Board 49: Work-in-Progress: An exploration of students' conceptualization of research after participating in an undergraduate research experience.

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Work-in-Progress: An exploration of students' conceptualization of research after participating in an undergraduate research experience.

Research Experiences for Undergraduates (REU) programs are designed to provide research-intensive summer experiences for undergraduate students, particularly those from less research-focused institutions. The REU program, funded through the National Science Foundation, is viewed as a mechanism for increasing graduate school attendance in STEM fields. Research investigating the outcomes of the program has been promising (Landis, 2005; Youssef et al., 2016), with potential benefits including increased interest in research, bolstered determination in pursuing post-secondary degrees, and improved research skills. However, much of this research has been limited to descriptive analyses utilizing self-report data collection methods, such as the Undergraduate Research Student Self-Assessment (URSSA) survey which asks about students' self-perceived gains from participating in REU programs (Alexander, Foertsch, & Daffinrud, 1998; Chaplin, Manske, & Cruise, 1998; Foertsch, Alexander, & Penberthy, 1997; Follmer, Zappe, Gomez, & Kumar, 2015; Kitto, 1998). While these studies are helpful for understanding the impact of REU programs, criticisms of self-report methodology abound. Self-report instruments rely on participants' accounts of their beliefs or perceptions about themselves, which are subject to memory and response biases (Cleary, 2011; Perry & Winne, 2006). Because of these limitations, other direct methods of measuring the impact of REU programs are needed.

This paper describes a work-in-progress study that uses an exploratory qualitative approach to investigate students' conceptions of the research process before and after participating in an REU program. Students' responses to a hypothetical situation intended to elicit conceptualization of the research process were examined and compared to the steps of the creative process (Mumford, Medeiros, & Partlow, 2012), which serves as the theoretical framework guiding the study. We argue that the research process or the scientific method is analogous to the creative process, as illustrated in Table 1. Creativity "requires the production of novel, socially-valued products" (Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991, p. 94). As with other creative endeavors, quality research makes a unique contribution to our understanding of a phenomenon and has social value. Creative pursuits, such as research, begin with problem construction (identification of a research question), rely on information gathering, and ultimately result in idea evaluation, implementation, and monitoring. Our conception of the creative process is informed by Litzinger, Zappe, Hunter, and Mena's (2015) creative process framework, which was adapted from Mumford, Medeiros, and Partlow's (2012) creative process model.

Two overarching research questions were addressed: Using a creative process framework, how do students in a chemical engineering REU program conceptualize the research process? How does this conceptualization change as a result of participating in the REU program? These questions will be explored through common qualitative research methods which are characterized as field focused, the researcher as the data collection instrument, words being used as data, and the inductive analysis of data while focusing on the participants' perspectives and maintaining a holistic view of social phenomena (Creswell, 2007).

Table 1: Link between the creative process & scientific method (adapted from Litzinger et al., 2015).

8 Stages of the Creative Process (Mumford et al., 1991)		Creative Process Model (Litzinger et al., 2015)			8 Steps of the Scientific Method (Crawford & Stucki, 1990)	
1	Problem Construction	1	Problem identification and definition	Monitoring	1	Define the question
2	Information gathering	2	Information gathering and organization		2	Gather information and resources (observe)
3	Concept Selection	3	Idea generation		3	Form an explanatory hypothesis
4	Conceptual combination	4	Idea evaluation			
5	Idea generation					
6	Idea evaluation	5	Planning		4	Design and Perform an experiment and collect data (test the hypothesis)
		6	Implementation		5	Analyze the data
					6	Interpret the data and draw conclusions
7	Implementation Planning				7	Publish results
8	Monitoring				8	Retest

Methods

Participants included 16 undergraduate students enrolled in a chemical engineering REU program at a large, mid-Atlantic research university. Twenty-five percent of the sample held under-represented minority (URM) status; 50% were females. Students were asked to write a response to a case statement before the REU program began and at the program's conclusion. The case statement asked students to imagine they were graduate students planning a research project and to create a rough plan to execute this research project with the goal of submitting a conference paper (see Appendix). The post-REU case statement was identical to the task provided for the pre-REU data collection. However, students were also asked in the post-REU task to compare their post-REU plan with their pre-REU plan, revise their pre-REU plan, and note any sources of inspiration for their plans (e.g., research partners, courses or labs). Students first wrote their plans on paper and then discussed their plans with one of the researchers. Follow-up questions were asked to help clarify the students' research plans and thinking. All sessions were audio recorded and later transcribed.

