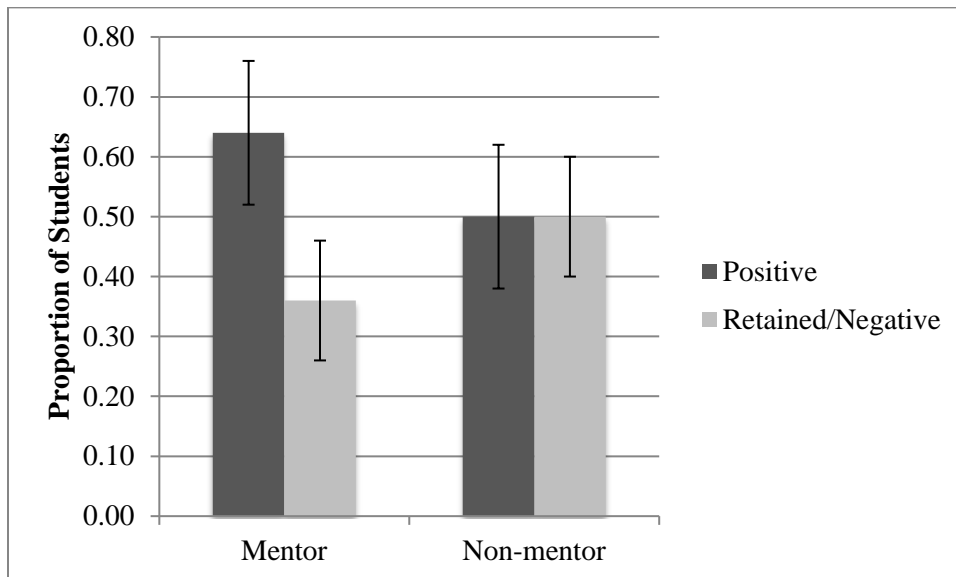
Figure 3.2 Comparison of Students' Pre-to-Post Scores

Figure 3.2. Proportion of students who improved their score from pre- to post-test compared to those who retained or decreased their score. The chi-square analysis (χ^2 value = 6.57; df = 1; $p = 0.01$) suggests that there is a difference either between the mentors and non-mentors or in performance (positive versus negative/retained). The 95% CIs indicate that there is no difference between mentors and non-mentors in terms of positive (improved) overall scores; however, in terms of negative/retained scores, it is not possible to determine significance because the CI bars overlap one another, but do not overlap the means. CI bars also indicate that there is a significant difference between the mentors who scored positively from pre- to post-test and the mentors who had negative/retained scores. The non-mentors showed equal numbers in terms of those who improved their score (positive) from pre- to post-test and those who either decreased (negative) or retained (no change) their score from pre- to post-test.

CHAPTER 4

SUMMARY, LIMITATIONS, AND FUTURE DIRECTIONS

Summary

Numerous sources agree that we, as educators, are not doing all we can to prepare a competitive workforce in science, technology, engineering and math. While research shows that there are many ways to better prepare our undergraduates as they matriculate through their coursework, there is one area that is often recommended, but under-studied, i.e. serving as a mentor. As a result, this body of work is dedicated to adding insight to studies that exist on the empirical evidence of its impacts. The purpose of the work included in this dissertation was to shed light on the impact mentoring has on the UG mentors, by conducting a systematic review (Chapter 2) and designing methodologically rigorous studies, using valid and reliable quantitative methods (Chapter 3), mixed methods (Appendix A), and qualitative methods (Appendix B) approaches. The paucity of available, rigorous work is likely because studying the impact of mentoring on mentors is a difficult task. In part, this is because programs that involve undergraduate mentors vary widely in terms of requirements, commitments, compensation, content, and theoretical frameworks, among many other variables. What has been discerned, even prior to the current work, is that mentors, when asked about their experience, tend to anecdotally have positive responses.

Now that we know, at least generally, that mentors tend to view their experience positively and we know that mentoring programs are highly variable, in order to draw any broadly applicable conclusions or recommendations, we need to attempt to study mentoring programs in a more methodologically rigorous manner. One step in this

direction that can be seen since 2013 is that more mentoring studies are including a theoretical or conceptual frame for their work. Another important advancement seen in studies since 2013 is that some mixed methods research is being conducted, which was not readily documented in the previous mentoring reviews. Mixed methods research may be particularly beneficial in the mentoring field because it, “may help you reach more justifiable and more complete study conclusions than using quantitative or qualitative methods alone” (Plano Clark and Ivankova, 2016, p.6). However, any methodologically rigorous research, including purely quantitative or qualitative methods, will further contribute to our understanding of this phenomenon.

Therefore, the current work in this dissertation was an attempt to gather more data on the impacts of serving as a mentor in methodologically rigorous ways. From this work, some common themes emerged. First, while UG mentors in NE STEM self-reported that they felt their critical thinking improved after mentoring (Appendices A and B), this was affirmed with the valid and reliable instrument, the California Critical Thinking Skills Test (Chapter 3). Specifically, after serving as a mentor, UG mentors significantly improved in their overall critical thinking ability in addition to their abilities in the subscales of analysis, inference, and numeracy, all of which relate to mathematical skill. These findings indicate that mentors not only feel they improve their critical thinking abilities by serving as a mentor, but there is actual quantitative evidence of this improvement.

Additionally, UG mentors self-reported improvements in personal attributes, many of which are considered important skills to make future STEM graduates employable (NACE, 2014). These included engagement (Appendix A), organizational

skills (Appendices A and B), preparedness (Appendix A), STEM content knowledge (Appendices A and B), teamwork (Appendices A and B) and problem solving (Appendix B). Additionally, mentors commented on the impacts mentoring had on their career trajectory, with some planning to include teaching and/or mentoring in their future career (Appendix A and B), while others felt mentoring had a direct impact on the processes of moving beyond their UG degree in terms of their application or interview for jobs or professional school (Appendix B).

Both qualitative pieces in this work included insights from the mentors about the challenges they faced. Notably, common themes regarding the challenges of serving as an UG mentor related to the mentees themselves, programmatic challenges (i.e. changes in numbers of students at the last minute or cancellation), and time management (Appendices A and B).

Overall, the current study utilized the Constructivist Learning Theory as the theoretical frame (Bruner, 1960), underpinned with Vygotsky's Zone of Proximal Development Theory (Vygotsky, 1934/1986). These Theories were well-suited to this work because both emphasize the social nature of learning and the use of scaffolding or structured interactions with the goal of generating meaningful learning (Bruner & Ratner, 1978; Wood, Bruner, & Ross, 1976), which is in direct alignment with the NE STEM 4U model. Additionally, both Theories emphasize that learning is student-centered and active. However, what is unique about the studies included herein is that I utilized these frames to better understand the learning that was taking place from the perspective of the teachers or, in this case, the UG mentors. Based on this work, it does seem as though mentors are co-constructing their knowledge and skills as they are facilitating the

mentees' understanding. This was particularly interesting as the UG mentors were not mentoring their peers or even near-peers, but rather they mentored audiences (K-8 students) that were much younger and at a much more basic knowledge level than the mentors themselves. Notably, in a previous study, we found that the mentees demonstrated gains in curiosity, inquiry, and scientific thinking after participating in the NE STEM 4U mentoring program (Leas, Nelson, Grandgenett, Tappich, & Cutucache, 2017). Taken together with the current findings, it appears as though the mentees and mentors are in a reciprocal relationship, where each is fostering learning and gains for the other via an active, social, and constructivist learning environment.

Limitations

While I attempted to employ rigorous methodology to the studies included herein, there are certainly some limitations of this work. Most notably, all of the studies involved mentors from the same program, NE STEM 4U. While this was a manageable place to begin, there is no doubt that more mentoring programs should be studied in order to draw broadly applicable conclusions. Additionally, while the sample sizes for each study were adequate, having a larger and more variable sample of UG across a wide range of colleges or universities would be ideal. It is especially important to begin with large sample sizes when utilizing a pre/post-test or interview scenario because it is always likely some students will drop out during the course of the study and not complete the post-test or interview. Another limitation of this study is that I did not have any details regarding the nature of the individuals who volunteered. While we do know that the volunteer mentors in this study come from a broad variety of backgrounds, GPAs, and

experiences, we don't know anything about their nature or personality type. This is important because it could be a factor in the findings of this study. If, for example, all of the volunteer mentors in this work were highly motivated individuals, it may be the case that nearly anything they do will lead to gains for those individuals.

Furthermore, while my longitudinal study was unique based on what I could find in the literature, there is much more that could be done with this study in terms of evaluation of the impacts serving as a mentor had on these former students, especially by incorporating a larger number of former mentors or those coming from a wide variety of mentoring programs. Overall, though, whether we were examining students who were currently mentoring or those who had matriculated out of college and on to a career, the major themes that emerged from this work indicate that serving as a mentor, while working through UG life science curriculum, provided many more gains than challenges for the UG mentors.

Future Directions

Based on this preliminary research, there are many future directions that one could take. First of all, I would recommend that more quantitative studies be conducted on the impacts of serving as a mentor, using valid and reliable instruments and appropriately selected statistical tests. However, a major issue with this recommendation is that there are not many validated and reliable instruments available to complete these types of measurements, so instrument design and development are key. One instrument that is available, the CCTST, should be used on a much more broad scale to see if serving as a mentor in a variety of programs leads to gains in critical thinking, when these UG are

compared to matched non-mentors. More of this work should be completed on NE STEM 4U mentors as well, because many of the sub-scale scores indicated borderline significance and a larger sample size could help elucidate whether or not mentors in this program show significant gains beyond those found in this specific study. Additionally, it would be interesting to investigate the sub-scales that relate to math skill, in particular the numeracy subscale, to determine if these scores show any correlation to ACT/SAT scores or even GRE and other post-baccalaureate exam scores, since math skill has been suggested to be an important indicator of future success in STEM fields (Trapmann et al., 2007).

Other areas of future work should involve studying the nature of the individuals who volunteer to better understand if there are common characteristics of these individuals that could potentially affect the gains or challenges of serving as a mentor. In other words, are the gains impacted by who the mentors are? Additionally, it could be interesting to better understand why teaching others seems to help concepts persist and develop in the teacher himself or herself. For example, why does having responsibility for others' learning lead to these gains when compared to only having responsibility for one's own learning?

Some of these questions may best be answered using more methodologically rigorous mixed methods studies, especially those that specifically address how the data are integrated with one another. Integration is an issue in many mixed methods studies as this type of research is becoming more broadly utilized by novice mixed methods researchers. Integration is the hallmark of mixed methods research, so how the quantitative and qualitative data are combined to lead to conclusions must be explicit

(Creswell, 2013). Mixed methods studies are particularly valuable for studying complex phenomena such as mentoring.

Lastly, because most of the research on the benefits of mentoring is designed to understand if these are lasting benefits (especially career preparedness), more longitudinal studies should be conducted. It is difficult to make valid claims that serving as a mentor improves the mentors' career skills if we are not studying the former mentors once they have moved into their professional lives. Based on exploration of the literature, there were no other studies, beyond the one conducted in this current work, that followed up with former mentors many years post-mentoring to gain an understanding of how this experience potentially impacted their current career or education status.

