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# Life's Lessons in the Lab: A Summer of Learning from Undergraduate Research Experiences

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## Abstract

Research experiences for undergraduates (REUs) seek to increase the participating students' knowledge and perceptions of scientific research through engagement in laboratory research and related activities. Various REU outcomes have been investigated, including influence on participants' content knowledge, career plans, and general perceptions of their domains of research. The complexity of REUs and dynamic nature of student development provide opportunity for exploring how REUs influence student growth. Our research focused on first- and second-year college students who participated in a residential REU program that took place in a chemistry department in a metropolitan university in the western United States. We assessed the standard REU outcomes and sought to document the emotions the students experienced through their participation. In addition, we used the developmental framework of self-authorship (Baxter-Magolda, 2004) as a lens to investigate the participants' professional identity development. Our mixed methods research revealed shifts in the participants' perceptions of science, increases in their knowledge of chemistry, and clarity in their career trajectories. We also found that the REU participants experienced profound levels of professional identity growth and used a number of affective terms, such as confidence, persistence, patience, and enjoyment, to describe their experience. Interpretations and implications are discussed.

## Introduction

Undergraduate research (UR) experiences have become widely adopted based on evidence indicating that the experiences enhance students' knowledge of research, domain-related content and process knowledge, and persistence in the associated careers (Landrum & Nelson, 2002; Russell, Hancock, & McCullough, 2007: Yaffe, Bender, & Sechrest, 2014). The recognized benefits of UR experiences have led to the development and support of research experiences for undergraduates (REUs) by organizations such as the National Science Foundation (NSF, 2012) and the National Institute of Health (NIH, 2011).

The successes and complexity of UR experiences (Kardash, 2000; Linn, Palmer, Baranger, Gerard, & Stone, 2015; Lopatto, 2003; Seymour, Hunter, Laursen, & DeAntoni, 2004) provide justification for the ongoing exploration of UR configurations and outcomes, and using the evidence to expand the number, effectiveness, and diversity of opportunities for students to gain exposure to and experience with scientific research. It is common for UR programs to be the focus of research and evaluation (Taraban & Blanton, 2008), which typically involves measurement of variables such as participant expectations, learning, and interactions with mentors (Eagan, Hurtado, Chang, Garcia, Herrera, & Garibay, 2013; Lopatto, 2004; Pedwell, Green, Lawrie, Myatt, Wang, et al., 2014). Other investigations of UR experiences have explored alternative variables and facets of REUs such as cultural influences and gender differences (Henne et al., 2008; Kardash, Wallace, & Blockus, 2008). Similar to the work of Hunter and colleagues (2007), we examine how the REU influenced the participating students' professional identity. In contrast to Hunter et al. (2007), our research participants came to the university from across the nation, they were first or second year students, typically first generation college students, residents on campus during their ten-week summer experience, and all were engaged in chemistry research.

We collected diverse empirical data to expose evidence of the participating students' shifts in knowledge of chemistry, understanding of the nature of science, their levels of identity as science, technology, engineering, or mathematics (STEM) professionals, and their feelings associated with their UR experience. Specifically, we were interested in what the students learned about themselves as researchers, their development as STEM professionals, and how their experience influenced their long-term education and professional goals. Similar to the work of Hunter et al. (2007), our report documents the substantial influence of the REU on the participating students' affective or emotional perceptions of scientific research and the association between their feelings and their identity development as STEM professionals.

## Research Experiences for Undergraduates

Undergraduate research experiences have been used as a method for increasing students' knowledge of the associated domain methods and content and as an approach for increasing student interest in and preparation for careers in a range of STEM fields (Kardash, 2000; Lopatto, 2004; Seymour, Hunter, Laursen, & DeAntoni, 2004; Wei & Woodin, 2011). Although REUs can take place in a range of disciplines, such programs have been particularly common in the STEM disciplines (NSF, 2013). Through participation in REUs based in the sciences, students gain experience with scientific methodologies, domain-associated practices, related content knowledge, and increased understanding of science concepts, while becoming formally introduced to scientific research as a profession (Hunter, Laursen, & Seymour, 2006). Thus, REUs extend the standard undergraduate curriculum by providing contexts that are conducive for enhancing student capacity and interest in scientific research, understanding of science, and knowledge of the work of scientists.

