Research Experiences for Undergraduates (REU) on Self-Regulated Learning in Engineering Education

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***Abstract*— Undergraduate research is one of the best practices to improve student learning and has a positive lasting impact on students' career choices and success. Extensive literature review shows that the vast majority of undergraduate research programs focus on Science, Technology, Engineering, and Mathematics (STEM) disciplinary research. This work-in-progress paper presents a new Research Experiences for Undergraduates (REU) Site program that focuses on STEM education research rather than STEM disciplinary research. This work-in-progress paper describes the overall framework of our REU Site program, student recruitment and selection in our most recent Summer 2015 program, and four REU research projects that share a common intellectual focus on self-regulated learning in engineering education. Representative comments from undergraduate student participants are provided to demonstrate the positive impact of this REU Site program.**

Keywords— Research Experiences for Undergraduates (REU); self-regulated learning; engineering education

I. INTRODUCTION

Extensive evidence [1-3] has shown that undergraduate research is one of the best practices to improve student learning and has a positive lasting impact on students' career choices and success. For example, Craney et al. [1] recently conducted a longitudinal research study to examine the benefits, outcomes, and goals for undergraduate research across disciplinary area and academic class standing. They reported that there exists a positive association between undergraduate research participants and their long-term achievement, as measured by higher graduation rates and higher number of national awards they received.

To foster and promote undergraduate research, the U.S. National Science Foundation has established a Research Experiences for Undergraduates (REU) program. The program sponsors undergraduate research in two ways [4]: 1) providing a small amount of supplemental funds to existing grant awards to involve one or two undergraduate students in research during the grant award period; and 2) providing a substantial amount of funds to establish a stand-alone REU Site program to involve eight to ten undergraduate researchers each year for up to three years. Lucena and Leydens [5] recently reported that the NSF has sponsored more than 640 REU Site programs since 1987. However, the vast majority of REU Site programs focus on disciplinary research in Science, Technology, Engineering, and Mathematics (STEM), such as research in mechanical engineering, electrical engineering, mathematics, and physical sciences. REU Site programs focusing on STEM education research have only recently become available.

The authors of this paper have conducted a systematic literature review using a variety of popular databases, such as the Education Resources Information Center, Science Citation Index, Social Science Citation Index, Engineering Citation Index, Academic Search Premier, the ASEE annual conference proceedings (1995-2015), and the ASEE/IEEE Frontier in Education conference proceedings (1995-2015). The results of our independent literature review confirm Lucena and Leydens's findings [5] that the vast majority of undergraduate research programs focuses on STEM disciplinary research, such as electrical engineering [6], software engineering [7], manufacturing [8], and nanotechnology [9]. To date, there exists little literature on REU Site programs that focus on engineering education research.

This work-in-progress paper is submitted for presentation at the FIE conference under the category of Innovative Practices. Our practices are innovative because our REU Site program focuses on STEM education research, particularly on engineering education research, rather than on STEM disciplinary research. The overall goal of our REU Site program is to motivate and retain talented undergraduates in STEM careers, particularly careers in teaching and STEM education research. The intended outcomes (expectations) of the program are: 1) the REU students develop fundamental understanding and skills for engineering education research, and 2) the REU students not only conduct research on self-regulate learning, but also practice self-regulated learning during their own "learning through research" processes. The preliminary results of student assessments conducted at the end of our program (see Section V) show that the program has achieved its intended outcomes.

In this work-in-progress paper, the overall framework of our REU Site program is introduced first. Then, student recruitment and selection in our most recent Summer 2015 program are described. Next, four REU research projects are described. These four research projects share a common intellectual focus and form the key component of our REU Site program. Student comments on their experience with this REU

Site program are also presented. The limitation of this study and future work are discussed in the Concluding Remarks section of this paper.

II. Overall Framework of this REU Site Program

Over a three-year project period, a total of 24 undergraduate students (eight students per year) are recruited from across the country to come to our university campus to participate in the 10-week REU Site program over the summer. The REU students have diverse backgrounds and experiences and major in different STEM disciplines. REU students participate in a variety of activities particularly designed to improve their technical skills (i.e., education research skills) as well as teamwork and communication skills. Table I shows the overall schedule of the 10-week summer activities of the REU Site program, which are described in the following paragraphs.

REU research projects: Two REU students form a research team and work on a particular research project. Each REU team is mentored by a faculty mentor and a graduate student mentor. These research projects will be described in a subsequent section titled IV REU research projects.

Orientation: On the first day of the summer program, we conducted orientation to introduce the REU program activities and all faculty, staff, and graduate students involved. Particularly, we conveyed what the REU students were expected to accomplish by the end of the 10-week program.

Seminars: A total of nine seminars were offered throughout the summer program on a variety of topics: No. 1: what self-regulated learning is; No. 2: educational data analysis with SPSS; No. 3: developing an educational research question; No. 4: a brief introduction to qualitative methods; No. 5: responsible research; Nos. 6-9: presentations of each of the four REU student groups on their own research projects.

Weekly reflections and debriefing: At the end of each week, REU students reflected on what they had learned during that week. As REU students conducted research on self-regulated learning, they also reflected on how they practice self-regulated learning in their research and daily life.

Focus group interviews: Both at the beginning and near the end of the summer program, focus group interviews were conducted to solicit student comments on this REU Site program.

The final symposium: Near the end of the summer program, the final symposium was held for all REU students to present their research findings. They submitted a final project report to their faculty mentors by the end of the last (i.e., 10^{th}) week of the program.

