The Impact of a Creativity-focused REU on Students' Conceptions of Research and Creativity

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The Impact of a Creativity-Focused Biomedical REU on Students' Conceptions of Research and Creativity

Abstract: Research Experiences for Undergraduates (REU) have been strongly supported through the National Science Foundation as a way to increase the number of students engaged with research and potentially attend graduate school. This qualitative study examines the impact of a creativity-focused REU program in biomedical engineering on students' conceptions of research and its relationship to the creative process. In addition, this study examines how faculty incorporate concepts of the creative process in their work with the REU students. Results of the study show that after participating in the program, students were likely to have a conception of research that was broader and more cyclical. Results also suggest that students recognize the connection between research and the creative process, and that the experience dispelled misconceptions of creativity that it only applies to the arts. Limitations of the study and future directions for the program and related research are discussed.

Introduction

According to the National Science Foundation (NSF), Research Experiences for Undergraduates (REU) programs strive to increase the number of students, including those from underrepresented groups, who are involved in research in meaningful ways (NSF, Retrieved February 1, 2018). The NSF Program solicitation estimates awarding grants for approximately 180 new REU sites each year with anticipated funding, including new sites and supplemental awards, exceeding $68 million annually. The number of awards and the amount of allocated funding suggests a perceived importance of the program for increasing the number of students involved in research.

One of the goals of many REU programs is to increase the likelihood that involved students will go on to graduate school in the STEM disciplines. As compared to a matched sample of undergraduates who did not participate in an REU program, Zydney and colleagues (2002) found that participating students had an increased likelihood of attending graduate school and felt that the program improved their career trajectories. Similarly, Seymour and colleagues found that students felt that their research experience allowed them to have a clearer picture of their post-graduation plans and felt more prepared for their career or graduate school. Other benefits of REUs include stronger self-perceptions of research skills (Follmer, Gomez, Zappe, & Kumar, 2017) and improved ability to understand and communicate research findings (Hsieh, 2013).

While almost all REU programs likely have similar goals regarding increased likelihood to attend graduate school or increased gains in research skills, each REU site typically offers a unique theme, often relating to the discipline or to the professional skill set. The REU examined in this study focuses on the incorporation of the creative process as it relates to research and the scientific method. Using this creativity-focused REU as context, this study seeks to further understand the potential impact that programs can have on students' perceptions of research, creativity, and the

relationship between the two. Students who understand that research in engineering is creative may be more likely to attend or explore graduate school as a possible path following graduation.

The CREATE REU: Examining the link between research and the creative process

The context of the study is an REU site located in the biomedical engineering program at a large mid-Atlantic research-focused university. The REU site, entitled Cardiovascular Research: Engineering a Translational Experience (CREATE), focuses on training undergraduates in the core technologies of nano-scale biomedical engineering for applications to new understanding of cardiovascular disease and the development of therapeutic interventions. The objectives of the overall program, described further in Huffstickler, Zappe, Manning and Slattery (2017), are to help students:

1. Conduct research on multi-scale problems to improve the understanding and treatment of cardiovascular disease (CVD).

2. Apply the creative process to solve engineering problems applied to CVD treatment or intervention.

3. Be able to describe the process of translating research into marketable technology.

4. Be able to identify requirements for success in graduate and professional schools.

As stated in the second objective listed above, one of the core elements of the program is linking the creative process to the scientific method. Despite the emphasis by national organizations to better integrate professional skills into the engineering curriculum (e.g. National Academy of Engineering, 2004), skills relating to creativity are often relegated to pockets of the curriculum such as design or entrepreneurship education (Zappe, Mena, & Litzinger, 2013).

The lack of integration of creativity into the larger engineering curriculum stems from several barriers. A study by Plucker, Beghetto, and Dow (2004) shows that faculty often have misconceptions of creativity as being innate, being a soft or fuzzy construct, and being limited primarily to the arts. As the authors state, "…faculty prior conceptions about creativity creates an atmosphere that severely restricts researchers' and practitioners' ability and desire to study and apply creativity." Kazerounian and Foley (2007) found a disconnect between engineering students' and faculty members' perceptions relating to creativity. Students felt that instructors do not value creativity and that they do not create classroom environments conducive for creative behaviors. Litzinger, Zappe, Hunter, and Mena (2012) found that faculty members were receptive to integrating creativity into technical courses if presented with conceptions of creativity as being a process, dispelling the myth of creativity as an innate, soft, and fuzzy construct solely applicable to the arts.

