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Becoming a researcher: A narrative analysis of U.S. students' experiences in Australia

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Abstract: *Undergraduate research experiences are becoming increasingly common in the United States and are encouraged in engineering as a way to give students "real world" problem-solving experience. We sought to understand the experiences of four U.S. students participating in an 8-week summer research program in Australia. Each student participated in interviews before, during, and after the program from which we constructed a narrative for each student describing their critical experiences. Narrative inquiry allows for holistic analysis of a phenomenon without categorizing or sub-setting the data, which can result in loss of context. Using this method, we identified themes across the four narratives to describe the multiple ways in which students assessed their "fit" in the research environment throughout the experience and how participating in the program influenced their future plans. Our findings provide insights for the design and implementation of research experiences both inside and outside of engineering courses.*

Introduction

Undergraduate research has been a growing movement in U.S. higher education since the 1980s (Streitwieser, 2009; Taraban, 2008). The foundation of the National Science Foundation's Research Experiences for Students (REU) funding program in 1987 has been followed by support from other foundations, organizations, and universities. The American Association for Colleges and Universities (AAC&U) has recognized undergraduate research as a "high impact practice," that is, one that has been widely researched and shown to benefit the education of students from a variety of backgrounds (AAC&U, 2007). Within engineering education, undergraduate research has been recognized as an opportunity for students to engage with ill-structured problems in an authentic problem-solving environment (Faber, Vargas, & Benson, 2016). Prior research has identified a range of positive outcomes from undergraduate research experiences, but few studies have focused on understanding students' experiences during such programs. This study considers the narratives of four U.S. students conducting research during a summer in Australia to explore the ways in which the students interacted with the "research environment." Understanding the process of how novices engage with research can inform the design of undergraduate research programs and course-related research activities.

Relevant Literature

Although engineering programs often emphasize problem solving as a core skill for engineers to develop, they have been critiqued for primarily providing students with well-structured, closed-ended problems to solve (Jonassen, 2014). Recent developments in educational practice have been working to address this concern and improve the in-class experiences of engineering students (Kolmos & de Graaff, 2014). However, engineering students can also develop skills and expertise through extracurricular activities that foster problem solving (Murzi, 2018; Strauss & Terenzini, 2007). Undergraduate research experiences have been recognized as one method to expose engineering students to an

authentic problem solving environment that complements the content learned in coursework (Faber et al., 2016; Murzi, 2018). Such experiences can also provide students with the opportunity to participate in a professional community of practice in a legitimate way (Hunter, Laursen, & Seymour, 2006; Thiry, Laursen, & Hunter, 2011). Learning in such an environment involves socialization of "newcomers" into the practice of the community (Lave & Wenger, 1991), which can support the development of identity or affinity with the profession (Hunter et al., 2006).

Investigations of undergraduate research experiences have highlighted a variety of positive outcomes (Taraban, 2008). At the most basic level, such experiences expand students' research skills and confidence in their ability to conduct research (Kardash, 2000; Seymour, Hunter, Laursen, & DeAntoni, 2004). These skills include data collection, data analysis, theoretical understanding, and awareness of how to approach research problems. Further, students report gains in the attitudes necessary to participate in a research community, including taking responsibility for a project, decision-making in a research context, and intellectually engaging in research discussions (Hunter et al., 2006; Seymour et al., 2004; Thiry et al., 2011). These outcomes have been described as the process of "becoming a scientist," indicating students' experiences of moving from peripheral to more full participation in the research community (Hunter et al., 2006). Such benefits are stronger for students who participate in research projects for an extended period of time (i.e., multiple semesters; Thiry, Weston, Laursen, & Hunter, 2012). Development of research skills and attitudes has been reported not only by student researchers themselves, but also by their academic mentors (Hunter et al., 2006; Kardash, 2000). However, not all undergraduate research experiences are identical. Variations in program components, such as time spent with academic mentors or in the laboratory, have been shown to correlate with both the skill- and attitude-based learning outcomes of undergraduate research (Taraban, Prensky, & Bowen, 2008).