Blinded case statement responses were paired (i.e., pre and post); these pairings served as the unit of analysis. The first author developed a codebook using the creative process framework as a starting point. Transcripts are in the process of being coded in N-Vivo using this initial codebook and to ascertain additional emergent themes.

Preliminary Results

Due to space limitations and incomplete data analysis, specific results of just two participants' responses are discussed here. Table 2 provides an overview of the phases of the creative process coded for the two participants. Ava[1] is a senior student whose response represents a fairly sophisticated understanding of the research process even before participating in the REU program. Ava's conception of the research process, even on the pre-REU task, aligns well with the creative process model—nearly every phase of the model is represented in her responses. One of the major themes that emerged in her pre-REU response is the *understanding that research needs to be novel and have value*, aligning with the definition of creativity (Plucker, Beghetto, & Dow, 2011). As Ava states, "One thing is you don't want to do something that's done already…I also said it's just good to keep in mind what the eventual application of the research you're doing for the project is." A second theme that emerged is that *research requires monitoring and adjustments*., an example of the monitoring stage of the creative process model. As she states, "There would be adjustments I need to make when I'm actually working through the bulk of the experiment or whatever. That's not something that's ever going to go exactly how I'm expecting it to."

Table 2: Phases of the creative process addressed by two participants before and after REU

		Problem identification	Info. gathering	Idea generation	Idea evaluation	Planning	Implementation	Monitoring
Ava	Pre-REU	■	■	■	■	■	■	■
	Post-REU	■	■	■	■	■	■	■
James	Pre-REU	■	■		■	■		■
	Post-REU	■	■	■	■		■	■

Note: Cells are shaded if the phase was coded for the participant. Blue = pre-REU, green = post-REU.

In contrast to Ava, James had less prior research experience. In the pre-REU response, James recognizes his lack of experience in research, as evidenced by the following quote:

> "You have to have a general idea of what you're looking at and not just go start from nothing and just hoping what it comes out. I guess. I don't know. I have no experience in research so I'm really not sure that's how it's done."

While James is a novice, he seemed aware that research included the creative process stages of *problem identification, idea evaluation, and planning*. James displayed one instance of monitoring too, but neglected to detail how he would generate a research idea and how he would implement the research process (e.g., collect and analyze data). Perhaps due to James's lack of experience, he seems to *defer to authority* often (e.g., "I will look for other people and experts for collaboration and for them to tell me what they think of the project if it would be a good

[1] Pseudonyms are used in this paper to protect confidentiality of research study participants.

idea.") James also focused on *obtaining resources* (i.e. materials, funding, and equipment) to conduct the research but did not comment on how these resources would be used.

One of the changes in James's post-REU response is an *increased specificity* regarding problem identification. As he stated, "I don't know if I did it last time, but looking for a specific problem that's occurring now and how I can address it". This is a marked change from the pre-REU response, in which James described the initial stages of problem identification more broadly. Another change in the post-REU response was the discussion of "trial-and-error" and an increased focus on *monitoring* of the research process, as illustrated below:

> "And then going to the plan-- start doing the experiment to see if it works. If it doesn't work, go again, and talk to my colleagues, or my PI, and see what I can do differently. And that trial and error, I think, [inaudible] new things until I finally get it right, or at least what I want. And then going again to my PI and see what he thinks"

James still defers to authority in the post-response (his advisor), but is coming to understand research as a messy process. James's conception of the research process also seems to have broadened, since he incorporates additional phases of the creative process model. Unlike the pre-REU response, he now incorporates the Implementation phase (i.e., data collection and analysis), and mentions writing up and disseminating his results. Nonetheless, James's relative inexperience is still apparent: "Maybe start writing a draft if it's going to get published or something. I don't know."