Another barrier concerns the challenge with finding sufficient time to cover technical content and incorporate professional skills.   Faculty may find it difficult to find the time to integrate aspects relating to creativity when under time constraints to cover a set amount of technical material.

Experiences such as REUs are more flexible in nature than the undergraduate curriculum, which can more easily allow for the incorporation of professional skills such as creativity.

Students in the CREATE REU participated in a series of workshops linking the creative process to the scientific method. Based on their workshop participation, students were asked to incorporate elements of the creative process into their summer research project. Workshops primarily focused on Mumford and colleagues' (1991) model of the creative process, which includes the steps of problem definition, information gathering, information organization, conceptual combination, idea generation, idea evaluation, implementation planning, and solution monitoring. Table 1 maps the steps of Mumford's model to the steps of the scientific method, as defined by Crawford and Stucki (1990). Huffstickler, et al. (2017) describe the mapping of the creative process to the scientific method in more detail.

Table 1: Relationship between the creative process and the scientific method

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

Each year, evaluation is conducted to examine whether the overarching programmatic goals are being met and to identify areas for improvement. This evaluation consists of a mixed methods approach of student surveys and interviews with faculty and students. The evaluation consists of both formative assessment as well as research elements that vary from year to year. For the 2017 program, three research questions were examined which serve as the foundation for this study:

1. How do students conceptualize research after participating in the REU program?

2. How do students conceptualize the relationship between research and the creative process after participating in the REU program?

3. How do faculty members incorporate concepts of the creative process into the laboratory experiences of the REU students? Do the approaches used by faculty influence how students' conceptualize research and the creative process?

This study builds on the previous work by Huffstickler, et al. (2017) by focusing more closely on students' understanding of research and its relationship to the creative process. In addition, changes were made in the 2017 program to better train supervising faculty on the relationship between the creative process and the scientific method. In addition, because graduate students are primarily responsible for supervising the REU students, changes were made to the methodology to see if the faculty instructed their graduate students in any way regarding working with the REU students.

Methods:

Procedures: This study uses a qualitative approach to examine the research questions. Both the faculty and the students were asked to participate in an interview at the end of the REU. The interviews were conducted by a graduate student in the College's teaching and learning center. All interviews were audio-recorded and later transcribed. Interview transcripts were coded by a graduate student from educational psychology who worked in the College's teaching and learning center. The coding used an iterative process to identify emergent themes.

Student interview questions, used to answer all three research questions, included the following:

1) How has your conception of research changed as a result of participating in the REU?

2) How did learning about the creative process and its relationship with the scientific method impact your understanding of research?

3) How did working in your research team (i.e., faculty mentors, graduate students, student pair/partner, if applicable) impact your experiences with and plans for research?

4) How did your mentors and research team impact your understanding of creativity?

Faculty interview questions focused on what approaches they used in the lab and included the following:

1) How did the program's emphasis on the creative process impact the way in which you mentored your REU student?

2) Did you discuss the REU's creativity emphasis with the graduate students and post-doctoral scholars who were directly working with the REU student?

Student Participants: Of the 10 REU students, 6 students identified as female (60%), and 4 students identified as male (40%). Nine students were recruited from universities other than the host university (90%). Six identified themselves as belonging to underrepresented ethnicities (60%), and 4 students identified as White/Caucasian (40%). Students reported their expected class standing for Fall 2016 as 2nd year (20%), 3rd year (40%), or 4th year (40%). Student ages ranged from 18-24 years old, with a median age of 20 and an average age of 20.6. Nine of the students agreed to participate in the interview.

Faculty Participants: Eight of the ten faculty mentoring REU students participated in the study. The faculty members who supervised the REU students were tenured or tenure-track faculty in the biomedical engineering department.

Results:

RQ 1: Students' conceptualization of research

Two major themes emerged from the interview data that helped to answer how students' conceptualizations of research changed following the REU. The two most frequently emergent themes included: 1) a broadened conception of research and 2) the cyclical nature of research.

Five of the nine students felt that research was *broader* than they had originally thought. Their broader conceptions came in different forms, from the variety of topics for the research projects to the methods used. The students had a better understanding of what research was and how it was conducted, and in many cases were surprised by how complex it could be. The following quote is an example of this theme:

> For some people, research means being in the lab and doing that stuff. And for some people, research is doing that and doing analytics on your computer. And then, for some people, it's like—one of my roommates is doing simulations on her computer all day. That's her research. And so, it's opened my eyes to like, there's tons of different kinds of research and different ways you can take it.