REUs have traditionally been typified by pairing a student with a faculty researcher for a one-to-one research experience that takes place outside of the standard curriculum (Lopatto, 2004); however, variations in the structure and foci of undergraduate research have been explored (Adedokun, Parker, Childress, Burgess, Adams, et al., 2014; Hakim, 1998; Kardash, 2000; Millspaugh & Millenbah, 2004; Nadelson, Walters, & Waterman, 2010). Customarily, a participating undergraduate student becomes involved in the research of a sponsoring faculty member, joining a research team to work on some aspect of the mentor faculty member's ongoing research agenda. Thus, students participating in REUs may take responsibility for some facet of a larger study, including searching the relevant extent literature, developing and exploring new methods, interpreting data, sharing results at professional conferences, drafting manuscripts for publication detailing some element of the research, and sharing findings at professional meetings (Burnley, Evans, & Jarrett, 2002). The REU program we studied followed a similar structure.

We contend that student assumption of the responsibility for developing, conducting, and reporting on an aspect of a larger research project may lead

participating students to perceive REUs to be high-stake endeavors. When exposed to high stakes learning situations, many students may experience deep emotions or a broad range of feelings (Ryan, Ryan, Arbuthnot, & Samuels, 2007). The likelihood of emotions associated with high stakes situations may motivate students to put forth more effort to assure success and positive feelings of comfort and satisfaction, rather than the negative emotions associated with failure, such as shame or sadness (Zimmerman & Dibenedetto, 2008). We argue that the perceived high stakes nature of REUs by the participating students may trigger an array of emotions related to the experience, prompting them to higher levels of engagement, initiative, and attention to detail, provoked by both mastery and performance goal orientation (Linnenbrink & Pintrick, 2002). We argue that increased engagement, initiative, and attention to detail are more likely to allow students to have successful experiences as scientists. We speculate that REU conditions allow students to experience success as scientists and foster a mastery goal orientation, which in turn increases the potential for REUs to positively influence students' development of an identity of themselves as professional scientists.

Investigations of REU experiences report a range of beneficial outcomes for those students involved (Lopatto, 2003; Russell, Hancock, & McCullough, 2007; Seymour, Hunter, Laursen, & DeAntoni, 2004). Additional reports suggest that REUs increase participants' interest and knowledge of scientific research and motivation to pursue scientific careers (Lopatto, 2007). However, it is widely recognized that many students engaging in REUs are already motivated to become involved in these activities and are predisposed to interest in science careers (Lopatto, 2007). The interplay between the characteristics and abilities that students bring to their REUs and the influence of the REUs on student development is complex and warrants ongoing investigation, particularly given the dynamic nature of research and student development. Thus, beyond the standard variables assessed in REUs, there continue to be aspects of the programs that surface and new lenses through which the programs are viewed that justify ongoing investigation of REUs' influence on students.

## REUs and Domain Knowledge

One of the anticipated benefits of REUs is an increase in the participants' content knowledge associated with the domain in which research is taking place (Hay & Barb, 2001). The rationale for the anticipated increase in knowledge is based on the perception that when students actually engage in the discipline-based research, they gain a deeper understanding of the discipline. Using a constructivist framework, REUs provide students with the opportunity to build on their prior knowledge to develop new and deeper understanding of domain-related professions in ways that are not afforded in the standard undergraduate curriculum (Matthews, 1998). Thus, REU experiences provide opportunities for high levels of engagement for students in situations correlated to experience in the professions of domains. REUs also create the conditions that require students to purposefully and strategically apply content knowledge from their coursework. We posit that the combination of engagement in STEM profession activities and the application of content knowledge is likely to lead to the development of greater understanding of concepts and the professional norms within a domain. Understanding the content and professional norms are fundamental to developing professional identity.

Further supporting the anticipation of increased gains in content knowledge and professional identity is the impact that learning in context or in situation can have on transfer and retention of knowledge (Greeno, Moore, & Smith, 1993). Due to the contextual nature of the learning in REUs, it is anticipated that students will gain deep understanding of content, procedural and professional knowledge, and will develop a higher capacity to apply the content in future situations which is fundamental to being able to relate to the situations and conditions within the profession (Hunter, Laursen, & Seymour, 2007).