Within the engineering education community, similar findings have been reported about students' development of a researcher identity (Benson et al., 2018; Faber & Benson, 2015). Students reported that they felt recognized as researchers through working on independent projects, presenting their work, receiving acknowledgement from research mentors, and talking about their research to people outside their field (Faber & Benson, 2015). Faber et al. (2016) also identified profiles of emergent researchers as they move from being a novice researcher toward contributing actively within a community of practice. This process was found to be related to both longer research experiences and increasing levels of autonomy within the research project. A novice researcher tends to be very dependent on research mentors with little decision-making responsibility, whereas a contributing researcher has become involved in making research decisions and feels integrated within the lab (Faber et al., 2016). Faber et al.'s (2016) work provides a closer look at the process through which students move from being a novice to a contributing participant in a research community. However, the existing research both inside and outside engineering education has been primarily dependent on pre/post assessment or simply post-experience interviews/surveys. Our study sought to explore undergraduate research throughout the entire experience to shed light on critical moments in students' engagement with the research community.

Theoretical Framework

Because the focus of this study was on understanding student narratives without prior expectations or hypotheses, we did not use a theoretical framework in the design of the study. However, after completing the narrative development process, we noticed several common themes across students' experiences that connected to ideas present in the *Person-Environment Fit* theoretical framework. Person-environment (PE) fit has been defined as "the congruence, match, similarity, or correspondence between the person and the environment" (J. R. Edwards & Shipp, 2007). Although a variety of PE fit theoretical models have been proposed over the years (J. R. Edwards, 2008), there are several common components across theories (J. R. Edwards & Shipp, 2007). A meta-analysis of PE fit

research suggested that PE fit is a multi-dimensional construct based on the fact that each dimension shows different influences on individuals' attitudes, organizational commitment, job satisfaction, and job retention (Kristof-Brown, Zimmerman, & Johnson, 2005).

J. R. Edwards and Shipp (2007) present a conceptualization of PE fit that organizes these concepts into three dimensions: Type of Fit, Level of the Environment, and Content Dimensions. The Type of Fit dimension describes differences between *supplementary* fit (i.e., similarities between person and environment) and *complementary* fit (i.e., weaknesses in person or environment are offset in strengths of the other). Complementary fit can be further divided into *demands-abilities* fit (i.e., environmental demand met by a person's abilities) and *needs-supplies* fit (i.e., person's needs met by an environment's supply). The Level of the Environment dimension captures the idea that fit can be identified between a person and different levels of their environment, including: individuals, a job, a group, an organization, and a vocation. Lastly, the Content Dimensions describe the characteristics by which PE fit are being analysed, ranging from general to specific. Three points on this continuum are identified: global (i.e., comparison in a general sense), domain (i.e., comparison on a broad variable), and facet (i.e., comparison on specific dimensions of a variable). Subsequent work has suggested that these conceptual dimensions may combine to form an overarching sense of PE fit (Jansen & Kristof-Brown, 2006), but initial findings have not supported this idea (J. A. Edwards & Billsberry, 2010).

Methods

In our study of undergraduate research participants, we used narrative inquiry as a way of understanding participants' experiences holistically. Narrative inquiry allows stories to be analysed in their entirety rather than coded and categorized as is typical in other forms of qualitative research (Kellam, Gerow, & Walther, 2015). Keeping stories intact allows researchers to understand the larger experience under study and identify themes that run throughout. Although relatively new in engineering education research, this method has been used in prior studies of engineering major choice (Cruz & Kellam, 2018), career decisions of engineering teaching faculty (Trellinger & Jesiek, 2017), and boundary spanning experiences of early career engineers (Jesiek, Trellinger, & Nittala, 2017). In this study, we used interviews from across a summer research experience to construct student narratives about their engagement with the research environment.