Overall, if we want to promote programs that benefit UGs, more research is needed to make evidence-based recommendations for mentoring programs. When recommending participations in programs such as these, it is also important to be realistic regarding the challenges UGs will face as they balance, often heavy, course loads and the demands of serving as a mentor.

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APPENDIX A

HOW DO UNDERGRADUATE STEM MENTORS REFLECT UPON THEIR MENTORING EXPERIENCES IN AN OUTREACH PROGRAM ENGAGING K-8 YOUTH?

Abstract

Background

Many university students are becoming involved in mentoring programs, yet few studies describe the impact of mentoring on the mentor. Additionally, many studies report that students graduating from college are not prepared to enter the workforce in terms of key career skills and/or content knowledge. Herein we examine the impact of our program, NE STEM 4U (Nebraska Science, Technology, Engineering and Math for You), in which undergraduate (UG) mentors engage K-8 youth in after school STEM experiments. The UGs reflected upon their experiences using post-mentoring evaluations, 12- and 24- week interviews and exit surveys. Many of the questions asked of the mentors related directly to their own professional development, such as self-evaluation of communication, organization, and problem solving skills, while other questions related to content knowledge and reflection.

Results

Post-mentoring, UGs reflected on the delivery/teaching significantly more ($p \leq 0.001$ for each) than other variables (i.e. their own content knowledge gains, the students' content knowledge gains, scaffolding the lessons, or overall professional growth). By analyzing the evaluations and interviews together, some significant, self-reported gains emerged. For example, 94.15% of the UG reported that the experience was beneficial to their education. Additionally, UG mentors self-reported significant gains ($p \leq 0.01$ for each)

moving from 12- to 24-weeks in the program in the categories of organization, STEM content knowledge, preparedness to teach, and engagement in the program. However, UG did not report significant gains in dependability. Importantly, when mentors ranked themselves at 24-weeks, they were blinded to (unaware of) the ranking they gave themselves at 12-weeks.

Conclusions

This study helps to fill a gap in the literature by allowing us to discern the gains UG mentors report attaining after mentoring to K-8 students. These data suggest that participation by UGs in this program promoted self-reflection as well as self-reported gains related to career preparedness and STEM content knowledge.

Introduction

Volunteer tutoring or mentoring programs that pair undergraduate (UG) students with K-8 students have been shown to improve academic skills for tutored students (e.g., Ritter, Barnett, Denny, & Albin, 2009) but few studies have examined the effects on the UG tutors themselves (Carpenter, 2015). Moreover, many of the past studies have focused on mentoring programs that emphasize math or reading, rather than science. Studies that examine how UG mentors think about and teach life science concepts to younger students could help to create a better understanding of the ideas that UGs have about life science concepts, how they integrate new knowledge they are learning from college coursework into the more elementary concepts they are teaching, and how engaging in these ideas helps them to develop as disciplinary thinkers.

By serving as tutors to younger students, the UG mentors act as “the more knowledgeable other” that is required for the zone of proximal development (Vygotsky, 1934/1986). They must decide on the scaffolds they need to use to help the younger students understand the material (Hmelo-Silver, Duncan & Chinn, 2007). In addition, by engaging with younger students in this way, UG mentors participate in a co-constructed zone of proximal development, in which the mentors learn from the students’ ideas as they help advance students’ understanding (Ash & Levitt, 2003). Further, how UGs reflect on their mentoring experiences, and the content they taught, can inform the design of mentoring programs; particularly the reflective components of those programs, in order to ensure academic benefit for the UGs as well as the students they are mentoring. In this way, prompts for reflection after teaching, according to Lin, Hmelo, Kinzer & Secules (1999) will promote, “active monitoring, evaluating and modifying (of) one’s thinking” (p. 43) to help UG mentors make sense of the experience, problem solve and adapt to different teaching (and learning) environments (Bruer, 1993). Additionally, promoting self-evaluation after mentoring can encourage the UGs to consider both their own content knowledge and how to best support younger students in life science lessons (Phillips & Bond, 2004).

Research Questions

In order to fill this gap in the literature, the current study was designed to examine UG mentors’ experiences as they engaged with mentoring life science lessons in an outreach program, utilizing reflection prompts to encourage UG mentors to evaluate their

mentoring experiences. Specifically, this study is informed by the following research questions:

1. In what ways does an after-school outreach mentoring program for K-8 students affect UG mentors in terms of personal development, as evidenced by professional preparation and academic/content gains?
2. What factors do UG mentors consider when they evaluate their experiences in an after-school outreach mentoring program for K-8 students?

Literature Review

There is a growing concern that the number of well-educated professionals in science, technology, engineering, and mathematics (the ‘STEM’ fields) is far fewer than needed, establishing a kind of “global race” for building the STEM pipeline (The Observatory, 2013). While this trend is evident in many countries, this literature review is primarily from the perspective of the United States. Reports, such as 2007 *Rising above the Gathering Storm* and 2010 *Rising above the Gathering Storm, Revisited* from the United States, indicate a critical need to meet and enhance STEM standards (Augustine, Barrett, Cassell, Grasmick, Holliday, Hackson, & Murray, 2010). These publications highlight a growing competitiveness among countries. At the same time, occupational projections, in the U.S. alone, predict a need for several million new college graduates with STEM degrees by 2018 (Carneval, Smith, & Stoll, 2010; Chen & Soldner, 2013; STEM Connector Report, 2014). Furthermore, publications such as *Vision and Change in UG Biology Education* (AAAS, 2011; Brewer & Smith, 2011), the Discipline-Based Educational Research (DBER) Report (Singer, Nielsen, & Schweingruber, 2012)

and the 2015 Employer Survey from the National Association of Colleges and Employers (NACE) *Job Outlook* publication (2014) all suggest a need to improve pre-professional training for STEM UGs if they are to be competitive job applicants that progressively contribute to the economy (Langdon, McKittrick, Beede, Khan, & Doms, 2011). For example, the U.S. Department of Commerce concluded that future earnings of individuals in STEM fields are, on average, 26% higher than salaries of their peers in non-STEM fields (U.S. Department of Commerce, 2011). By all accounts, the economic and societal benefits of meeting the STEM challenge are substantial and may well be a major economic driver that makes a better life for populations worldwide (New York Academy of Sciences, 2014).

To meet these challenges, the retention of existing STEM UGs within college programs is particularly important (NSB, 2010). Previously released STEM Attrition Report (ED/IES, 2013), which examines the attrition of college students from STEM fields over six years, indicates that 48% of those pursuing a bachelor's degree and 69% of those pursuing an associate's degree in STEM majors left these fields of study. Furthermore, approximately one-half of the students that left STEM majors switched to non-STEM fields, and the remainder typically exited college prior to earning a degree or certificate (ED/IES, 2013).

Beyond the need to retain STEM majors, there exists a growing need for STEM professionals that can productively interface with recent advancements that cross both science and technology. These advancements have radically changed not only the application of science, but also STEM learning and the professional fields associated with that learning. As outlined in the Vision & Change report (AAAS, 2011), the dynamic and

interdisciplinary STEM environment of the 21st century requires that scientists not only understand core disciplinary concepts, but also use critical thinking, communication, reflection and reasoning skills to translate those concepts to real-life solutions. In turn, UG education must change to ensure that students understand the core concepts and also develop the core competencies necessary to succeed in today's STEM professions.

Employers from various professions, including STEM and non-STEM areas, recognize the importance of developing core professional skills (i.e. communication, problem solving, critical thinking, and teamwork). Recently, a survey of employers reported that many college graduates lack the leadership and organizational skills they need to succeed in the workplace (Dostis, 2013). Additionally, in the current NACE *Job Outlook* publication (2014), over 70% of the employers participating in the survey seek attributes of leadership, teamwork, a strong work ethic/dependability, and communication skills (written and verbal) in their future employees. In light of these recent reports, it is imperative to capitalize on practices and methods that successfully develop a well-trained and prepared STEM workforce.

While innovative and engaging STEM education has the potential to prepare students to be successful contributors in the workplace, too often, STEM classrooms are dominated by traditional, transmittal lecture formats. This teaching style is often viewed as necessary for delivery of heavy content loads in STEM courses. Many faculty feel that they must “cover all of the material.” It has been well documented that this type of traditional lecture does not increase critical thinking or problem solving skills (Aguirre, Balsler, Jack, Marley, Miller, Osgood, Pape-Lindstrom, & Romano, 2013; Rabe-Hemp, Woollen, & Humiston, 2009; Tiwari, Lai, So, & Yuen, 2006). While hands-on

laboratories and their instruction can support content knowledge and expand problem-solving skills, labs are often prescribed in nature, thereby falling short of fostering critical thinking (Cooper, Underwood, Hilley, & Klymkowsky, 2012; Dolan, 2012; Hmelo-Silver, 2004). In contrast, active-learning strategies where UGs are involved in research, teaching, and mentoring enhance the UG experience and build a community prepared for graduate schools, professional schools or the workforce (Karukstis & Hensel, 2010). These instructional approaches also help students to learn and retain complex concepts (Avanzato, 2000).

While these techniques are said to improve undergraduate education, little research has been done to understand the value of mentoring for the mentor (Carpenter, 2015). Malone, Jones, & Stallings (2002) examined the effects on UGs tutoring elementary students and found changes in UGs' perspectives, including their identity and personal development, as well as on teaching and learning. Many of the UGs reported that the tutoring experience helped to reinforce academic content learned previously. Similarly, they learned from their tutees as they helped those students to learn (Malone et al., 2002). However, Malone et al. (2002) focused on UGs who were considering a career in teaching and the tutoring was part of a service learning component of an education course; therefore, the academic content focus was regarding teaching methods, scaffolding lessons, and concepts. Other programs have examined how UG mentors impacted high school students in their pursuit of STEM careers (e.g., Marable, 1999); however, the effect the experience had on the UG mentors was not examined.

Peer tutoring has also been a focus of past research and has been shown to help support tutors' own academic learning (Roscoe & Chi, 2007; Roscoe & Chi, 2008). This

academic learning typically occurred through self-monitoring of comprehension, integrating new knowledge with prior knowledge, and in constructing and elaborating knowledge (Roscoe & Chi, 2007). However, peer tutors usually focused on delivering knowledge to their tutee rather than on developing their own knowledge (Roscoe & Chi, 2007). Tutors were more likely to build knowledge and engage in metacognition of their own ideas when tutees asked them questions that required an inferential answer (Roscoe & Chi, 2008).

While some evidence suggests that tutoring or mentoring other students can help the academic learning and confidence of UG mentors (Rao, Shamah, & Collay, 2007), as well as professional skills development, such as communication, organization, and teamwork (Grant, Liu, & Gardella, 2015), more work is needed to determine the effects mentoring has on the UG mentors (Carpenter, 2015). This is becoming increasingly important as more STEM-related departments are increasingly developing outreach programs to primary and secondary schools (James, Laatsch, Bosse, Rider, Lee, & Anderson, 2006; Tanner, Chatman, & Allen, 2003; Williams 2002). It will be important to investigate the impacts on the UGs mentoring younger STEM audiences as such programs become more prevalent.