Also coded as part of *broader*, one student expressed how the experience helped her to realize how big the scope of research is and how much she doesn't know:

> Well, I didn't realize that there was a lot-- that there was all of this. It's pretty easy to be blind to a lot of things… I didn't realize the numerical analysis would help, or [how important it was]. I didn't even know that was a field of study before this…Because I have no idea now [laughter]…and now I know a lot more [laughter]. So…it has changed my view on research a lot.

Three of the students emphasized that research was a *cyclical*, nonlinear process. These students mentioned that they previously thought that the research process was a linear, step-by-step process. Their statements emphasize that they see research now as being nonlinear, and in some cases, a messy process. The following quotes exemplify this theme:

> I've always viewed [research] as a very linear process, like research, create experiment, test it, get results, go back. But the creative process is like research,

test it, go back, create it, go back. So, it's very-- I guess it's a lot messier than I thought it was, basically the creative process and the scientific method.

[The program showed] me that the scientific method is not necessarily a step-by-step process, it's more something you have to come back to …And I knew that to some extent, but sometimes you have to go back and completely change your entire question-- research question or what you're trying to investigate, which is something I might not have always realized…

Two students felt that the program did not impact their understanding of research. One of these students had participated in an REU previously, so already felt that he or she had a good understanding. The other student also felt that he or she already had a good understanding of research and did not feel that the program impacted that understanding.

RQ 2: Students' conceptualization of the relationship between research and the creative process

Three major themes emerged from the interview data that helped to answer how students' conceptualizations of the relationship between research and the creative process changed following the REU. The three most frequently emergent themes related to: 1) breaking misconceptions of creativity, 2) understanding the link between research and creativity, and 3) the impact on research activities. These are discussed below.

Students were specifically asked how learning about the creative process impacted their understanding of research. For this question, the theme of *breaking misconceptions of creativity* emerged in some student responses. As one student noted, he or she previously did not see research as being related to creativity. The student's statement reflects the frequent misconception of creativity as being related to art, rather than to engineering or the sciences. This student also recognizes that being creative in research involves a systematic process, rather than a freewheeling activity. The quote below illustrates this point:

Well, I wouldn't have said that research was creative before [laughter]. It's not exactly-- it's not the first thing that comes to mind when you think research. At least for me. But it's definitely there. And that it could save some time if you make some clever, clever decisions and choices. When I think creativity, I think art and things like that. But it's not—I don't think that transfers over the same to research. I think it's more—creativity and research seems to be more making clever decisions and thinking outside the box. Not so much just coming up with wild ideas and [laughter] throwing darts at the wall.

Similarly, another student said:

Initially, I thought creativity had to do with art majors and I thought that I wasn't creative at all but I think creativity is being able to—with research being able to come up with new parameters if something in your protocol fails, so yeah it helps you realize that creativity is not just about the arts, it's about being able to solve this and change this, yeah.

Relatedly, multiple students felt that the experience helped them to understand the *link between research and creativity*.

> I've been taught that [research is] supposed to be far more creative. There's a definite creative process that's supposed to be involved in research. They emphasize that several times throughout several workshops, so I've been doing my best to implement that into my work.

In this quote, the student suggests a realization of the focus on the program on creativity, although the tenor of the quote seems somewhat skeptical. This skepticism could stem perhaps from the fact that the student is a novice, or perhaps that he or she has not been able to truly participate in the creative aspects of the research process. Another student suggested the lack of creative tasks associated with the REU:

> I thought [the program] would be more like, you're handed a project, I think, and go with it, especially because this was the CREATE program. So I thought, oh, you're creating your own project based off of what you think you should do. But, we were kind of given a project and then told the steps of what to do.

Two students' responses were coded as *impact on research activities*. These students felt that learning about the creative process in the workshops helped them to consider aspects of the research in a different way. One student felt that learning about the creative process would be helpful in working on research back at his or her home institution. However, he or she did note that the opportunities to apply the creative process during the REU were limited as the project was already well structured.