Participants

The participants for this study were four U.S. civil engineering students participating in an eight-week summer research program in Australia. The program was funded through the National Science Foundation's International Research Experience for Students (IRES) program, which supports research collaborations between U.S. universities and partner universities abroad. Students were admitted to the IRES program through an application process that included submission of a transcript, a CV, and a short essay of research interest. Students were selected based on their prior research and academic experience and interest in the research available at the partner university, with the intent of identifying students who would be successful in the program. During the program, students were paired with an academic at the partner university and assigned to work on one of their research projects. All of the students participated in various parts of the research process, with an emphasis on gaining fieldwork experience. The students had opportunities for both short-term (i.e., one-day) fieldwork trips and a longer-term (i.e., 1+ weeks) experience.

All students were required to participant in data collection as part of the evaluation process for the grant, but we obtained their consent to use the data for research purposes in line with the requirements for human subject research provided by the Institutional Review Board. Details about the participants are shown in Table 1 below.

Table 1. Overview of Participants

Participant #	Prior Research Experience	Prior Global Experience	Gender	Year in School
1	Only class projects	2-week study abroad in high school	Male	Senior
2	One semester	2-week study abroad in college	Female	Junior
3	One-week field trip	2-week study abroad in college, family travel	Female	Junior
4	Eight-week summer research, two semesters	Eight-week summer research abroad	Male	Senior

Data Collection

Each student participated in four semi-structured 30-minute interviews throughout the program. The timeline and content of this interview sequence are shown in Table 2. All of the interviews were conducted by the graduate student evaluator for the IRES grant, who travelled with the students to Australia for the summer. The middle two interviews were scheduled to occur before and after the longer fieldwork experience for the summer.

Table 2. Interview Sequence

Interview #	Timing	Content
1	1-month pre-program	Prior research and global experiences, expectations, concerns, understanding of research process, career goals
2	Mid-program pre-fieldwork	Research experience to this point, prior fieldwork experiences, expectations for fieldwork
3	Mid-program post-fieldwork	Research experience to this point, fieldwork experiences, lessons learned, research process, career goals
4	1-month post-program	Overall research experience, transition back to school, lessons learned, key experiences, career goals

Data Analysis

All of the interviews were transcribed and then developed into narratives using the *narrative construction* method (Kellam et al., 2015). This method involves using direct quotes from a student's interviews to construct a narrative story about their experience with connecting text added by the researcher to improve the flow. To help the narrative read more naturally as a story, the story is written in first-person and quotes are not indicated in the text. The narrative construction method has the benefit of removing authorial distance (by writing in the first person) but can reduce narrator reliability by not indicating direct quotes. This method was selected because of its ability to develop a holistic account out of a series of events, bringing order and meaning to the data (Kellam et al., 2015).

The researcher developing the narratives first read through each of the interview transcripts in depth. Then, focusing on one participant at a time, she reviewed each interview again and identified quotes describing key events, experiences, and student responses (i.e., critical incidents). These quotes were moved to a spreadsheet and grouped based on the critical incident or experience they described. The narrative for each student was then constructed around the critical incidents, moving both chronologically and from general experiences to more specific incidents. The final narratives were reviewed holistically by both researchers, who then identified connections to PE fit framework (the framework was not part of the study during narrative construction and was only introduced during the final cross-narrative

analysis and interpretation). The overarching narrative presented in this paper describes the common themes across all four narratives in light of PE fit concepts.

Limitations

This study is limited by its focus on students who participated in a single program (which was a convenience sample). Research experiences take a variety of forms, so this study of summer research experiences may not be transferable to all research experiences. Summer programs may be more likely to give students their own projects to work on as they are dedicated to doing research full time compared to within-semester research experiences. A second limitation is that all the student participants came from the same department at the same institution. Institutional variables are relevant in the experiences of undergraduate students, so it will be important to consider context in interpreting the results for potential transfer to other situations. This IRES program sent students from a large research-based institution in the mid-Atlantic region of the U.S. to a large research-based institution in Australia. Research programs in other contexts may result in narratives different from those described in our study.