Methods

Intervention: Pre-professional Training Under an Outreach Program Platform

The model we created to address these growing STEM challenges and calls for action in the improvement of STEM education is called NE STEM 4U (Cutucache, Luhr, Nelson, Grandgenett, & Tappich, 2016). This program is a student-run, faculty-

supervised program that provides inquiry-based after school STEM activities for socioeconomically disadvantaged youth in grades K-8 in the Omaha (NE) Public Schools (OPS). Most UG students in the NE STEM 4U program are volunteers (herein referred to as mentors) from disciplinary STEM or professional education departments at the University of Nebraska at Omaha (UNO). Some mentors in leadership positions, such as student officers, are supported by modest stipends. The program incorporates several key practices and methods that contribute to retention of UG students and preparation of a well-trained STEM workforce mentioned above. For example, we use problem-based learning (PBL) as our model of instruction. For the students who are instructed using PBL, it has been shown to improve critical thinking and social skills, increases aptitude, enhances mastery of subject matter, and improves retention of information (Chng, Yew, & Schmidt, 2011; Nicholl & Lou, 2012; Salinitri, O'Connell, Garwood, Lehr, & Abdallah, 2012; Wiznia, Korom, Marzuk, Safdieh, & Grafstein, 2012).

Our model for pre-professional training includes a 3-fold approach involving research, teaching, and mentoring (Figure 1). Here, we assess the impact of the NE STEM 4U program on the UG mentor participants using several sources of self-reported data. The self-reported data include post-mentoring surveys, interviews, and end of program surveys.

Research Approach and Context

The outreach program, NE STEM 4U, pairs UG and graduate students as STEM mentors with elementary and middle school students. The student mentors provide after-school STEM activities by leading lessons using hands-on activities to middle school

students with the aim of providing opportunities for the students to experience disciplinary topics and potentially pursue studies and careers in a STEM area. The program initially began in the spring of 2013 and continues to serve 7-10 Omaha Public Schools per year. It is set up as a pre-professional training program for UG students in that mentors learn how to teach effectively, communicate, conduct research, and provide outreach to area students.

UG mentors teach lessons in the after-school program with themes, such as Forensics or Medicine, that each cover 6-week periods. Each mentor commits at least 4 hours per week to prepare topics, design experiments, and teach the lessons to students. Mentors volunteer at the after-school program once per week and typically commit at least one year to the program. In order to be accepted as a member of NE STEM 4U, students must submit an application as well as a curriculum vitae or resume, their GPA, and a cover letter that describes their motivation for membership in the organization. To date, the program has had 109 UG mentors. About 40% of the students have been in the program since it started in March of 2013, while the remainder began in August of 2014. The mentors are from a variety of backgrounds and all have an interest in STEM, but are not necessarily in a STEM major.

Participants

From the pool of mentors, selection for inclusion in this specific study was limited to UGs who mentored life science lessons during the fall semester 2013, spring semester 2014, and/or the fall semester 2014. This brought the total number of mentors included in the current study to 18. Demographic information about our mentors related to year in

school, major, ethnicity and gender is presented in Tables 1 and 2. Because only 3 graduate students participated in this study, their information was pooled with the UGs to protect the identities of participants. All protocols described herein were reviewed and approved through the University of Nebraska Medical Center and the University of Nebraska at Omaha's Institutional Review Board (IRB#548-12-EX). The consent of the participants was obtained at the beginning of the study; moreover, they were reminded every 12-weeks that their participation in data collection was voluntary and that they could withdraw at any time.

Data Collection and Analyses

For the purpose of this study, mentors were asked about their experiences in three ways: post-mentoring surveys, 12- and 24-week interviews (or, first and then second semesters), and a post-program interview. Table 3 includes a summary of each of these instruments. Figure 2 illustrates a timeline of data collection. Each mentor was asked, but not required, to complete a survey after each lesson they taught. Surveys were submitted online through the University of Nebraska at Omaha OrgSync Website (www.orgsync.com) from the fall semester 2013, spring semester 2014 and fall semester 2014. These survey responses were used to examine how the mentors reflected upon their experience in teaching STEM lessons (n=64 total) (Table 3A).

To understand how UG mentors were evaluating their mentoring experience immediately after it had occurred, we calculated the percentage of affirmative and negative responses for the first five questions of the survey. Then, we evaluated the open-ended questions to find recurring themes and subsequently generated a rubric to

further score the survey (Supplemental Table 1). The rubric was sent to experienced STEM faculty (external to the project) for refinement and calibrated by independently scoring surveys from UG mentors across 3 researchers and examined for inter-rater reliability. The rubric was then used to score the post-mentoring surveys (n=64). After scoring, descriptive statistics were calculated, followed by paired, two sample t-tests to look for significant differences in averages. Subsequently, a Pearson's Correlation analysis was used to determine what, if any, significant correlations existed.

Second, each UG mentor volunteered to be interviewed by program faculty, using a semi-structured format (Merriam, 2009) after 12- and 24-weeks in the program. For the interview, students were asked to rank themselves in five categories, including: Organizational skills, preparedness for mentoring, STEM content knowledge, engagement skills (i.e. keeping youth engaged), and dependability, on a scale from 1-10 (10 being the best) (Table 3B). Students were blinded to their previous self-ranking (i.e. from 12 weeks prior). To detect changes over time we compared 12-week ratings to 24-week ratings and determined an average for each category at each time point in order to detect any self-reported changes over time. Subsequently, we calculated the significance of these differences using a Student's t-test.

The interview also entailed a series of open-ended questions assessing the mentor's views of NE STEM 4U and the potential impact NE STEM 4U had on such topics as critical thinking and problem solving skills, future teaching/mentoring, and the mentors' likes/dislikes in the program. The specific questions asked during these interviews can be seen in Table 3B. All interviews were fully transcribed at the time they

were conducted for analysis, coded and examined for themes (Miles, Huberman, & Saldaña, 2014; Yin, 2014).

The data associated with the end of program were collected via written exit surveys from students matriculating out of the program (n=8). Data were gathered from students that were part of the program through the final semester of their senior year as well as students who decided not to participate in their final semester. Questions about career readiness and impact of NE STEM 4U in career preparation were the focus of this interview (Table 3C). We plan to conduct 5-year follow up interviews to assess the impact of NE STEM 4U on career readiness/effectiveness. These interviews will begin in 2018.

Findings

In the first research question, we asked, “In what ways does an after-school outreach mentoring program for middle school students affect UG mentors in terms of personal development (development of professional skills and academic/content knowledge)?” In the post-mentoring surveys administered to all mentors at the end of the mentoring experience, a total of 94.2% of respondents indicated the experience was “beneficial to their education” (Table 4). In addition, 93.6% of mentors indicated they felt a “sense of accomplishment with helping community members” (Table 4). Mentor’s self-reported gains as a result of the NE STEM 4 U program increased over time of participation from the 12-week interview to the 24-week interview. In particular, mentors self-report of their own skills included significant gains in organization, preparedness, and engagement skills, as well as content knowledge (Figure 3). Below are quotes from

the mentors (12- and 24-week interviews) illustrating their own feelings about their personal growth:

One mentor said, “Definitely felt more confident (after mentoring) in STEM content as a whole.”

Another mentor indicated, regarding organizational skills, “Teaching has helped (my) organization a lot – you can’t walk into a classroom unorganized and have it go well. Teaching has helped organizational skills because others rely (on you) when committed to doing something.”

Related to core science concepts and content, mentors denoted, “(Mentoring) helped me to incorporate things that are good scientific questions.”

“(I am) very good at biology, but in other areas (TEM) lacking and so teaching has helped improve knowledge in TEM.”

Other mentors explicitly discussed how NE STEM impacted their communication skills, “Better communicator now.”

“If (I) can explain to other people, (I) can explain to patients how to use insulin effectively.”

From the interviews, 55.5% of the NE STEM 4U mentors conveyed that they would include mentoring in their careers. Additionally, 18.5% of interviewed mentors reported that their experience with NE STEM 4U had caused them to change their career trajectory to teaching science. Lastly, when UG mentors were directly asked if they intended to include teaching in their future career, 40.7% of NE STEM 4U mentors indicated that, while they did not wish to change their major to teaching, they would make a point to include teaching of some age group in their careers. Regarding changing their career to teaching, one mentor noted,

“For my career, I am now planning to include teaching at college or grad school level.”

Another mentor became aware, through NE STEM, that he/she enjoys mentoring and teaching enough to incorporate it into his/her career, “While I don’t plan to change my major to teaching, after mentoring, I do think I would like to have some aspect of teaching others in my career.”

In exit surveys, all but one (85.7%, n=7 out of 8) of the student mentors matriculating out of the program stated that participating in the NE STEM 4U program directly improved their career readiness. Moreover, those mentors who were involved in curriculum planning, development, or other leadership positions, highlighted the strengths they gained from serving as leaders in NE STEM 4U as well, even though they were not specifically asked a question about this aspect of the program on the exit survey. Below are a few select quotes from the exit surveys in which mentors explicitly connect NE STEM 4U to their future, beyond their undergraduate degree:

“(NE) STEM 4U played a role in my ability to educate kids about complex material in a way that they can understand, which I think will benefit me in my future when I educate patients.”

“Well, this experience allowed (me) to make a weekly routine on the given day of teaching and I think this is a trait that is expected when one graduates, so having this extra commitment helped me gain more experience outside of taking classes.”

In the second research question, we asked, “What factors do UG mentors consider when they evaluate their experiences in an after-school mentoring program for middle school students?” Mentors voluntarily completed post-mentoring evaluations after each time they taught a lesson to middle school students. We found five common themes emerged as mentor’s evaluated their experience, specifically: their own content knowledge, the students’ content knowledge, reflection upon the delivery/teaching, scaffolding of the lessons for the students, and the mentor’s professional growth.

Interestingly, some mentors reported that the experience helped with their own life science content knowledge, made them better teachers, or provided professional growth. However, in our analysis of these evaluations, mentors engaged in reflection of their teaching/delivery to a significantly greater extent than any of the other factors we scored (discussion of mentor content knowledge, student content knowledge, scaffolding of the lesson, or professional growth; see Table 5 for descriptive statistics). Below are a few quotes selected from the post-mentoring evaluations that relate to how preparing to teach and teaching itself were beneficial for both the mentor and mentee:

“Today, we presented a lesson on things that I didn't know very well. In all honesty, I learned a lot of cool new information upon reading the lesson plan and preparing. It also reinforced me theory that I learn best by teaching others.”

“Some of the students seemed really indifferent to the experiment, but once I took the time to break it down and work through it with them, it went much smoother.”

“Practicing for an hour before the experiment was very helpful. We will certainly continue to do that. We felt a lot better prepared, as a team. It was very clear today that the kids learned and had a great time. They really enjoyed the lesson and were looking forward to doing it at home.”

Another mentor reflected upon how their teaching is impacting the students and that it is inspiring, “I feel like (NE) STEM is helping to inspire inquisitive young minds. I'm really hoping they pursue careers in the STEM field. Many are very smart and excited about science. I'm excited to see what the future holds for them.”