These anticipated gains in domain knowledge are held by both students and faculty. As Lopatto (2003) reports, faculty have expectations that student engagement in REUs will afford opportunities for them to apply their content knowledge. Surveys of students designed to determine the most beneficial outcomes from engagement in undergraduate research experiences revealed "learning a topic in depth" to be in the top ten (Lopatto, 2003).

We assert that student professional identity development is associated with their domain knowledge. Thus, when researching REUs, there is justification for examining the influence of the experience on the participating students' content knowledge, how they approach both using prior knowledge for learning and how they approach acquiring new knowledge.

## REUs and Professional Identity

When examining students' professional identity growth, it is beneficial to use a framework that can effectively describe program influences on students' perceptions of themselves as professionals. We have selected Baxter Magolda's (2004) self-authorship framework to guide our investigation of REU influences on the participating students' professional identity development. The self-authorship framework has been used in prior research on REUs (Hunter, et al. 2007). Self-authorship has been used primarily to explore and explain personal identity development. However, we find that the structure of the self-authorship framework lends itself well to examining and explaining students' professional identity development.

The self-authorship framework (Baxter Magolda, 2004) is a developmental model that suggests that as students advance in their education, they transgress from using external references or cues as indicators of their identity to the use of internal references in their identity expression. Thus, we anticipate that students in early stages of professional development use external cues, such as course-work grades, academic major, finishing a degree, comments and approval by faculty members, or other institutionally-based elements, as references when sharing their professional identity. We would also expect a higher prevalence of performance goal orientation of these students (Linnenbrink & Pintrick, 2002). Similarly, we would expect students who are in more advanced stages of professional identity development, who have developed greater levels of professional self-authorship, to communicate their professional identity using more internal references, such as interest, self-reliance, motivation, self-confidence, eagerness, a sense of responsibility, collaboration, and a desire to share their knowledge. We posit that students with more advanced professional identity are also more likely to have a mastery goal orientation.

Self-authorship development is catalyzed by experience, interactions with others, mentoring, and context (Baxter Magolda, 2004). According to Baxter Magolda (2004) self-authorship develops as people successfully negotiate situations of responsibility, effectively solve complex problems, have positive interactions with diverse populations, and become comfortable with conditions of uncertainty and ambiguity. REUs, by nature, can effectively afford the conditions necessary to promote self-authorship, although the actual influence on particular students is both contextual and individualized (Hunter, Laursen, & Seymour, 2007; Ing, Fung, & Kisailus, 2013). The references that REU participants use to communicate their professional identity are indicators of their level of self-authorship development, and signify the level to which students have internalized their professional identity.

Thus, the language and references students use to describe themselves as professionals are key indicators of their level of professional identity development. We contend that, when examining data for the impact of REUs on the participants, it is useful to seek data that includes students' responses that can be used to determine influence on their self –authorship development and the associated professional identity development.

## REUs and Emotional Engagement

The association between experience and emotions (affective variables) can be powerful and influential on student development and achievement (Krumrei-Mancuso, Newton, Kim, & Wilcox, 2013; Pekrun, Goetz, Titz, & Perry, 2002). Lapatto (2003) recognizes the

importance of providing emotional support in research experiences as he indicates that REUs should be structured to ". . . contribute to the emotional and social needs of the student" (p. 140). We speculate that the importance of attending to the emotions of students engaged in REUs is the potential association with student competency development.

We embrace Epstein and Hundert's (2002) definition of competence, which they define as "the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values and reflection in daily practice for the benefit of the individual and community served" (p. 226). This definition of competency, which includes the use of emotions, suggests students are likely to develop competency through engagement in REU experiences (Seymour, Hunter, Laursen, & DeAntoni, 2004).

We contend that association between emotional states and competency development (Epstein & Hundert, 2002) provide rationale for attending to and fostering positive emotional states during students' REU experiences. The expectations that REU experiences will build participant competence suggests that participants' emotions are likely to be influenced by and influential on their UR experiences, which provides warrant for assessing the emotions that students associate with their REU experiences. The influence of emotions tends not to be considered in models of REU influences and variable interactions (Brew, 2013).