> I really liked the creative process workshop that we did at the beginning…For me, I guess it more impacted my way of thinking about the research than it actually impacted my particular project this summer. I think it'll impact me more when I go back home to the lab that I'm going to than it will with this particular project. Just because this project was already given to me when I came and was already sort of outlined. I kind of had an idea of what I was doing at the beginning. So with this particular project—I mean, it came into play a couple times where I was like, "Okay, I can go back and brainstorm because that's the next step in the--" it came back to me a couple times.

The other student focused on the notion that the research and the scientific method is a cyclical, non-linear process and that creativity helps to make decisions about what to do when the research project is not going as planned. In this quote, the student recognizes that the scientific method include aspects of idea generation:

> Something I might not have always realized that maybe the best thing [to do] if something is not working [in a research project], just kind of go back and redefine the entire thing instead of trying to keep working at what you originally set out to do. So in that way, the creativity part would be coming in up with that new

idea [laughter] and using just different knowledge that you have in…trying to figure out that problem.

RQ 3: Faculty members' approaches to incorporating the creative process

The faculty were asked how their mentoring approaches had changed in order to incorporate the creative process into the REU student experience. The results of the responses were quite mixed. Three of the faculty said that they had explicitly addressed creativity during discussions with their students. For example, one faculty member, as described in the quote below, focused on discussions with the student to demonstrate the creative process when coming up with research ideas. In this quote, he or she acknowledges the fact that the student is a novice, while still giving opportunities for the student to provide innovative ideas in the research process:

> Initially it was explicit. So, when I would talk to them about the idea and going to the literature, that's where, you know, I would talk about creativity. Let's sort of think outside the box. You see what other people have done and you can't necessarily—science isn't about repeating what other people have done. You have to add to the literature. And so you have to think about that when you think about what would be the next steps…what else could we study? And to me that was an opportunity for a student to go to the literature and say, "Okay, my idea was thinking about how are these technologies being used clinically?" So, could they be creative to look at and review the literature, even though they're just getting used to the jargon and come back with some ideas…

Another faculty member specifically mentioned the training provided at the start of the REU, where the faculty mentors were presented with information on how to link creativity to the scientific method. The faculty member felt that thinking about how to incorporate creativity encouraged him or her to allow the REU student to be slightly more independent when coming up with research ideas:

> Yes. I would say I certainly paid attention to those elements of creativity probably more than I did in the past. Thinking about that chart that you had with winding it up with the scientific method…But the notion of allowing her to design her own project after having considered this and this, really, I was more opened to that then maybe I normally would have been. I normally might have been cautious about taking that risk with a student. Not a risk to me so much, but I wouldn't want a student to get through a summer and feel like they hadn't accomplished anything.

Finally, a third faculty member stated that he or she emphasized the idea of choice as it relates to the creative process. The quote below also demonstrates the notion that faculty were open to creativity being beyond arts and being applicable to disciplines that may seemingly be disparate:

> Every time that a choice had to be made, I emphasized the fact that choosing is part of the creative process and making sure that this is apparent to them, that this is— in fact, even in their own presentations in the end, they remarked, at least in a

broader level, the idea that mathematics is a creative enterprise--usually, those two things don't go together, but [the students] actually absorbed the concept that there is a lot more creativity than one might think in the creation of a mathematical model and even in the computer implementation of the model.

A few faculty did not feel they did anything differently than normal. One participant did feel that he or she already provided ample opportunities for students to be creative:

I didn't do anything different than I normally do. I like to give my students a lot of freedom. There's always a balance of guiding them and letting them—they have to have ownership of the project to do well. And so that involves the creative parts of problem-solving and troubleshooting and thinking about hypotheses and all of that. So, in terms of my research, I didn't change things, but it reinforced those ideas about allowing creativity being part of the research.

Faculty were asked how they addressed the program goals with the graduate students or post-docs working primarily with the REU students. Of the eight faculty, six mentioning having *direct conversations* with the graduate students. However, these conversations appeared generally to be somewhat *limited in scope*. The example quotes illustrate the types of conversations about the creative process that were conducted with the supervising graduate students:

I have some discussion with him, not a whole lot…I didn't follow up with the graduate student to see how much he had kind of implemented or put that in the discussion, but I think they both have that in mind.

I even printed that slide [from the faculty training session] to my grad student. Okay, this is the creative process…

I didn't have a very lengthy conversation. It was just sort of brief that we shouldn't be telling the students what to do.

I definitely mentioned it to [the graduate students]. I did not formally introduce some of the training that [the REU personnel] had introduced to us…

One faculty member acknowledged that no discussions had taken place with his or her graduate students who were supervising the REU student.