T-test analyses (Table 6) were completed to compare the variable of reflection upon teaching/delivery to each of the other measured components (mentor content knowledge, student content knowledge, scaffolding the lessons, professional growth), respectively. Significant differences were seen between reflection upon teaching/delivery of the lesson compared to every other variable measured. These data indicate a clear

impact on student self-reflection regarding their conveyance of the lesson and the level of engagement with the youth.

No other significant differences existed among the scored items on the evaluations. However, using Pearson's Correlation analysis, we observed significant correlations between how the mentors reflected upon scaffolding the lessons and three other areas: Reflection upon student content knowledge, reflection upon teaching/delivery of the lesson, and reflection of their own professional growth. No other variables showed significant correlations. These data indicated that while the mentors did reflect upon their engagement with the youth, they were unable to clearly articulate specific areas of focus of that metacognitive process.

When mentors were asked what they would do differently the next time they taught a lesson, three major themes emerged: Increasing their self-confidence, enhancing their professional skills, and improving interactions with the primary and secondary school students. For example, regarding self-confidence, one mentor said,

“I like hearing from the after school administrators and aides that the students are learning a lot and are having a great time. The fact that the students are talking about our experiments after they leave, and are excited about them, makes me feel confident, like I am doing what I am supposed to be.”

Regarding professional development and skills for a future career, another mentor commented,

“Communication and the ability to teach are skills that can translate into a variety of fields. Honing my communication skills and figuring out how to present ideas in a way that can be understood by people of different ages and intellectual capacities will be extremely helpful in my future career.”

Regarding improving interactions with the students, mentors said,

“I think the cool lesson plans are helping to spread the excitement of STEM. Our group at ‘School X’ has gotten a lot bigger! It's really exciting to watch.”

“The kids had a lot of fun! They probably didn't even realize they were learning. Many were talking about how fun the game was as they were leaving. I'm hoping they talk to their friends about how fun STEM is and recruit more kids to join in the fun.”

It is clear that these UGs focused on how they could improve their self-confidence, enhance their professional skills, as well as improve their engagement and interactions with the participating youth.

Discussion

NE STEM 4U is a pre-professional training program for undergraduates that engage socioeconomically disadvantaged youth in the community through an outreach program including STEM experiments. This study focused on the impact the UG mentors reported that NE STEM 4U had on them. While we hypothesize that the youth in the program also benefitted, this impact is beyond the scope of this study and will be presented in a subsequent, forthcoming paper. We proposed that the mentors would experience NE STEM 4U as a benefit to their education, fostering an increased sense of organization, STEM content knowledge, preparedness, dependability and engagement. We also proposed that this program would lead to further refinement of career goals, ultimately improving their career readiness in STEM areas. Furthermore, we investigated whether participation in this program caused mentors to include teaching and mentorship in their careers.

We observed powerful affirmation from mentors that they feel this program was beneficial to their education (Table 4). Moreover, UG mentors reported improvements in personal attributes, many of which are considered important skills to make future STEM graduates employable (NACE, 2014). These included engagement, dependability,

organizational skills, preparedness, and STEM content knowledge (Figure 2), with significant improvements self-reported in all areas except dependability. This may be because of all of the self-ranking categories, UGs ranked themselves, on average, the highest in terms of dependability at the early (12-week) interview, so there was not much room for increased self-rank in this area (Figure 2).

While it may not be surprising that, in terms of evaluating their experiences immediately after mentoring, UG mentors evaluated themselves significantly more by reflecting upon their teaching/delivery of the lesson than they did in any other category (Table 6), we were intrigued by the correlations we found. UG mentors who evaluated their own scaffolding of the lessons for younger students also showed significant correlations to reflecting upon the content knowledge of students, the teaching/delivery of the lesson, and their own professional growth. It is well documented that scaffolding strategies can greatly enhance learning (Hmelo-Silver, 2004; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, Soloway, 2004) for the student, so it seems consistent that mentors who reflect upon their own scaffolding of lessons would also reflect upon the younger students' content knowledge and their own delivery of the lesson. However, the actual relationship between reflecting upon scaffolding the lesson and reflecting upon professional growth remains to be determined.

Interestingly in their reflections, UG mentors include much information about the students, thereby implying that they really see themselves as “teachers” and the authoritative figures. Based on the reflections and interviews, this teaching/mentoring intervention through community engagement impacted many of the undergraduates' communication skills and confidence. Grant et al. (2015) similarly found improved

communication and confidence in UGs who were involved in public engagement with middle and high school students.

Peer mentoring and faculty-student mentoring have been shown previously to enhance higher-order thinking skills, build stronger relationships among undergraduates, improve career performance and increase satisfaction in career choice (Roscoe & Chi, 2007; Roscoe & Chi, 2008; Malone et al., 2002). Our data lend further support and extend these results with NE STEM 4U mentors expressing the development of strong relationships across the cohort. Anecdotally, mentors cited specific benefits such as having a more veteran student available to address questions about when and how to apply for professional school, or recommend the order in which they should take their biology courses.

Excitedly, the NE STEM 4U program continues to grow with an increasing number of undergraduates seeking the opportunity to participate. In the past 18 months alone, the program has grown from 8 students at inception to over 60. The program grew from 8 students participating year 1, to 65 year 2, to 31 this past year (this past year many students taught more often than once weekly-thereby decreasing the number of students needed). We expect the mentor cohort to stabilize at approximately 25-35 per year.

Limitations and Areas for Revised Practice

In this program, first, we engaged OPS schools in socioeconomically disadvantaged areas displaying the lowest science and math scores (we did not include schools with high performance on standardized assessments). All of the youth participants are a part of a single school district and they were assumed to have the same

general background in education as their peers from a different school within the same district and geographically close by—though we understand that it is difficult to match students in terms of academic ability for intervention groups. Additionally, not all after school time programs in the participating district run identically as there is an independent site director for each school.

Secondly, although we train all of our NE STEM mentors with the same process, we do not place limitations on the way they choose to teach. We do have overarching requirements in our program such as: teach in a PBL format, complete an experiment, keep all students engaged, and do a daily assessment followed up with a long-term assessment, but we do not force all mentors to accomplish this in the same way. This can cause variations in the depth of the student participants' comprehension of the STEM material. However, this also fosters critical thinking and encourages the independence of mentors—furthering their training in 21st century learning skills.

Lastly, the faculty to mentor ratio was also a challenge as we grew as a program. Specifically, this led to a high workload for the involved faculty including: substantial personnel management time, on-going coordination with public school sites, management of funding, applying for additional funding, researching the effectiveness of the program, and training and certifying incoming evaluators and working with consultants for external evaluation. Providing the program during university academic year breaks also posed a challenge, leading to a revision of the program to exclude participation during winter and spring university breaks. Only seven students voluntarily participated during the summer months to prepare PBLs and materials for the following school year as well as analyze data. Therefore, as the program expands, staffing issues and staffing management will no

doubt continue to be one of the greatest challenges. Retention plays a role in this challenge, too. For example, we had a mentor dropout rate of 15% with undergraduates citing lack of time for commitment to the program and the need to begin preparing for pre-professional admission exams.

Conclusions

While more and more STEM-related departments within universities are developing community outreach programs to primary and secondary schools (James et al., 2006; Tanner et al., 2003; Williams, 2002), little research has been done to investigate the impacts of mentoring on the UG mentors (Carpenter, 2015). This study helps to fill that gap in the literature by providing insight into the gains the UG mentors report attaining after mentoring to middle school students. Specifically, mentors provided feedback and self-evaluation through post-mentoring reflections and interviews that revealed gains in professional training (organizational skills, communication, and preparedness), content knowledge, and engagement. Additionally, mentors reflected significantly more ($p < 0.001$) upon how they delivered the lesson than they did about their own content knowledge, the students' content knowledge, how they scaffold the lesson, or their own professional growth in the post-mentoring reflections.

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Table 1. General demographics for UG student mentors included in this study.

| | Level | | Ethnicity | | Gender | |
|--------------------|---------------|----------|-----------|-------|--------|--------|
| | Undergraduate | Graduate | White | Asian | Male | Female |
| Number of Students | 15 | 3 | 16 | 2 | 9 | 9 |
| Percent of Total | 83.3 | 16.7 | 88.9 | 11.1 | 50 | 50 |

Table 2. Student characteristics of undergraduate student mentors related to major and college preparation.

| | Major | | 1 st Generation student | | Transfer | | If transfer, from where | |
|--------------------|---------|---------------|------------------------------------|------|----------|------|-------------------------|------|
| | Biology | Biotechnology | Y | N | Y | N | CC | 4 Yr |
| Number of Students | 10 | 8 | 7 | 11 | 14 | 4 | 10 | 4 |
| Percent of Total | 55.6 | 44.4 | 38.9 | 61.1 | 77.8 | 22.2 | 71.4 | 28.6 |

Table 3. Questions administered to NE STEM 4U UG and graduate participants regarding their experience in the program. **A.** Prompts from post-mentoring survey completed by NE STEM mentors after mentoring K-8 youth. **B.** Prompts from interview administered in person to NE STEM mentors at 12- and 24-weeks into the program. Students were not allowed to see how they had rated themselves prior. Questions 1-5 were on a scale of 1-10, 10 being the highest score. **C.** Prompts administered to NE STEM mentors graduating from the program (i.e. not returning the following academic year due to graduation). Questions from the end of program survey were administered to students graduating from the program immediately after their separation (+/- 40 days).

A. Questions from Post-Mentoring Survey

1. What activity did you participate in and on which date?
2. Did you find this experience to be beneficial to your education?
3. Did you feel a sense of accomplishment with helping community members?
4. What would you do differently next time?
5. What did you like most about the experience?
6. What did you like least about the experience?
7. How do you think this experience most helped the community?
8. Please provide feedback on your K8 students during this lesson in regards to engagement, comprehension, and other observations.
9. Other comments:

B. Questions from 12- and 24-week Time point Interview

1. Rate your organizational skills
2. Rate your preparedness skills
3. Rate your engagement skills (i.e. ability to grab attention through meaningful discussion)
4. Rate your dependability skills
5. Rate your communication skills
6. Can you think of a time recently where you have had to problem solve or think critically in NE STEM? If yes, please describe.
7. What kind of career do you expect to enter?
8. Do you plan to include teaching and/or mentoring in your career?
9. What is one thing that you have liked about the NE STEM 4U program?
10. What is one thing that you have disliked about the NE STEM 4U program?

C. Questions from End of Program Survey

1. Provide your college major(s)
2. Provide your GPA
3. What is your career plan?
4. Do you have an employer or a form of employment already identified?
5. Have you had any job opportunities as a result of the NE STEM 4U program?
6. What was (were) the best experience(s) for you in NE STEM 4U and why?
7. What recommendations do you have to improve NE STEM 4U?
8. Did you feel as though you were adequately prepared to begin a career after completing your UG major at UNO? What, if any, role did NE STEM 4U play in that level of preparedness?