In addition to competency, emotions are likely to be linked to other professional behaviors such as self-efficacy (Kavanagh & Bower, 1985), autonomy (Patrick, Skinner, & Connell, 1993), self-determination (Deci & Ryan, 2000), and tenacity (Hartley, 2011). For example, confidence and self-esteem are likely to influence self-efficacy behaviors, satisfaction and comfort may influence acting autonomously, patience and fondness may influence self-determination, and enjoyment and enthusiasm may influence tenacity and persistence (Adedokun, Bessenbacher, Parker, Kirkham, Burgess, 2013). The documented association between emotions and an array of professional behaviors suggest that there is additional justification for investigating the emotions students associate with their engagement in REUs, particularly with regard to professional identity development.

## Methods

The goal of our research was to determine what influences an REU had on the participating students. Specifically, we sought to uncover evidence that the REUs influenced the participants' professional identity development and their understanding of themselves as STEM professionals. We used the following questions to guide our research:

- *What did the participants indicate that they learned about science based on their research experience?*
- *How did the participants perceive their research experience influenced their consideration of research science as a career?*
- *What did the participants share to indicate that the research experience enhanced their development of their identity as a professional?*
- *What emotions did the participants voice in relation to their research experience?*
- *How did the participants approach learning new content or complex concepts?*

### Participants

The participants in our study were the 10 students engaged in a 10-week-long externally funded research experience for undergraduates program in a chemistry department. There were 6 females and 4 males, of average age of 21.4 years. One of the participants was a freshman, 5 were sophomores, and 4 were juniors. Seven of the participants were Caucasian, 2 were Hispanic, and 1 was Pacific Islander. Chemistry or biochemistry was the major for 8 of the students, with 1 majoring in biology and 1 in pre-engineering. The majority of the participants indicated that they had plans to attend graduate school to study chemistry or biochemistry, with the remaining sharing botany, medical school, and materials science as their primary intended direction for continued study. Half of the participants were returning for a second summer of UR and were expected to act as peer mentors to the others in their first year of the REU program. Our research on the impact of the mentoring structure in this REU is ongoing and will be reported in a future article.

### Procedure

REU structure. The National Science Foundation-funded research experience for undergraduate (REU) program discussed in this study was in its second year of implementation. The residential program drew applications from around the United States for the 10 summer research positions, all of which were located in the same chemistry department at a public metropolitan university in the Rocky Mountain west. With two exceptions, participants were assigned in pairs to faculty engaging in laboratory research. Placement into the research labs was based on participants' expressed interest in the sponsoring faculty's line of research, and the students assumed primary responsibility for their projects. The focus for the research was negotiated between the faculty and the undergraduate research student based on the needs and interests of both. In all instances, the students were actively mentored by their assigned faculty member, as well as by a peer mentor who was an experienced lab member from the home institution. Depending on the particular research lab, the peer mentors were either advanced undergraduate students, graduate students, or technicians. Only faculty advisors and peer mentors who were committed to proactive mentoring of the participants were included in the program.

In addition to the laboratory experiences, the chemistry REU participants met once a week to discuss and present their research. The participants also met once a week with the larger summer student research community to engage in professional development activities, such as attending seminars and taking part in small group discussions. They attended conferences, seminars, social events, and prepared a poster of their research to present at a regional research conference. The residential program was structured such that the REU participants lived on campus in the student residence halls for the duration of their summer experience.

**Data collection.** For our research we utilized a mixed methods approach to collect data, using a combination of quantitatively-based surveys (pre- and post-summer experience) and interviews. For this report we focused on the data gathered during the interviews of the participants. We will report the quantitative data after the final year of the program, which will provide us a larger sample size and, therefore, more meaningful analysis and necessary statistical power.

Our interview protocol contained questions intended to expose participants' perceptions of the REU influence on their understanding of science, professional identity development, approaches to learning and problem solving, feelings about research and science, and their general experiences in the laboratories. We prompted students with statements or questions such as, "Share with me how working in a research lab has changed or influenced your perceptions of science" and "Tell me what science you are learning" and "How has your REU experience influenced your desire to be a scientist?" Based on the participants' responses, we also asked clarifying questions to generate dialog to illuminate the influence of the REU on the students' knowledge and perceptions of science and research as well as their professional identity development. We audio recorded the interviews and transcribed them for analysis. All interviews were conducted by the same researcher and lasted between 18 and 27 minutes.