Findings & Discussion

In this section, the four narratives are discussed as a group to explore the similarities and variations across the four students' experiences in the undergraduate research summer program. The key finding from this study is that all four students described different ways that they were exploring the *research environment* for potential fit with their future career plans. Thus, we have introduced terms from the PE fit theoretical framework to structure the discussion and highlight the various ways that a student may determine that they do or do not "fit" into the research environment. The three levels of fit that were most central to the student narratives were: person-individual fit, person-group fit, and person-vocation fit. Within each of these categories, the other dimensions of the PE fit framework also emerged as relevant factors in students' overall experiences (highlighted in italics in the following sections). Direct quotes are not included in reporting the findings to avoid isolating pieces of the narratives. This decision was made based on prior examples of narrative research (e.g., Cruz & Kellam, 2018; Trellinger & Jesiek, 2017). Rather, the narratives have been considered holistically and overarching storylines are reported and discussed in the context of prior research. A longer excerpt from one of the narratives is included in Appendix A to provide an example of the final narrative format.

Person-Individual Fit

Connecting with a mentor during the research program was a critical experience for most of the students. Although prior work has highlighted that time spent with academic mentors can improve student learning outcomes (Taraban et al., 2008), the students found that their more meaningful connections often occurred with graduate students. This observation was particularly important for students working for academics who took a hands-off supervisory approach. One student emphasized that without their graduate student mentor, the summer would have been a miserable experience with little guidance. Another felt that discussing their project with their mentor was the best way to learn more about the field. The students all provided examples of how their mentoring relationships contributed to their overall success, creating a *needs-supplies* fit within their summer research experiences.

Across the narratives, students pointed to a variety of positive outcomes from the development of a mentoring relationship. Similar to the earlier research on the development of research skills (Kardash, 2000; Seymour et al., 2004), most students discussed learning about the research process and how to conduct fieldwork experiments. Several students emphasized that working closely alongside their mentor allowed them to observe different skills first and then put these into practice in their own projects. However, the mentoring experience often went beyond the basics of helping students develop the skills necessary to complete their projects. One student observed their mentor's approach to work-life balance

and willingness to take time to help others despite being busy with projects. Another had opportunities to discuss current events with their mentor while doing fieldwork and became more comfortable interacting with professors in general. A third discussed how their mentoring experience helped them understand the importance of finding a supportive advisor in graduate school. Thus, although most students found *person-individual fit* within a mentoring relationship, the *domain* (i.e., content) of this connection varied across students.

Although *person-supervisor fit* is a common relationship considered within the PE fit literature (J. R. Edwards & Shipp, 2007), the students in this study tended to emphasize the importance of feeling like a *colleague* in their mentoring relationships. Over the course of the summer, several of the students discussed developing confidence in themselves as a researcher because their mentor treated them as one. As mentors assigned the students more complex tasks, the students could see that they were being trusted with important parts of the project. One student described how their mentor eventually stopped getting out of the car during a fieldwork trip and let them collect all of the samples. Another student whose supervisor entrusted them with the management their own project began to see themselves as a leader and consider how this experience might relate to a career as a professor. The students' progression towards seeing themselves as colleagues to their mentors shows movement from peripheral to more complete participation in a research community of practice, aligning with the findings from earlier work (Hunter et al., 2006; Lave & Wenger, 1991). However, the narratives also suggest that *demands-abilities fit* is important in making this transition. The students began with different levels of research skills, and it was important that their mentors assigned tasks that aligned with their initial skill level and continued to adjust for their growing confidence and understanding over the course of the summer research experience.

Person-Group Fit

Throughout the summer, each of the students described assessing their fit with different groups within the research environment. Where the students' person-individual fit assessments tended to focus on *complementary fit* (i.e., person and environment meeting each other's needs), their person-group fit assessments focused on *supplementary fit* (i.e., similarities between person and environment; J. R. Edwards & Shipp, 2007). For example, research groups are one of the most common groups encountered in the research environment. The summer research program gave students access to two research groups focused on related research topics. Students assessed their fit with these groups based on a variety of *domain* (i.e., content) characteristics. Some students focused on the research topics of the groups and identified which research group aligned better with their personal interests. Others focused on the communication and interpersonal practices of the groups and found certain team environments more or less aligned with their preferences.