9. What did you feel as though you were missing in your UG career at UNO for career and/or preparation for professional school?
10. Would you be willing to provide feedback about how NE STEM 4U might have helped your career in the next year and in 5 years? If so, please provide the best ongoing contact information for you.

Table 4. Results of post-mentoring surveys from participating undergraduate students.
 *Most students cited “cancellation of afterschool programming” as reasons for negative responses.

| Prompt | Type of Response | |
|--|-------------------------|-----------------|
| | Affirmative | Negative |
| Did you find this experience to be beneficial to your education? | 94.15% | 5.85%* |
| Did you feel a sense of accomplishment with helping community members? | 93.63% | 6.37% |
| What would you do differently next time? (Mentors could select more than one) | | |
| It is related to the lesson | | 37.63% |
| It is related to classroom function | | 31.44% |
| It is related to self-preparedness | | 29.38% |
| It is related to the youth | | 17.53% |
| It is related to the school | | 9.28% |
| Other | | |
| What did you like most about the experience? (Mentors could select more than one) | | |
| It is related to the youth | | 61.88% |
| It is related to the lesson | | 37.62% |
| It is related to classroom function | | 15.35% |
| It is related to self-preparedness | | 29.38% |
| It is related to the school | | 8.42% |
| Other | | |
| What did you like least about the experience? (Mentors could select more than one) | | |
| It is related to the youth | | 29.28% |
| It is related to classroom function | | 22.65% |
| It is related to the lesson | | 18.23% |
| It is related to the school | | 13.26% |
| Other | | 16.57% |

Table 5. Descriptive statistics for post-mentoring surveys.

| Scored Items | Mean | Standard Deviation | Minimum score possible | Maximum score possible | Minimum score achieved | Maximum score achieved |
|--|------|--------------------|------------------------|------------------------|------------------------|------------------------|
| Mentor content knowledge | 1.08 | 1.10 | 0 | 3 | 0 | 3 |
| Student content knowledge | 1.12 | 1.02 | 0 | 3 | 0 | 3 |
| Reflection upon teaching/delivery | 2.08 | 0.91 | 0 | 3 | 0 | 3 |
| Scaffolding the lesson | 1.31 | 0.96 | 0 | 3 | 0 | 3 |
| Professional growth | 1.25 | 1.37 | 0 | 3 | 0 | 3 |

Table 6. *T*-test analysis comparing reflection of lesson delivery to each measured component (mentor content knowledge, student content knowledge, scaffolding the lessons, professional growth), respectively. Significant differences were seen between reflection upon teaching/delivery of the lesson compared to every other variable measured.

| Scored Item 1 | Scored Item 2 | df | <i>t</i> | <i>p</i> * |
|-----------------------------------|---------------------------|----|----------|------------|
| Reflection upon teaching/delivery | Mentor content knowledge | 63 | -5.657 | <0.001 |
| | Student content knowledge | 63 | -5.889 | <0.001 |
| | Scaffolding | 63 | 5.671 | <0.001 |
| | Professional growth | 63 | 3.997 | <0.001 |

*Significant at $p < 0.001$

Table 7. Pearson's Correlation analysis revealed significant correlations between mentors who evaluated the scaffolding of their lessons and three other areas: Student content knowledge, reflection upon teaching/delivery of the lesson and their own professional growth. No other variables showed significant correlations.

| Scored Item | Correlation | Significance* |
|---|-------------|---------------|
| Student Content Knowledge & Scaffolding Lessons | 0.377 | 0.002 |
| Reflection Upon Teaching/Delivery & Scaffolding Lessons | 0.334 | 0.007 |
| Professional Growth & Scaffolding Lessons | 0.279 | 0.026 |

*Significant at $p < 0.05$

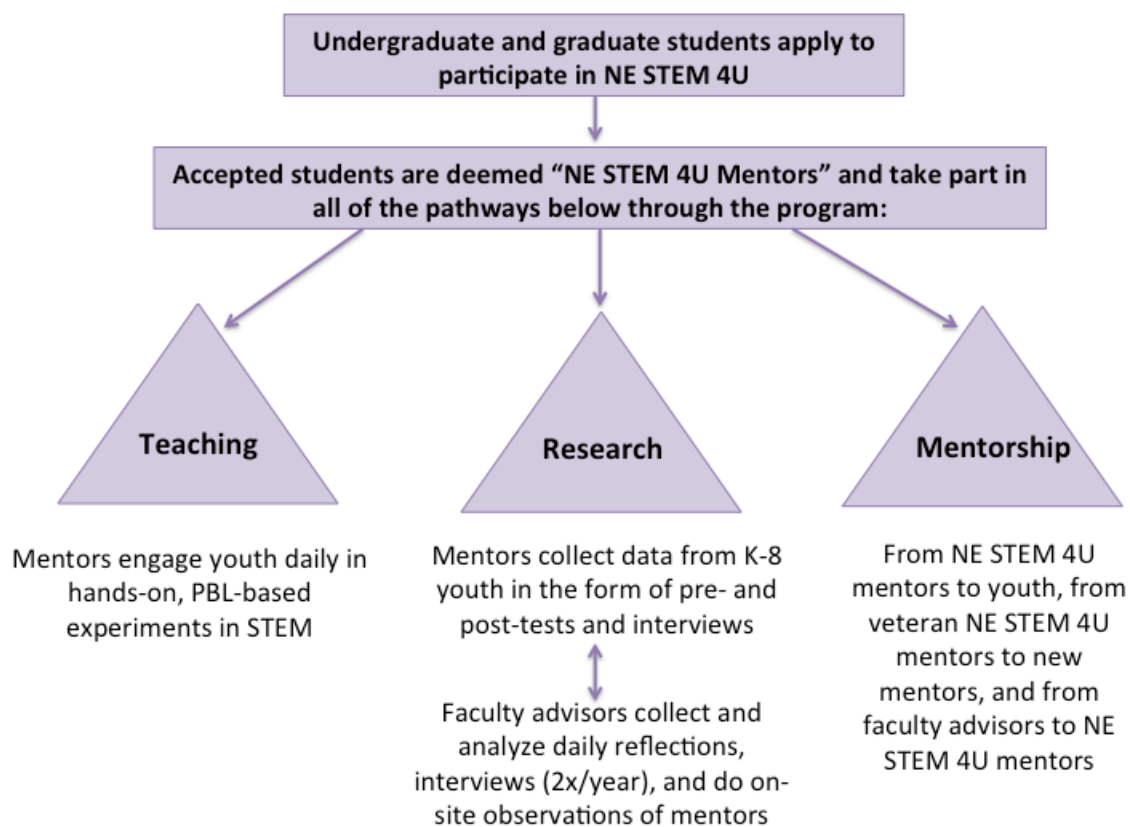


Figure 1. Flow chart of the structure of the NE STEM 4U program.

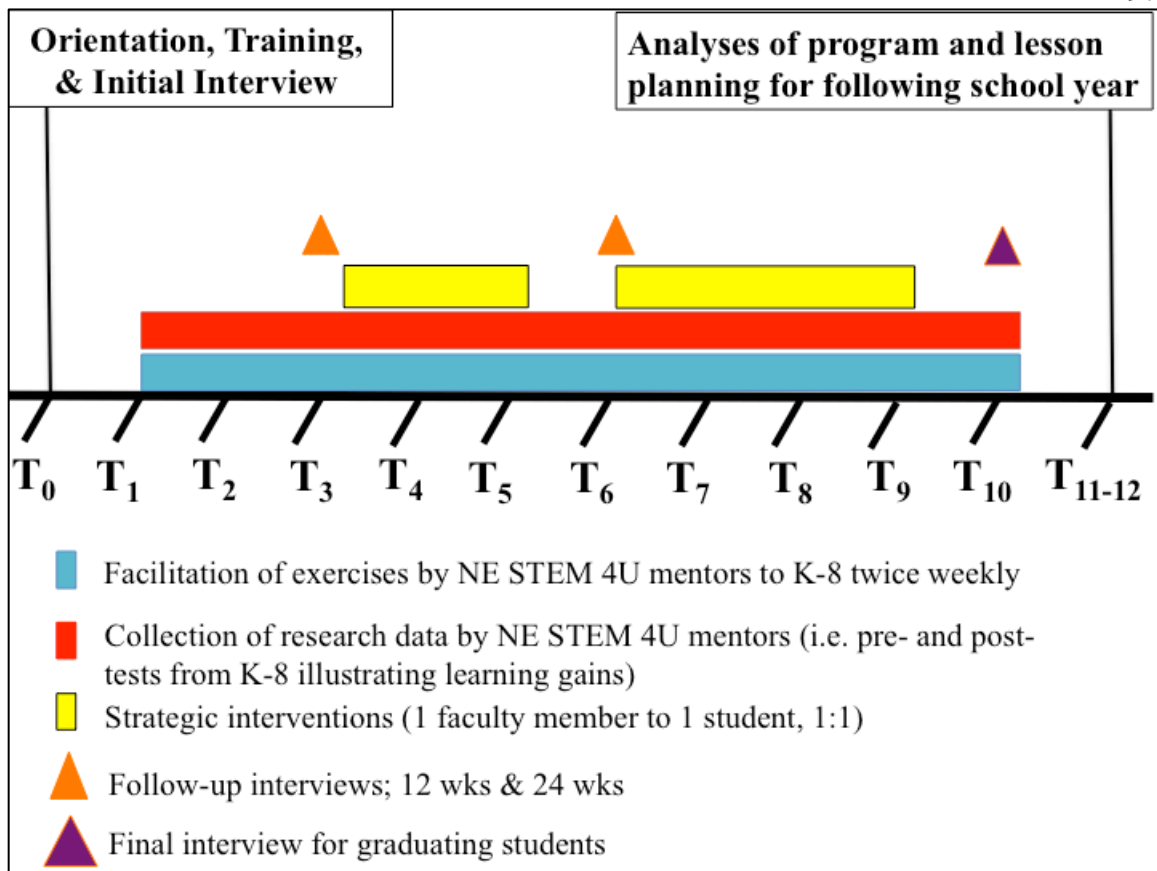


Figure 2. Timeline of data collection during program implementation and assessment representative of an academic year. T, time as measured in months.

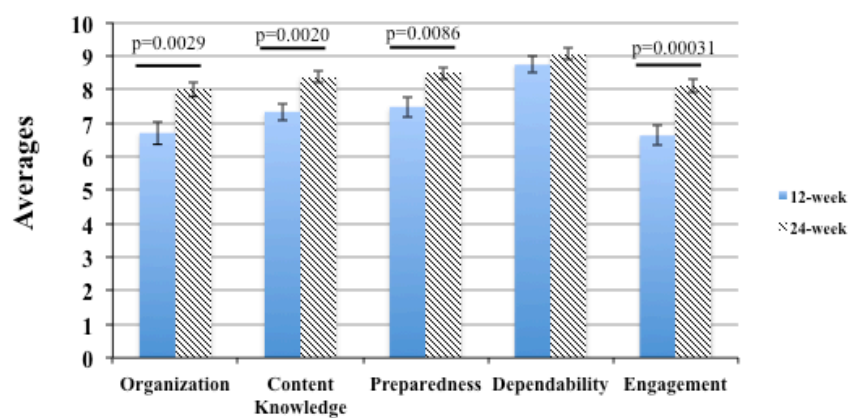


Figure 3. Averages of self-reported data related to organization, STEM content knowledge, preparedness to teach, dependability, and ability to engage youth from NE STEM 4U mentors. All but one of these measurements (dependability) showed significant improvement ($p \leq 0.05$) as mentors rated themselves progressing from 12-weeks in the NE STEM 4U program to 24-weeks, $n=27$. Bars represent the mean and error bars represent standard error. P-values, using a Student's t-test, are reported above each category that was statistically significant.