**Analysis.** We conducted a content analysis of the interviews (Miles & Huberman, 2002) using a combination of a priori and post hoc coding. Through our coding we sought to expose evidence of participant growth in understanding of science, approaches to learning and problem solving, personal development as a STEM professional, and career development, which were all aligned with our interview protocol. Thus, our a-priori coding included references to increased knowledge of science, references to identifying themselves as STEM professionals, references to thinking and problem solving, and commitment to science as a career. In our post-hoc coding process we examined the data for emergent

themes that we did not anticipate to occur based on our interview questions and research focus, such as expressions of emotions.

## Results

**Learning of science.** Our first research question asked, *What did the participants indicate that they learned about science based on their research experience?* To answer this question, we coded for indicators of increase in science content knowledge. Our content analysis revealed that all the participants indicated that they had experienced increases in their knowledge of chemistry and scientific processes related to their projects. For example, REU Participant 5 responded, "I have learned a lot about quantum mechanics and how quantum dots work, and therefore about luminescence." Similarly, REU Participant 6 revealed growth in knowledge through the statement, "… we are functionalizing gold nano rods while other students are working with just nano particles, so the difference would be the nano particle would be spherical, so it would be a simpler shape while we're trying to work on an actual rod. So it's kind of similar, yet since the surface of a rod is not the same, there are a couple of different things and it's not quite exactly the same so we can still ask questions…." This comment reflects increases in chemistry knowledge in relationship to engagement in research activities and includes the appropriate use of the associated science terminology, both of which are indicators of increases in understanding of concepts that were directly associated with their projects.

The content analysis of the participants' responses to our science learning prompt revealed students also learned more about the processes of doing science. For example, REU Participant 6 responded, "…it changes how I view how certain scientists approach the experiments that they do…" and from REU Participant 7, "I've definitely learned that there is a lot more trying that you have to do before you get the result that you can report." These statements are evidence of shifts in the participants' knowledge of science practices and Nature of Science (McComas, Clough, & Almazroa, 2002), both of which are fundamental to research, engagement as a science professional, and are anticipated to be influenced by engagement in REUs.

**Career pursuit.** Our second research question asked, *How did the participants perceive their research experience influenced their consideration of research science as a career?* To answer this question we examined the result of our coding for interest and pursuit of science as a career. Our analysis revealed engagement in the REU program led the participants to experience shifts in their consideration of research science as a career. As REU Participant 1 stated, "Well, it's made it a lot more broad for me, there's a lot more options, especially talking to a lot of the older students here and some of the post-docs, you have this idea of what it's going to be, and I had this preconceived notion of what science work was, and it's not the case." We exposed evidence that students engaging in reflection of their professional consideration did not necessarily bring clarity to their career path as is evident in this passage by REU Participant 2, "I'm not sure that I really want to become a professor, so maybe I could go into some kind of other research lab or something. Still kind of on the fence, which is a little nerve-wracking." Similarly, we found some of the participants were more eager to pursue a career in research after their experience, as made evident by this statement by REU Participant 3, "I didn't know what I wanted to do and then, after this summer, I decided that I am leaning more towards the research side."

It does appear that the nature of the experiences may have a delayed influence on the participants' career decisions and pursuit. As REU Participant 4 states, "I'm enjoying working the lab much more than I thought I would so, as far as steering me in a career, it's definitely having an influence and an impact on what my decisions will be — though they're undetermined at the moment." The previous REU participant statement makes evident that even though the students may have enjoyed the research experience, they may be left wondering what the next step is in terms of their career paths. However, the REU experience will provide them with a basis for their decisions.

Regardless of the ability of the participants to share or clarify their choice of a career path, their responses make apparent the REU influence on the participants and the high likelihood that the experience provided guidance for career decisions. Although the REU may not have resulted in students specifically choosing scientific research as a career path, it certainly expanded the participants' experiences and knowledge in multiple directions, providing an expanded foundation upon which they could base career decisions.

**Development as professionals.** Our third research question asked, *What did the participants share to indicate that the research experience enhanced their development of their identity as a professional?* To answer this question we examined the results of our coding corresponding to participant development as professionals, particularly associations of the participants identifying themselves as scientists and their contribution to the larger scientific community.