Although only two participants are discussed here, two preliminary themes among all analyzed transcripts (~75% of all transcripts) have already been identified. The first is that students' conceptualizations appear to become more sophisticated and specific after completing the REU program. That is, students typically responded to the pre-REU case statement using general terms (e.g., "create a new method by which the company could produce its medicine." – Abraham), often not addressing all phases of the process. But in the post-REU case statement, language was more specific (e.g., "Prepare your research materials. Get access to any equipment you need, any chemicals you might need, and anything else that would be necessary for your project." – Abraham) and typically more phases of the process were addressed.

The second is that students appear to defer to authority less often after completing the REU program. Statements like "So maybe one adjustment would be, say the ideas I present to the professor aren't good enough" (-- Bella) were often found in the pre-REU responses and indicate a deference to authority. A change in tone often occurred after the REU program, indicating a more collaborative relationship: "Also, during this time, my faculty advisor and I will be forming a long-term plan on how I should be progressing through the experiments" – Bella.

Discussion and Next Steps

Data analysis of the transcripts is still ongoing. Current work is focusing on ensuring the data analysis follows standards for rigorous qualitative research, using recommendations made by the engineering education community (Kellam & Cirell, 2018; Walther et al., 2017; Walther & Sochacka, 2014).

The two identified themes provide additional evidence for the benefits of the REU program. It has always been a goal of the REU program to introduce students to research in hopes of encouraging them to pursue graduate school (cite). In pursuing this goal, it is important to consider whether the REU program changes students' conceptualizations of research, because doing so (and doing so accurately) will inevitably influence their decision to pursue graduate training. Having a more accurate conceptualization of research is important when deciding whether to attend graduate school. Inaccurate conceptualizations may cause students to be upsettingly surprised upon arrival to graduate school, and drop out. Meanwhile, more accurate conceptualizations may encourage those who would excel in graduate school to actually pursue it. Allusions to this point have been made in previous research (Follmer, Zappe, Gomez, & Kumar, 2016). In this evaluation of a biology/materials-oriented REU program Follmer and colleagues found that students reported an increased understanding of research and the process involved. They quoted one student as saying: "I've gained a better understanding of what research is and how to go about it and just the process of doing it and seeing how people interact together in the lab." The present study corroborates and extends these findings by providing more direct measurement of this reported development in understanding.

The analyses of the two study participants and identification of preliminary themes illustrates the utility of the task for understanding students' changes in their conceptualization of research. The task provides information about students' conceptualization of research as it aligns with the creative process. This method may be helpful in providing information for researchers on the impact of REU programs, beyond what may be available from traditional self-report methods.

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Appendix

Pre-REU Case Statement

Name: Date:

Case statement

You are a graduate student in a chemical engineering lab at [institution name]. Your faculty advisor has asked you to come up with a unique research project. The goal is that you'll independently design and conduct the research study, eventually submitting a paper about it for a conference.

Think through what you would do to execute the research project. What do you need to do and what decisions would you make? If it helps you to answer, you can situate the project within any context in chemical engineering (or another engineering discipline).

Construct and write down your plan for the research project on the paper provided. You'll have about 10 minutes to write and then you'll be asked to explain your plan.

Post-REU Case Statement

Name: Date:

Case statement

You are a graduate student in a chemical engineering lab at [institution name]. Your faculty advisor has asked you to come up with a unique research project. The goal is that you'll independently design and conduct the research study, eventually submitting a paper about it for a conference.

Think through what you would do to execute the research project. What do you need to do and what decisions would you make? If it helps you to answer, you can situate the project within any context in chemical engineering (or another engineering discipline).

Construct and write down your plan for the research project on the paper provided. You'll have about 10 minutes to write and then you'll be asked to explain your plan.

This should not be a direct copy of the plan used for your REU project. We want your perspective on how to take a research project from idea to publication.