Supplemental Table 1. The following is a rubric for scoring NE STEM 4U post-mentoring surveys to gain some general insights on what mentors mention in several key areas of interest, including mentors content knowledge, students content knowledge, metacognition, scaffolding, and mentor’s experience. This rubric is intended to help quantify responses in a range represented from a score of 0, with no evidence of a trait to a score of 3, representing more detailed explanatory evidence.

| Criteria | 0 | 1 | 2 | 3 |
|--|---|---|---|---|
| Increase in mentor’s content knowledge | No mention of their own content knowledge | Mentioned their own content knowledge but no increase | Mentioned an increase in their own content knowledge without going into detail | Mentioned an increase in their own content knowledge and explained how the experience led to the positive change |
| Increase in students’ content knowledge | No mention of students’ content knowledge | Mentioned students’ content knowledge but not an increase | Mentioned an increase in students’ content knowledge without going into detail | Mentioned an increase in students’ content knowledge and how the experience led to that positive change |
| Reflection on delivery of the experience/ reflection on teaching | Mentor does not mention the lesson in reflection | Mentor mentions something about the lesson | Mentions something that they thought could go better, but no mention of <i>how</i> it could go better OR something that they wanted to do to improve the lesson OR mention how he/she would change delivery of the lesson | Mentor recognizes that they could improve something about the experiment AND mention a specific example of how it could be improved |
| Scaffolding use | No mention of how mentor engaged with students | Mentor mentions students in the context of the lesson but gives no instructional details | Mentor discusses some instructional details of structuring the lesson for students | Mentor gives a clear and detailed description of how the lesson was structured for the students |
| Mentor’s professional growth experience in STEM | No mention of how the experience changed their professional ideas | Mention of how experience changed ideas or led to professional growth with no details mentioned | Discussed how the experience changed their ideas or led to professional growth with explanation in terms of their own self | Discussed how the experience changed ideas or led to professional growth in terms of communicating or teaching youth and/or interacting with fellow mentors (e.g. in communication skills or problem solving) |

APPENDIX B

HOW DO FORMER UNDERGRADUATE MENTORS EVALUATE THEIR MENTORING EXPERIENCE 3-YEARS POST-MENTORING: A PHENOMENOLOGICAL STUDY

Abstract

This phenomenological study involves a unique, longitudinal assessment of the lived experiences of former undergraduate mentors (n=7) in light of their current experiences (i.e. career or advanced schooling). The objective of a phenomenological study is to engage in in-depth probing of a representative number of participants. Specifically, we followed up with graduates of the Nebraska STEM 4U (NE STEM 4U) intervention 3 years post-program, with the overall goal of describing the mentors' experiences using the lens of their current experiences. This type of longitudinal perspective of mentoring is greatly lacking in the current literature. At the time of the interviews, all graduates were either in a STEM career or STEM-based graduate/professional program. Three major themes emerged: Career, inspiration, and challenges. Each of these themes was further broken down into sub-themes to describe the essence of the mentoring phenomenon for these individuals. This information may be beneficial for any programs that engage undergraduate students in mentoring.

Introduction

The Nebraska Science, Technology, Engineering and Math 4U (NE STEM 4U) intervention is the first to include a three-fold approach, immersing undergraduates in teaching, research, and mentoring (Cutucache, Luhr, Nelson, Grandgenett, & Tapprich, 2016). The related research questions of the program target undergraduate student

learning outcomes that align with the *Vision & Change* (AAAS, 2011) core competencies. From most accounts, the United States is not producing enough professionals qualified in STEM to meet existing needs; additionally, new STEM graduates must have ample pre-professional preparation to make them competitive job applicants and progressively contribute to the economy within those jobs (NAS, 2010).

The growing need for qualified STEM professionals corresponds with recent advancements in science and technology that have radically changed not only the nature of science, but also the nature of STEM learning and professional fields. As outlined in the *Vision & Change* report, today's dynamic STEM environment requires that scientists not only understand core disciplinary concepts, but also use 21st century skills such as critical thinking, communicating, and reasoning to apply those concepts to real-life problems (AAAS, 2011). In turn, undergraduate biology education must change to ensure that students understand the core concepts and develop the core competencies necessary to succeed in today's STEM professions (Dolan, 2015). The importance of developing core professional skills is also recognized by employers, who report that many college graduates lack the leadership and organizational skills that they need to succeed in the workplace (NRC, 2012). Therefore, it is imperative to capitalize on best practices and methods that have demonstrated retention and preparation of a well-trained future workforce.

The NE STEM 4U program incorporates several such practices, including focusing on active learning and involving undergraduate students in hands-on disciplinary practice experiences through **teaching, researching, and mentoring**. Based on previous studies, these methods are associated with gains in approaching scientific

problems, laboratory techniques, logical thinking, personal development, and lower attrition rates (Nagda, Gregerman, Jonides, & Hippel, 1998; Bauer & Bennett, 2003; Lopatto, 2004; NRC, 2005; Eagan, Hurtado, Chang, & Garcia, 2013; Prunuske, Wilson, Walls, & Clarke, 2013). Critically, all three key features of this intervention (teaching, research, and mentoring) are rooted in theory previously recognized by the National Research Council (NRC, 2000 & 2012). The theories supported by NRC reports include the recommendation of putting science learned in the classroom into practice. Through the NE STEM 4U program, undergraduates are able to take what they have learned in the classroom and translate it into active STEM lessons that are then shared with their community.

Likewise, many universities across the country are increasingly encouraging undergraduates to participate in mentoring, yet little research has been done to understand the ways mentors view their experiences (Budge, 2006; Carpenter, 2015; Rao, Shamah, & Collay, 2007). The gap in the literature becomes even more pronounced when we consider that former mentors are rarely followed up with post-graduation, to gain a picture of how these individuals reflect upon their experiences after having more “real-world” experiences, such as a career or advanced education and to define how, if at all, mentoring experiences shaped these successes.

To that end, what is well documented is that peer mentoring and faculty-student mentoring foster higher-order thinking and build strong relationships among undergraduates, resulting in a stronger sense of community, more responsible behavior, and higher productivity (Pita, Ramirez, Joacin, Prentice, & Clarke, 2013; Eby & Lockwood, 2005; Aikens, Sadselia, Watkins, Evans, Eby & Dolan, 2016). In a

randomized control trial, students that received mentoring showed higher performance in classes and higher satisfaction in career choice (Kim & Park, 2013). Additionally, studies suggest that mentoring can positively impact the mentor's career skills (Page, Wilhelm, & Regens, 2011; Laursen, Thiry, & Liston, 2012) and academics (Carpenter, 2015; Nelson, Sabel, Forbes, Grandgenett, Tapprich, & Cutucache, 2017), but no studies, to our knowledge, have followed up with the mentors several years after graduation to determine if these gains were actualized upon entering a career or continued schooling. Therefore, in this report, we focus on the undergraduate mentoring component of NE STEM 4U to understand how former undergraduate mentors perceive the phenomenon of mentoring in light of their current positions (i.e. in a career or professional/graduate school).

NE STEM 4U Program

To provide context, undergraduate mentors in our program offer three, 8-week sessions of active learning per year at each school. In each session, NE STEM 4U mentors, working in teams of 2-3, deliver two after-school activities per school per week for 1 hour at a time. On average, the program engages 500 Omaha Public Schools (OPS) students across all schools in each 8-week session. The sessions are designed to increase interest and understanding in STEM topics among socioeconomically disadvantaged students in OPS and to provide opportunities for these students to pursue STEM education and careers. At the same time, the NE STEM 4U undergraduates gain valuable discipline-based experience through their roles as instructors, researchers, and mentors (Cutucache et al., 2016).

In this program, there are 3 levels of mentorship: 1.) From faculty advisors to undergraduates, 2.) Peer mentoring from undergraduates to undergraduates, and 3.) From undergraduates to youth participants. Faculty advisors serve as sounding boards to undergraduates to assist with career aspirations and educational choices. As peer mentors, upper-level NE STEM 4U undergraduates mentor lower-level undergraduates in the program. This includes making recommendations about coursework, extracurricular and volunteer opportunities, and the resources necessary to prepare for STEM jobs and professional or graduate school. The more experienced NE STEM 4U students also mentor new mentors in their instructional and research-related roles within the NE STEM 4U program. Lastly, undergraduates serve as role model mentors to youth, in an effort to deliver content and expand inquiry, but also to familiarize the youth with college life and to provide confidence to the youth as they graduate to the next grades. While mentoring is known to provide benefits to both the mentees and the mentors, little research is available that follows former undergraduate mentors after graduation to better understand the impacts mentoring may have on the undergraduate's future. The current study helps to fill this gap in the literature.

As researchers, we have many years of experience teaching undergraduate and graduate students in Biology. We are very passionate about improving undergraduate education and have worked toward this end by incorporating active learning in the classroom and involving students in more authentic experiences, such as research and outreach. About 4 years ago, we developed NE STEM 4U in order to benefit the community as well as our undergraduates. We have designed our research to evaluate the outreach program to determine how our undergraduate mentors perceive this experience.

If we find in our research that mentoring is not benefitting our mentors, we want to make adjustments in the program so the undergraduate mentors benefit from investing their time.

Purpose

The purpose of this study is to better understand how undergraduate mentors reflect upon their mentoring experiences in the long term; in particular, in light of their current knowledge and experiences 3 years post mentoring, how do these former mentors view their experience? This study is unique because we describe this viewpoint using the lens of the former mentors' current experiences (i.e. graduate/professional school or career); notably, this longitudinal perspective of mentoring is greatly lacking in the current literature.

In order to better understand this phenomenon, the current study employs the Experiential Learning Theory (ELT) as the theoretical framework. ELT defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). We also employ Vygotsky's Zone of Proximal Development Theory (Vygotsky, 1934/1986) because this mentoring/teaching relationship is known to be "transformative for both students and teachers" (Ash & Levitt, 2003, p.1). More specifically, by engaging the younger students in this way, undergraduate mentors may participate in a co-constructed zone of proximal development, in which the mentors likely learn from the students as they assist in developing the students' understanding (Ash & Levitt, 2003). Notably, both of these theories address the ideas of transformation.

In this study, we encourage previous mentors to reflect upon their experience to better understand how the former mentors view the mentoring phenomenon and if it was potentially transformative for the mentors in the long term.