In response to the question regarding the impact of the REU on their development as a scientist, all participants indicated that the experience influenced their development as a STEM professional. The participants shared that they had become more self-reliant or self-directed learners, arguably fundamental indicators of a professional identity. For example, REU Participant 8 shared, "If it's not working quite the way I want it to, sometimes I'll go in on Sci-Finder or something to see if there's a better way to do it." Similarly, from REU Participant 2, "I Googled a lot because I did not understand [the paper]." The increase in participant self-reliance for seeking information is an indicator that the REU afforded the conditions that fostered student engagement in behaviors that are associated with professionals.

A second indicator of development as a professional that we exposed was increased self-confidence in work among the REU participants. As REU Participant 8 shared, "I've been able to pick out what things might be going wrong a little bit better, and I am beginning to realize that maybe I don't know as little about chemistry as I thought I did. So, it's bringing my confidence up." The participants' increase in confidence suggests that the experience fostered greater identification and comfort with being a researcher and working in the lab. Again, the participants shared experiences that included references to behaviors that are typically associated with the work and habits of professionals. Further, the students frequently used internal references when sharing their development as professionals, which indicates that they had transgressed from external cues of identity to a more self-authored perspective.

A third indicator that we exposed was a desire for or engagement in sharing their summer research work and knowledge with others outside of the REU program. Several of the REU students indicated that they wanted to or had already planned to share their research with students and faculty at their home institutions and with the larger community through posters or presentations at professional conferences. Many of the participants had responses similar to REU Participant 5, who stated, "I did all the work, I'd like to talk to someone about it." The desire to share knowledge gained from research is an activity at the core of scientific research and is considered to be a key practice of science professionals. The participants' responses indicate that they understood the professional responsibility of engaging in opportunities to share research processes and findings. Some of the participants provided more detailed plans for sharing their research as reflected in the comment of REU Participant 4, who stated, "I know I'll do a seminar as far as what I've learned here." The plans to present information learned in the REU in a seminar, or participate in a poster session, as many students may have done during their REU experience, reflect a level of engagement indicative of roles of professionals.

The fourth indicator of professional development we exposed was reflected in the participants' sharing of a sense of belonging to the greater science and research community. As REU Participant 1 stated, "I like the dynamic of having such a close knit group and being able to communicate stuff too, I'm going to have my first poster session. I was able to see the other students do the poster session at the ACS conference and I'm excited about that." This passage reflects the participant

identifying with the university research community as well as the larger scientific community. Similarly, REU Participant 8 shared, "They never really think of me as just a summer research student, they treat me like I'm just one of their lab members." The sense of belonging to the larger community is a key indicator of the participants' professional identity development, and make apparent the conditions of the REU afforded the participants opportunities to gain a greater sense of belonging to the local and larger scientific community. The students' sense of belonging further reinforces the notion that the conditions created by the REU fosters the participants professional identity development.

**Expressions of emotions.** Our fourth research question asked, *What emotions did the participants voice in relation to their research experience?* To answer this question, we examined the coding related to the participants' expression of emotions. These emotions included, but were not limited to, confidence, frustration, patience, feeling overwhelmed, fear, satisfaction, enjoyment, and happiness. We present our findings in Table 1, listing the predominate emotions, the number of participants who explicitly expressed the emotion, and a representative passage by an REU participant sharing the emotions.

REU Participant 6 shared "What we do with the synthesis and the experiments we run process-wise are really simple and I like that, it makes it pretty simple for me, but it would be nice, I think it would be interesting and pretty engaging to learn something that has a lot of complexity to it." Similarly, REU Participant 7 shared, "...sometimes in lab because there's a pretty strict recipe or algorithm to follow and that doesn't happen in research. In research you're kind of wading through the waters trying to figure it out for yourself a lot of the time." The transition to more of a mastery goal orientation is reflective of approaches to problem solving and learning that is aligned with the work of professionals, and therefore would be indicators of the development of identity as a professional.

## Discussion and Implications

Research experiences for undergraduates have been recognized and documented as having a positive impact on undergraduate student development (Landrum & Nelson, 2002; Russell, Hancock, & McCullough, 2007). Our research examined some previously explored variables as well as some unexplored aspects of REU influence on the participating students.