Students were also asked about their experiences with the faculty and the graduate student mentors. Their perceptions were varied, with some feeling that creativity was not emphasized by the research team. Four of the students specifically said that creativity was not explicitly discussed, as shown by the following example quotes:

I thought it was just understood within what the project is. Is like, oh, you have to be creative to come up with this CAD design. Yeah, so I don't think it was actually ever mentioned that, okay, you're trying to be more creative. I think it was already implied within the project that, okay, creativity is obviously involved.

Mostly we just talked about my experiments and I don't know if that's creative…

> Well, I don't think my mentor was aware of the program selling point was the creativity, honestly [laughter]. Neither my PI, I think. So yeah, I don't think they were aware of that.

Other students felt that the nature of the tasks assigned to them did not afford them with opportunities to be creative. One student felt that part of the reason for this concerned the nature of being a novice in the lab, as illustrated by the following statement:

> I guess I haven't had too much of a chance to be creative. Because a lot of this is over my head. And [the faculty member] is the one that's making the big decisions or the decisions that are that you can deem creative. Because I wouldn't even know where to begin [laughter].

Another student felt similarly, as shown below:

> Well, I still see myself as kind of like the same [in terms of creativity] I guess because I can't say I've really been super creative this summer. Because like I said, for the most part, I have been able to try to implement the creative process, but for the most part, I have been working with [the graduate student] on his main project.

Discussion

Research Experiences for Undergraduates (REU) programs allow for a focus on the professional skill set that can be challenging for instructors of technical engineering courses. This study examined the impact of a creativity-focused REU on students' conceptions of research and how it relates to the creative process. The results of the study indicated that the REU impacted students' conceptions of research, to be broader in scope and more cyclical than originally understood. The exception to these results were students who felt that they already had a good understanding of research. The results also suggest that students were better able to make the connection between the creative process and research and that the experience helped to break some misconceptions about creativity.

While the REU did seem to have impacts on conceptions of research and the creative process, students did not necessarily feel that the program helped them to be creative. They often felt that the tasks assigned to them did not allow them opportunities to use the creative process. One of the limits on the ability for students to utilize the creative process in the REU is the nature of the tasks that are assigned to them. Students are primarily asked to carry out tasks on an already crafted research project, which limits the steps of the creative process that can be applied, such as idea generation. A tension exists between providing opportunities for the REU students to be creative and the knowledge that it takes to be creative. This can be a challenge to faculty on how to help students generate new and valuable ideas in a discipline when they are novices. One of the hopes of the REU is that students will carry their knowledge of research and creativity into their future career paths, which potentially may include graduate school. A potential future research study could examine the long-term impacts of the REU on students' conceptions of research and the creative process.

The results of the study suggest that training increased faculty buy-in regarding the link between creativity and the scientific method. However, many faculty still do not fully incorporate strategies

or instruction relating to the creative process in the laboratory setting. The results suggest that the primary exposure to the creative process occur during the REU-sponsored workshops. However, for the most part, students need to make the connections between the workshop and their research project on their own. The guidance from the faculty and the supervising graduate student is limited in most cases.

In addition, the results suggest that graduate students tend to work most closely with the REU students, yet may not be aware of the focus of the REU on creativity. While we interviewed faculty, the undergraduates primarily worked with graduate students in the lab setting. This poses a problem to the implementation of the creative process, as the graduate students are likely less aware that the REU has a focus on creativity. For future years, leaders within the program may want to train the graduate students regarding what the REU is about and to discuss the relationship between research and the creative process.

The study has some limitations that need to be addressed. First, the sample size of both faculty and students for the interviews is fairly small, due to the size of the program. This small sample size makes the evaluators more dependent upon qualitative data, such as the interview data described here. Surveys have also been administered to the students before and after the REU experience, including measures of creative self-concept. However, a sample size of 10 does not provide enough statistical power to be able to capture differences before and after the REU experience. The interview data does provide rich description of individual students' experiences in the program, but readers need to be cautious about the generalizability of the responses. Another limitation of the program is the reliance on faculty and student perceptions. Future research may want to include a content analysis of student-created artifacts to see if there is evidence of the application of the creative process. Another possible research area, yet unexplored, concerns whether or not a focus on creativity in an REU setting might increase students' likelihood to explore graduate school as a potential path following graduation. Students, and women in particular, who see research as creative in nature might be more willing to explore this possibility.

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