This research follows the phenomenological tradition because we investigated the essence of the mentors' shared experiences in mentoring K-8 students. The objective of a phenomenological study is to engage in in-depth probing of a representative number of participants. Specifically, it follows the descriptive phenomenological tradition described by Husserl (1913/1983), because the overall goal is to describe the lived experiences of the mentors in light of their current experiences. As Husserl (1970) expressed regarding phenomenology, we want to not only understand the experience of the mentors but also their perceptions of the mentoring experience, by encouraging them to focus and reflect back upon that experience.

Therefore, the central question of this study is: **After being in a career or professional/graduate school for 3 years post-mentoring, how do former UNO undergraduate mentors describe and reflect upon their experiences of mentoring K-8 students in an after school STEM program?**

Methods

The authors of this study interviewed the NE STEM 4U mentors who completed their mentoring 3 years ago and are currently either in a career or continued schooling (n=7). We selected these mentors because they provide a unique, longitudinal perspective of individuals who experienced the same phenomenon (mentoring) and can now reflect back upon their mentoring experiences after working in a career or graduate/professional

school for at least 3 years. Sanders (1982) suggested that sufficient information might be collected from three to six individuals, while Creswell (1998) proposed long interviews with up to 10 people is appropriate for a phenomenological study.

Data Collection

Semi-structured interviews guided by open-ended questions were conducted with former mentors from NE STEM 4U in the fall of 2016. The interviews followed the phenomenological tradition, which requires long, informal, flexible and interactive sessions in order to collect “rich, vital, substantive descriptions of a phenomenon” (Moustakas, 1994, p. 116). Utilizing this open-ended format allowed the researcher to follow cues given by the interviewee. In order to prepare for the interviews, the interviewer followed the principles set out by McNamara (2009), namely: 1.) choose a setting with little distraction; 2.) explain the purpose of the interview; 3.) address confidentiality; 4.) explain the interview format; 5.) indicate typical interview length; 6.) tell interviewees how to contact the interviewer if desired; 7.) ask if the interviewee has any questions before beginning the interview; and 8.) don't rely on memory to recall their answers.

Additionally the interviewer was not involved in NE STEM 4U at the time the interviewees participated as mentors, nor has the interviewer participated in the program as a mentor at any time. This was intentional to encourage the interviewees to be honest and open about their responses as well as to ensure that the interviewer would not convey bias or preconceptions into the data collection or analysis processes.

Upon graduation from the NE STEM 4U program at UNO, NE STEM 4U mentors were asked if they would give consent to be contacted up to five years post-mentoring to participate in follow-up studies. Only those who voluntarily gave consent were contacted for the current study (n=7). Additionally, prior to the start of the interviews, informed consent forms were emailed to all participants. At the beginning of the interview, the interviewer asked for permission to record the interview and interviewees were told that a pseudonym would be assigned to ensure their personal information would be kept confidential. All methods, data collection, analysis, as well as data management and storage, described herein, are covered under the approval #548-12-EX from the University of Nebraska Medical Center/University of Nebraska at Omaha Institutional Review Board.

The interviews lasted approximately 30 minutes and started with some general discussion of the interviewee's current career/professional school to help create the full picture of the interviewees, to establish rapport (Smith, Flowers, & Larkin, 2010) and to make them comfortable with the conversation (Creswell, 2007). Additionally, the researcher encouraged the interviewees to think back to the period when they were mentoring in NE STEM 4U in order to return the former mentors to the time of the event and restore the emotions and feelings they experienced, as suggested by Moustakas (1994). Of the seven interviews conducted, four were conducted over the telephone and three were conducted in person. All interviews were recorded and transcribed verbatim. Member checking was completed as participants were sent interview transcripts for review and corroboration of accuracy. The general interview questions/prompts were:

- After you graduated from UNO, what did you do in terms of employment or continued schooling?
- Are you currently employed or in graduate/professional school? Please provide detail.
- Reflect back and describe your mentoring experience in NE STEM 4U.
- What does mentoring mean to you?
- What contexts/situations affected your experiences of mentoring?

As a former mentor, when you reflect back upon your mentoring experience:

- What, if anything, do you feel you gained? Why?
- What was the most difficult aspect of mentoring? Why?
- In hindsight, did the mentoring experience influence what you are doing now – why or why not?

However, as is common for the semi-structured interview, additional probes were used at some points or, alternatively, if the interview was flowing well without additional prompts, the interviewer, “made a short note of key words/topics the participant referred to” for follow up (Smith, Flowers, & Larkin, 2009, p. 65). In general, the interviews were flexible and open, which according to Koch (1996), allows the interview process to stay as close to the lived experience as possible.

Data Analysis

In the current study, the researchers used the modified Stevick-Colaizzi-Keen method of analysis (SCK) originally modified by Moustakas (1994) and later simplified by Creswell (2013). Before conducting the interviews, the researcher participated in self-reflection and Epoche to be unbiased and set aside prejudgment (Giorgi, 1997;

Moustakas, 1994). The researcher's experiences were bracketed to ensure those experiences or preconceptions would be reduced as much as possible, precluding influence on the study or interpretation of the phenomenon (Chan, Fung, & Chien, 2013). This was done, as described by Moustakas and others, by repeated rounds of reflection upon any preconceptions or prejudgments the researchers may have had. These prejudgments were written out and reviewed until the researchers felt "an internal sense of closure" was achieved (Moustakas, p. 89, 1994; Colazzi, 1978).

After transcription, the researchers read over the interviews many times and utilized NVivo 11.4 to assist in data analysis, beginning by horizontalizing the interviews into preliminary groupings, listing every quote relevant to the experience. In other words, when the interviewees mentioned an idea, these ideas were collected as codes, or horizons, according to Moustakas (1994), using *in vivo* coding wherever possible. Once this was completed, codes were evaluated for redundancy and overlap and, for the coded text (invariant constituents) that remained, two questions were asked: 1.) Does the text contain relevant information from the actual lived experience; and 2.) Can the text be identified and labeled? Any text that was deemed irrelevant, repetitive or vague was eliminated. From the text that remained, themes were generated utilizing *in vivo* terms as much as possible. The themes were used by the researchers to generate, "a textural description of the experience - what happened" (Creswell, 2013, p. 193). The overall themes that emerged were then compared with the complete interview of each participant to validate that the themes were consistent with the interview. The textural descriptions were considered in light of the context in which the phenomenon occurred to provide a "structural description" or meaning of these descriptions (Creswell, 2013, p. 194). In

other words, we describe two elements for each assertion, the descriptions or themes that emerged from the interviews (textural descriptions) and the meaning of these descriptions (structural descriptions). Taken together, these descriptions were used to describe the essence of the phenomenon (Creswell, 2007).

Validity of the data was determined using participant review and peer review. Participants were asked to review the transcripts and the findings, to ensure their experiences were accurately represented. This respondent validation increases the credibility and validity of the study (Creswell, 1998). Additionally, peers and a qualitative analysis faculty member from the University of Nebraska, Lincoln, who were not involved in the study, reviewed the data analysis to ensure the phenomenological process was accurately followed and researcher bias was minimized (Creswell, 2007).

Results & Discussion

To begin the interviews, former mentors were asked to describe what they were currently pursuing as a career or continued schooling. Of the seven mentors interviewed, five were in a STEM-related professional/graduate school and two were pursuing a career in a STEM field.

All of the interviewees very positively remembered their mentoring experiences in NE STEM 4U. As they reflected back upon their experiences in light of what they currently know and have experienced, three major themes emerged: **career, inspiration, and challenges**. These themes were subsequently broken down into sub-themes based on the interviews. The breakdown of the themes can be seen in Figure 1.

The first major theme related to **career skills** gained from the experience. We have broken this down into two categories: i.) *indirect career skills gained*, meaning the skills are so-called 21st century skills (i.e. communication, problem solving, team work, critical thinking, organization and planning) that could potentially benefit the former mentor in their career or other areas, and ii.) *direct career skills gained*, meaning participating in mentoring in NE STEM 4U directly helped them achieve where they are today, in terms of potentially being notable on their resume, during their interview, or directly influencing their career trajectory.

Below are some quotes from former mentors regarding **indirect career skills gained**:

Communication-

Explaining scientific concepts to kids can – it's not always the easiest thing to do. So it's something you kinda have to work at, and I kind of have had the same experience talking to patients, explaining something kind of complicated and turning it into terms that are understandable and that are manageable.

This quote directly correlates the skill of communicating complex concepts to mentees to communicating complex concepts to patients in the mentor's career trajectory.

Communication and problem solving/critical thinking-

So to put people who are not necessarily thinking like teachers, to put them in that role, it's like if you explain something one time and you can see deer in the headlights out in the classroom, you have to kind of re-engineer how you're going to communicate that information. So I feel like it was – I think it was good in that regard, you know, communication being huge.

By using terms such as “re-engineer and communication,” this suggests that the mentor realized that teaching lead to critical thinking in order to solve the problem of better communication to his/her audience.

Critical thinking & problem solving-

I think it impacted my critical thinking, but sort of in a nontraditional way that you think of critical thinking. I think it is sort of, like, critical thinking and problem solving hand-in-hand. I can remember a few times where we were talking about something that was pretty difficult, so whether it was DNA and replication or something like that, a pretty complex process, and I just remember a few times having the kids just look at me and be like, ‘We have zero clue what you're talking about right now.’ So, being able to, in that moment, think of a different way to be able to present it to them that was more relatable to their life and more relatable to how they think about things, I think, enhanced those skills in myself because it was constantly forcing me to think of different ways to present material that seems so trivial to me because it's something that I've been thinking about for a decade.

This mentor also acknowledges that, as a mentor, even though he felt very confident in his content knowledge, he had to be aware the mentees did not have the same knowledge/experiences and had to restructure how the material was presented for different audiences.

Organization, teamwork, planning, and critical thinking-

I think if you were somewhat disorganized, it definitely would help kind of help you collect your thoughts, make sure that you're on the same page with people

that you're mentoring with, and just working with the kids and making sure that – the worst thing to happen is to go to a school and you have absolutely no idea what's going on as far as what that lesson is today – that day, and it was an exercise in, you know, the night before or earlier that afternoon, looking up that lesson, kind of, ‘Okay, I can explain this and this way,’ or, ‘Oh, I really like that way of explaining it,’ and kind of tweaking – reversing the lesson in your head, kinda helping organize your thoughts a little bit before you go was – mandatory for me. I mean, some people, I'm sure they can jump right into it and do just fine, but for me, I had to rehearse a little bit in my head. I'm like, ‘Okay, this is how I'm probably gonna do this.’

Here the mentor talks about evaluating her own thoughts and presentation style in addition to being organized and prepared as a team.

Team work & planning -

“Just anytime I'm working with a team of students with different backgrounds - interpersonal skills and teamwork and task allocation, those things all apply.”

Another student commented,

It always seems that no matter how many teams you work on, every single one of them is different and the contributions by members are always different, and so sometimes it's very easy to be on a team and sometimes you certainly think that being on a team is a detriment and you have to figure out how to make it work.

These mentors refer to how every team of mentors is composed of different, unique individuals; each with their own skills, so to be successful there must be some awareness and planning/structuring of the team around those strengths (and likely weaknesses).