Our first finding confirmed that student engagement in REUs profoundly influences their science knowledge, which is consistent with prior research (Hay & Barb, 2001;Trosset, Lopatto, & Elgin, 2008). We found all of our participants learned more about science and expressed deeper understanding of the science related to their research. We speculate that the context and nature of the REU structure created the conditions that required students to develop deep content knowledge, relying on their understanding to effectively complete research-related tasks and commitments. The context afforded by the REU engaged the students in ways of learning that are not ready attained in traditional learning environments, and therefore explains why REUs are likely to be highly effective for enhancing students' content knowledge. Similarly, we found that the students developed a deeper understanding of the processes and nature of science, which has also been documented previously (Trosset, Lopatto, & Elgin, 2008). Again, we attribute the conditions and context of the REU that require participants to effectively do the science, which in some cases included the reorganizing and/or refining of laboratory procedures to successfully complete research assignments. Thus, we posit the expected levels of responsibility and engagement in REUs provide the conditions that motivate students to develop deeper understanding of research procedures and processes and gain knowledge of the broad spectrum of work that scientists do.

Our second finding was related to increased clarity in the career trajectories of the participating students. Similar to the findings of Lopatto (2008), our data revealed that students' engagement in an REU allowed them to gain greater insight into the work of research scientists. The increase in student insight explains the influence of the REU on students' career plans. Some of the participants recognized that the high level of dedication of university faculty toward research and the time the scientists commit toward their careers may be inconsistent with the students' desired lifestyle. In other words, they thought their mentors spent a lot of time working and some of the students did not see themselves dedicating as much of their life toward their careers. Others were ready to make the commitment of time and energy toward a career as a scientist. Regardless, our research shows that REUs influence students' career plans by providing them with a basis for consideration of their career choices.

Our third finding was based on the analysis of data through the lens of self-authorship (Baxter-Magolda,

| Emotion | Number of Participants | Representative Passage by Participant |
|---|---|---|
| Confidence | 6/10 | **Participant 10:** "Confidence. I can stand up in front of a room of people and talk about my work now and not freak out before doing it." |
| Frustration | 3/10 | **Participant 8:** "I love it but there are days when I just get really frustrated with a reaction not working and I don't understand why so then things slow down and it kind of takes me off my schedule so I realized that I have to be a bit more flexible than I really like to be most times." |
| Patience | 5/10 | **Participant 5**: "I think because of the nature of the experiments I've had to become a lot more patient." |
| Overwhelmed | 3/10 | **Participant 9:** "...at first I was a little intimidated. Oh no, I don't want to mess up and then he feels like he wasted his resources on an undergraduate." |
| Fear/Apprehension | 4/10 | **Participant 1:** "So I was really nervous about being in the lab." |
| Satisfaction | 9/10 | **Participant 3:** "I understand what I have learned in class better now too because I'm seeing it for real and I really like that, that coursework was really good coming into this summer." |
| Happiness | 7/10 | **Participant 1:** "I'm going to the first, my first poster session, I was able to see the other students do the poster session at the NORM 2012 conference but I'm excited about that." |
| Enjoyment | 8/10 | **Participant 4:** "I'm enjoying working in the lab much more than I thought I would..." |

**Table 1. Emotion, Number of Participants Communicating the Emotion, and Representative Participant Passages**

2004) to expose data representative of professional identity growth. Again, we are building on the work of Seymour and colleagues (2004) and examining students early in their academic careers, in a residential REU program, and all working within the same department at the university. Our analysis revealed that the REUs required the students to be more self-reliant and self-confident, two constructs that are directly related to self-authorship and professional identity development. Further, the REU structure provided students with the opportunity to gain expert-level knowledge in the domains where they were conducting research, knowledge that they were eager to share with the greater community. We maintain that the students' development of deeper knowledge influence their perceptions of themselves as science professionals and their professional responsibility to share the information with the larger scientific community. Deeper knowledge is associated with the internalization of identity (Baxter Magolda 2002). Further, the participants indicated that they felt part of the research community they were working within, which we maintain is an indicator of membership of community and an expression of professional identity. Based on our data, we maintain that REUs promote the development of professional identity in students (self-authorship) through interactions with the mentors, the high level of responsibility to carry out a project, and through the necessity for the participants to engage in professional behaviors. Thus, REUs are likely to be effective methods for fostering and supporting student development of their professional identity, internalizing cues as evidence or indicators as they progress in their self-authorship.