Because the research program took place in Australia, another assessment that several students made was their fit within Australian culture. Most students described the differences in work-life balance attitudes and "whole being health" as positive aspects of the culture that they admired and wanted to emulate as much as they could upon returning to the U.S. These students identified *supplementary fit* between these Australian cultural values and their personal values and aspirations. On the other hand, some students identified a lack of fit between the casual, unstructured nature of the Australian work environment and their preferences. One student also discussed how the Australian sense of humour was significantly misaligned with their own and that it had surprised them how important this misalignment turned out to be. This student concluded that they would prefer not to live in a place where they could not tell whether people were joking.

The students' various assessments of *person-group fit* played a significant role in their resulting thoughts about future graduate school experiences. Most students completed the research experience with a more refined sense of their research interests and discussed how this would guide their choice of graduate programs, advisors, and research projects. Some

students expanded on this topic by emphasizing the importance of studying a topic they are passionate about (an example of *person-job fit*). Other students commented on how their experiences in the different research groups helped them understand the importance of fitting in with the people they would work with. These students planned to carefully research the group culture of graduate programs to which they applied. Lastly, one student interested in going abroad for graduate school emphasized the importance of researching the cultures of the countries they considered to ensure some alignment between their personal values and preferences and those of the host culture. Although previous work has identified interest in graduate school as an outcome of undergraduate research programs (Hunter et al., 2006; Seymour et al., 2004), we found that students also had more nuanced perspectives on what they wanted and needed in their graduate school experiences.

Person-Vocation Fit

Because undergraduate research experiences often function in an apprenticeship model, they present an opportunity for students to "try out" research as a possible future career (Hunter et al., 2006; Kardash, 2000). It was evident across all of the student narratives that assessing *person-vocation fit* was a central part of the summer research experience. Several of the learning outcomes of undergraduate research experiences that have been discussed in earlier studies turned out to be important as students made this assessment, specifically: 1) learning to ask research questions, 2) understanding the research process, and 3) developing fieldwork data collection skills. As students came to understand these aspects of research as a vocation, they either found themselves confirmed or confused about their plans to pursue a research career. Because the students were assessing specific components of the research career for alignment with their preferences, they were assessing *supplementary fit* at the *facet* content level.

All of the students discussed the ill-structured nature of research projects and how this was a contrast to their prior work in engineering coursework. Most of them connected this contrast to the types of questions that research works to address, describing them as "broad," "open-ended," and "vague." Similarly, students discussed the "non-linear" and "flexible" aspects of the research process, emphasizing that there was no single correct approach. Throughout the summer, the students engaged in the process of learning to ask research questions and identify a strategy to try to answer them. For some students, this experience was freeing, allowing them to use creativity and develop skills in self-directed learning. For others, the ill-structured nature of the questions and projects was more overwhelming. One student described feeling "intimidated" when faced with a research question and not sure where to start. Working with a mentor to develop a plan with some structure helped this student, but the overall experience caused them to question their vocational fit with research. Fieldwork experiences also highlighted the inherent uncertainty in research as a vocation for several students. Although all of the students enjoyed their fieldwork and cited it as a highlight of the summer, some of them truly relished the "troubleshooting" nature of the work. Overall, the ill-structured nature of research projects seems to be a *facet* of the research vocation that attracted some students and repelled or at least challenged others.

Another *facet* of the research process discussed by some students was the level of interaction with other people. Some students found that research involved more collaboration than anticipated and appreciated being part of a team. On the other hand, some students noted that research involved a lot of individual work and wondered if another vocation would provide more opportunities for interacting with people. Thus, although they were all working on projects in the same research groups, the assessment of whether research involved "a lot" or "little" personal interaction varied across students.