Furthermore, several of the former mentors found that mentoring had a **direct application to career**; below are a few quotes from the former mentors related to this gain:

Career choice-

I think that it also helped me realize that research wasn't necessarily where I wanted to be, that training or education is more of where I wanted to be, and so I think that it really opened my eyes to a variety of career opportunities that involved more of training or education side of science as opposed to just the bench work and the lab work.

This mentor discovered, through the mentoring experience, that she did not want to follow the basic science research path, but rather found a passion for education and training.

Application/Interview-

I've kind of had focused on going to PA school for quite a while at – when I started NE STEM, so that was pretty set, but what I noticed on my interviews for school – and I got – I was accepted to a few PA schools, but they really liked to – they didn't really like to talk about my biochemistry grade. They didn't really want to talk about, necessarily, my – yes, about my patient care experience before school, but they were interested in what I did outside the classroom, and having NE STEM as something on my application – I mean, not that I did NE STEM for

an application booster alone or anything like that, but it was nice conversation piece for an interview and it was brought up at every single school interview I had. They said, ‘Oh, tell me a little about this. We're not exactly sure what this is.’

Interview-

I think that having that sort of type of skill or the ability to say that you mentored kids in the sciences, I think in my job now, specifically, it probably helped because they realized that if I could break it down to that content level and context for seventh-graders, I could probably do it for people of any variety of skill levels. So I think that it probably helped in that way directly.

Both of these former mentors note direct career gains from the mentoring experience related to the application and/or interview for professional school or career.

STEM content knowledge (direct), communication and preparation (indirect)-

When you explain something to somebody else, you have to know it at such a deeper level than what you would normally – so even doing NE STEM 4U, where even – I mean, they're pretty basic scientific concepts, you know? And I graduated UNO with a science degree, but it was even helpful for me to really dig in deep on a particular topic and really investigate it and kind of anticipate questions that kids might have. But you solidified concepts when you had to explain them.

When this former mentor reflects upon “knowing” at a deeper level, this relates to having a robust understanding of content. This directly corresponds to preparation as well, because the interviewee expressed that he had to “dig deep on a particular topic” in

anticipation of questions. Furthermore, it was also noted then that explaining (communicating) was an important part of the mentoring experience.

Additionally, five of the former seven mentors interviewed also spoke about inspiration, which is the second theme that emerged. Related to inspiration, former mentors either reflected upon how the faculty mentors inspired them and/or how the idea of inspiring the younger students was one of the most rewarding and memorable aspects of the mentoring experience. Below are a few quotes related to **inspiration**:

Faculty to mentors-

The big thing I remember when I look back on my time here was actually just working with Dr. X personally. She's a good influence. She's a really hard worker. She'd accomplished a lot and she was someone to look up to."

Another student noted,

On campus when you find a professor that is passionate about their work and knowledgeable and you appreciate that, I don't know how everyone else is, but that means a lot to me. It still does when I'm sitting in lectures now when I see people that are devoted to their work and they're studying their pursuit. That pushes me forward.

Both of these former mentors directly reflect upon being inspired by a faculty member while working in the mentoring program.

Mentors to students-

"You can catch a couple of them. Not all of them are interested, but you catch a couple of them going through that experience that I went through and that's where the personal rewards are."

Another student mentioned,

While I was in it, I didn't necessarily understand the full impact that it would have on the community, and I think stepping back from it and really thinking about even just a few of the kids who came every day and enjoyed it every single week, I think that I fully understand now that even if it's – even if I had an impact on only one student, that is something greater than I could've possibly thought would happen, and especially being a woman in the sciences, being able to effect change in seventh grade girls' mindsets about science is a pretty awesome feeling to have, and so I think that at the time, I certainly didn't understand the impact that a program like NE STEM could have on a community, and going to other places where there are lack of afterschool programs that are directed towards the STEM field, I think that it's something that's certainly important.

These former mentors shared strong reflections about feeling rewarded because they inspired the mentees.

The final theme that emerged was **challenges** that the former mentors experienced while mentoring. These related to the students themselves and function of the program (i.e. cancellation of program by the school, extra students added that week, etc.) or time, meaning the time constraints that the mentors felt.

Below is a quote related to the **challenges** one mentor felt. A similar theme was recorded for all seven interviewees:

I think that for me, I'd say that 80 percent of my experience was really, really great in that I had kids in my lessons who were attentive and who cared and who were interested, but then I also spent some times in some schools where it was a

lot harder to maintain attention and just to maintain your student interest in those classrooms, so those times often made it difficult – [laughs] – because, you know I think that I went into it really wanting to make an impact, and to not see that play out in those times was pretty difficult.

This quote indicates that the mentor reflected upon the experience positively, but remembered feeling frustrated by disruptive or uninterested students.

“The negative for me is the time commitment, I was very strained because I was finishing my UG education. It is manageable though.”

Another common sub-theme related to challenges in the program was the issue of time. Several mentors mentioned that they would have liked to do more, in terms of being more involved in the research or lesson planning, for example, but that they were unable to commit additional time.

This study differed from previous research on mentoring from the mentor’s perspective by: (1) taking a phenomenological approach, and (2) utilizing a longitudinal, 3-year, post-mentoring perspective. In this study, the emphasis was on understanding and describing the lived experiences of these individuals; notably, using the lens of their current experience (i.e. career or graduate school). The overarching question of this study was, after being in a career or professional/graduate school for 3 years post-mentoring, how do former undergraduate mentors at UNO describe and reflect upon their experiences of mentoring K-8 students in an after school STEM program?

In this study, all interviewees provided thoughtful and insightful answers to the questions posed and seemed to genuinely reflect upon their experiences with NE STEM 4U in an overwhelmingly positive tone. This may not be surprising, as much prior

research suggests that mentoring positively impacts mentors; however, while many studies claim that mentoring benefits mentors in terms of career preparedness, communication, problem solving abilities, among other skills, to our knowledge, no other studies have followed up with the mentors to determine if these benefits were actualized several years post-graduation.

In the current study, former mentors reported that mentoring led to direct and indirect career gains (Figure 1). Likewise 5 of the 7 former mentors interviewed expressed some component of inspiration related to their experience, either from faculty to themselves or from themselves to the K-8 youth they were mentoring. Lastly, while reflecting upon their mentoring experience, all mentors also noted challenges brought about by mentoring, related either to the mentees and programmatic challenges or the challenge of time constraints.

While these results are specific to this study and may not be broadly applicable, this study is unique due to its longitudinal nature and may serve as further evidence of the benefits of mentoring for the mentors themselves. It also serves as an expansion of our current knowledge of the impact of mentoring on mentors, as opposed to the often-cited impact of mentoring on mentees. Finally, it may also provide awareness for the challenges mentors express in such programs so that these potential challenges can be mitigated or made known upfront.

Limitations

Hermeneutic considerations for this project include the personality types of participants. Specifically, while the description of realm of being through reflected

experience (Husserl, 1970; Lavery 2003; Valle, King, & Halling, 1989), and the subsequent impact on current ventures, were our desired outcomes, we need to admonish the fact that not all individuals will perceive such interventions in an impactful way to then subsequently report on them. While we designed the interview questions (listed in the methodology) to minimize such limitations on perceived beliefs (Osborne, 1994), and lead to positive, genuine communication (Gadamer, 1960/1998) and the cultivation of impact on the individual, limitations still exist in terms of individual reporting, as well as the potential for misinterpretation by researchers. To help alleviate that limitation, we provided much of the raw responses herein, and asked for outside viewpoints from other researchers to further validate that our interpretation of the data was accurate.

Moreover, we recognize that memory distortions and/or lapses could occur during the window of this longitudinal study. To address these limitations, we designed interview questions such as “reflect back...what contexts/situations affected your experiences of mentoring” to deploy exemplary intuition to have the individual reflect and hold an idea in his/her mind, and then elaborate on it (Klein and Westcott, 1994; Lavery, 2003). Therefore, we acknowledge these limitations from this study, as well as the relatively small sample size, as being the most profound weaknesses (with subsequent methods attempted to minimize the pitfalls).

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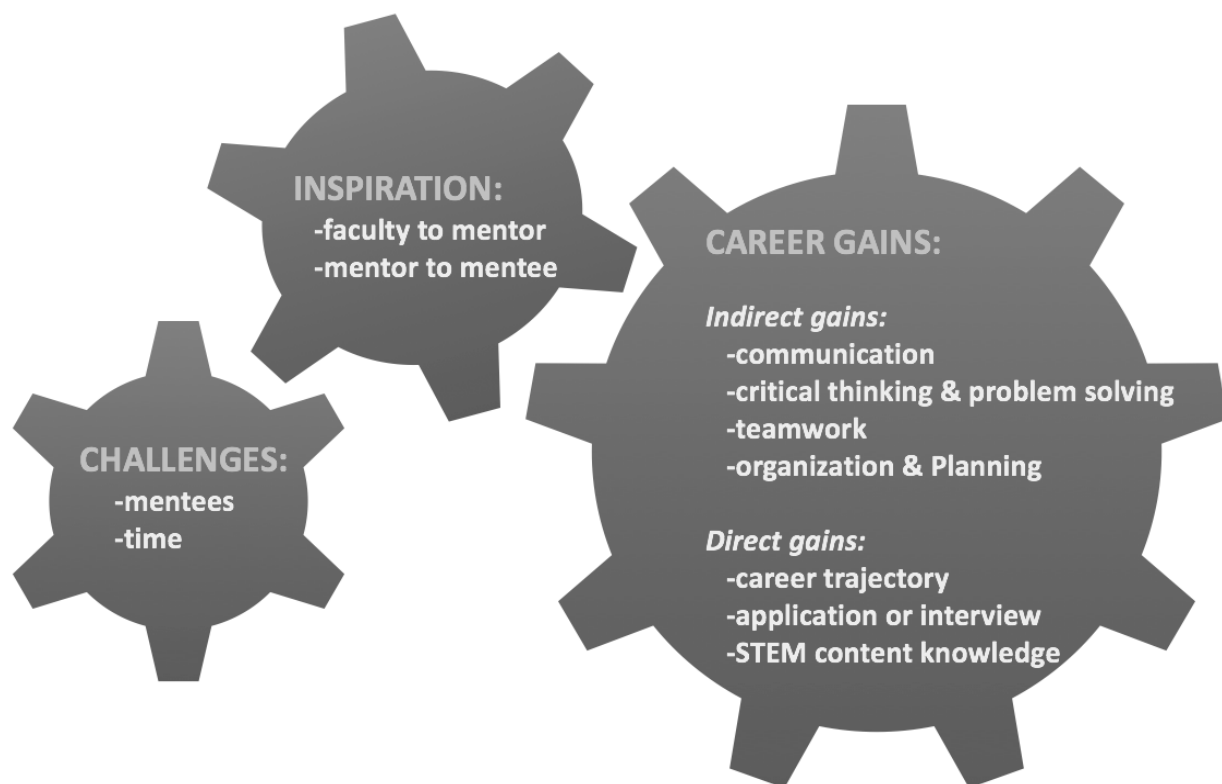


Figure 1. Three themes, career, inspiration and challenges as well as sub-themes that emerged from analysis of data.