Our fourth finding was related to the REU participants' emotional engagement in their research experience. It is apparent that engagement in the research experience impacted the students on an emotional level. Given the link between emotions and competency and among other aspects of professionalism, our findings suggest that REUs are likely to create the conditions that impact growth in competency, as the students shared feelings connected to their involvement in the REU that reflected self-reliance, motivation, tenacity, and independence. We attribute the perceptions of high stakes associated with the REU (e.g. students have personal responsibility for completing tasks that others are relying on) engage students emotionally, since emotions are coupled with professional competencies (Epstein & Hundert, 2002). We maintain the perceptions of high stakes by the students promoted a high level of cognitive and affective commitment to their experience, which was linked to the expectation of their performance and competency in the laboratory. Although we did not measure emotional shifts, we maintain that student engagement in the REU on an emotional level is likely to impact their professional behavior development.

The final finding was a transition of the students from a performance goal orientation to more of a mastery approach to problem solving through their involvement in the REU. We speculate that the conditions afforded by the REU allows students to became more familiar with the role of a researcher and as they begin to self-identify as science professionals they shift from a focus on completing tasks to a focus on learning with tasks as part of the process. We also posit that the mastery approach to learning further reinforces the desire to understand more about the concepts and process for the sake of knowledge rather than to complete tasks. How and why students' goal orientation evolves through their REU experience is an excellent direction for further research.

## Implications

Given our findings, it is apparent that REUs afford conditions that can have profound influence on multiple aspects of students' personal and professional growth. The student growth associated with engagement in an REU is multifaceted, which suggests that multiple variables are at play as are multiple aspects of student development. Given the potential for student growth and the profound impact of the REU that students express as they reflect on their experience, there is substantial support for providing students with research experiences to foster their content knowledge and professional development. The multifaceted nature of the REU impact also provides support for providing a range of services and structures to participants to assure that their intellectual, professional, and emotional growth are encouraged.

The potential for REUs to influence a range of affective variables suggest that program faculty and directors should be prepared to foster positive emotional development of students. Thus, mentors and sponsors may need to extend their support beyond the more common REU foci on the research content knowledge, procedures and techniques, career options, and presentations of results, and also attend to students' fears, apprehensions, excitement, and confidence. One of the primary goals of REUs is to foster student development as professionals, and, as our research has revealed, this development likely includes attending to a range of emotions.

Our evidence indicating that REUs may promote participant development of professional identity suggests that REU program directors and mentors would benefit student development through explicitly providing students the opportunities to reflect on and engage in professional activities. Engaging students in conversations, problem solving, development of new processes, interpreting results, and communicating finding are activities that are likely to catalyze student development of professional identity. The mentoring, modeling, and opportunity to practice professional activities are fundamental to student development of professional identity, and therefore should be attended to in REU program planning and implementation.

Our evidence suggests that REU programs that are structured similarly to our summer program that almost forces the development of a strong cohort—through shared housing, frequent programmatic social and professional development events, and solid mentoring—will have similar outcomes. This supposition is tentatively supported by responses collected from our one participant who did not live on campus which indicated that the student had a notably different experience than the students who resided in university housing. Thus, the structure of a REU program is likely of great importance with regard to achieving desired outcomes.

## Limitations

There are a couple of limitations of our study. First, the information the students provided in reflecting on their experience was not substantiated by observations of their behavior or interviews of those working with the students. Observations of the students and interviews of faculty and others working in the laboratory may provide additional insight into the impact for the REUs on the students. The interviews and observation are an excellent direction for future research.

The second limitation of our project is the constrained sample size. We only sampled the 10 students involved in a single residential REU program. The collection of data from students engaged in a wider range of REUs may reveal different results. We would encourage others studying REU programs to gather data similar to those we collected in our study to determine the extent to which other REU programs are fostering student professional identity development and engaging participants on an emotional level. Further, the collection of data from a larger number of participants would provide the statistical power necessary to effectively conduct analyses to both quantitative and qualitative data.

# Conclusions

Research experiences for undergraduates have been found to have a profound impact on students. REUs can help students gain clarity with their knowledge of content and research. Further, the experiences provide students with an additional basis on which they may make career plans. However, our research has revealed that REUs also provide opportunities for students to develop their professional identity and competency. Thus, the benefits and outcomes of REUs are likely to be situational and diverse, which provides warrant for ongoing investigation of the impact of research experiences on undergraduates.

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