At the start of the summer, each of the students expressed an expectation that they would pursue graduate school and likely a research-related career. Students who were more comfortable with the ill-structured nature of the research process further confirmed their plans. These students compared their summer research favourably against prior industry

internship experiences, where their projects had been more structured and supervisors more hands-on. In comparison, students who were intimidated by the open-ended questions or uncertainty of research projects questioned their initial plans. One student decided by the end of the summer that they would prefer a job in industry, feeling that this would allow them to "take action" based on research findings rather than work on the open-ended questions. Similarly, a student who wanted more interaction with people began to consider law school as an option for finding better *person-vocation fit*. In each of these cases, learning about the research process helped the students assess their fit with research as a vocation.

Implications & Future Research

Although prior research has identified positive outcomes of undergraduate research, our findings provide a more nuanced perspective. Through the lens of the *person-environment fit* framework, we identified various ways that the students in our study used critical experiences in their research program to assess their fit within the research environment. Our findings support earlier research suggesting that specific program components may influence student learning outcomes (Taraban et al., 2008) and provide insight into the different ways that students respond to these components. For example, being mentored by academics, participation in research groups, and exploring ill-structured problems can all lead to different interpretations from different students. We suggest that these differences may be because students are using these experiences to assess person-environment fit.

Based on these findings, we suggest that undergraduate (and potentially also graduate) research experiences could be facilitated with the intent of helping students make these assessments. If a desired outcome of such programs is to encourage students to consider graduate school and/or a career in research, it is important to include authentic research experiences to enable accurate fit assessments. It is also essential that program facilitators acknowledge the different prior experiences, values, and expectations of different students. This means that providing the same experience to several students may lead to varying results. Checking in with each student periodically throughout a research experience may help identify questions or concerns that individual students are facing as they seek to assess their fit in the research environment—and it may help them process those feelings. Although our study focused on a summer research program, we believe that these recommendations could apply in either a course-based or extracurricular research experience.

Our study was limited in its focus on a single program and small number of students. Future work could explore student experiences across different types of research programs to see how they vary. Based on our experience, we would recommend the use of narrative inquiry as a way to see a holistic story within data. The process of constructing the narratives, although time consuming, was valuable in providing a structure through which to analyse data collected over several interviews. By capturing data at several points in time, we gained a unique perspective on student development as a process, which can be overlooked in the pre/post analysis often used in educational research. Reading the narratives also allowed us to see connections between student experiences and their subsequent conclusions and decisions about the research environment, providing insights that may have been lost using traditional qualitative methods.

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Appendix A

The following is an excerpt from the narrative for Participant 2. This section represents one critical incident from their summer experience: being mentored by a Ph.D. student.

One of the highlights of my summer was working closely with the PhD student on my project. I remember the moment where he came up to my desk and asked "Hey would you want to work on this for me?" It was so satisfying to have that acknowledgement, because I didn't ever talk to the faculty advisor I had been assigned, which was very upsetting. But this PhD student took me under his wing, explained everything to me, and really went out of his way to make me feel like I was working towards something. I would have had a miserable time if he had not stepped up to that role.

As a part of the mentoring experience, the PhD student I worked with would give me papers to read and ensure that I understood them. He gave me smaller tasks to work on and I would always tell him to give me literally anything to do, because sometimes even dumb tasks teach you a lot. Just working next to him and seeing what he did every day was helpful. I felt like I was able to do tasks that he already knew how to do so he could work on more difficult things. At the same time, he did a really good job of showing me the whole process and making sure I understood how my tasks fit into the bigger picture.

Ultimately I realized that which project I worked on didn't matter as much as having a supportive mentor. Getting that one-on-one interaction where he could answer my questions was way more important than being on a specific project. I felt like I learned a lot even if I didn't come up with as many deliverables as I might have wanted. I know some of the other students managed their own projects, but I would definitely have chosen to help someone out, because I have realized that you can learn a lot from working with someone else.

This experience has really shown me what I want in a graduate school program. I definitely want good mentorship and to feel like I am supported. That's my bare minimum requirement, because I don't know if I would do well with an advisor that isn't supporting me at all.