III. Student Recruitment and Selection

We advertised our REU Site program via a variety of channels including email distributions to targeted institutions, a variety of list serves, and personal contacts. In the most recent Summer 2015 program, we received 57 applications from 22 states across the country, among which 46 were complete with all required documents, including the application form, purpose statement, resume, unofficial transcript, and two letters of references. Based on a comprehensive rubric, eight applicants were selected to participate in our Summer 2015 program.

TABLE I. Overall Schedule of 10-Week Summer Activities of This REU Site Program

Week No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
REU research projects	√	√	√	√	√	√	√	√	√	+
Orientation	√									
Seminars (No.)	1-3	4	5		6	7	8	9		
Weekly reflections and debriefing	√	√	√	√	√	√	√	√	√	
Focus group interviews	√								√	
The final symposium									√	

Note: + Final project report due

Figure 1 shows the histogram of graduate point average (GPA) of these 46 applicants. The average GPA of these 46 applicants is 3.43 with a standard deviation of 0.46. The average credit hours they had completed prior to application is 68 with a standard deviation of 35.

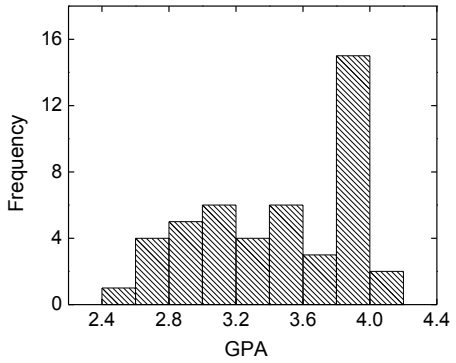

Fig. 1. Histogram of the applicants' GPA

Table II and III show student demographics of the 46 applicants. Female applicants accounted for 58.7% (see Table II). A significant percentage of racial minority students (see Table III) also applied for this REU Site program. Recently, a number of national education initiatives in the United States have been proposed to increase the number of women and minority students to diversify the STEM workforce. Our program positively responded to national education initiatives.

TABLE II. Student Demographics: Gender

Total number of applicants	**Male**	**Female**
n = 46	19 (41.3%)	27 (58.7%)

TABLE III. STUDENT DEMOGRAPHICS: ETHNICS

White	Asian/Pacific Islander	African American	Hispanic	Other
26 (56.5%)	10 (21.7%)	5 (10.9%)	3 (7.5%)	2 (4.3%)

IV. REU RESEARCH PROJECTS

REU research projects are the key component of our REU Site program. To provide REU students a coherent research experience, we have designed four REU research projects that share a common intellectual focus on self-regulated learning in engineering education. Self-regulated learning is learners' "self-generated thoughts, feelings, and actions which are systematically oriented toward attainment of their goals" [10]. Extensive research evidence has shown that self-regulated learning plays a significant effect on student academic success across disciplines, gender, and ethnicity [11, 12]. These four REU research projects are briefly described below.

REU research project #1 aims to understand how student's self-regulation strategies are used in problem solving. This research has the following hypothesis: students with experience in applying a computational thinking strategy use different self-regulation strategies than less experienced ones. Under the guidance of a faculty mentor and a graduate student mentor, REU students learned to collect and analyze data of undergraduate and graduate student participants solving daily, computational problems using a verbal protocol technique.

REU research project #2 aims to study the effect of computer simulation and animation on students' meta-cognitive skills in a foundational engineering dynamics course. The research question is as follows: How does computer simulation and animation affect students' meta-cognitive skills in learning and problem solving in engineering dynamics? REU students worked with their faculty mentor and graduate student mentor to conduct qualitative research including data transcription, coding, and analysis.

REU research project #3 aims to understand correlations between Conceptual Design Blending (which is a teaching intervention delivered in engineering graphics solid modeling courses), creativity, mindsets, and spatial thinking in engineering mechanics. REU students worked with their faculty mentor and graduate student mentor to conduct quantitative research to study the potential relationship between Conceptual Design Blending, a student's perception of their potential to succeed in engineering (mindset), creativity, and spatial thinking.

REU research project #4 aims to explore the strategies employed by undergraduate students who undergo a research experience for the first time. This research parallels recent work using qualitative and quantitative measures to explore student engagement during professional development activities in the classroom. Working closely with their faculty mentor and graduate student mentor, REU students learned about mixed methods design, how to create and conduct interviews and surveys, and how to collect and analyze data sets through transcription and coding methods.

In addition to the overall program schedule shown in Table I that applies to all REU students, each REU research project has its own weekly schedule due to its own research focus. Student research activities varied from project to project. Table IV shows an example weekly schedule of a representative REU research project.

TABLE IV. EXAMPLE WEEKLY SCHEDULE OF A REPRESENTATIVE REU RESEARCH PROJECT

Week (No.)	Student activities	Reports submitted to the faculty mentor
1	• Attend seminars Nos. 1-3 • Review 10 articles on meta-cognition and self-regulated learning (seven articles provided by the faculty mentor and three articles found by each REU student) • Learn how to create annotated bibliography (i.e. synopsis) • Learn qualitative research methods • Learn how to code	A report containing at least five synopses of articles on meta-cognition and self-regulated learning
2	• Attend seminar No. 4 • Review 10 articles on problem solving and think-aloud methodology (seven articles provided by the faculty mentor and three articles found by each REU student) • Create annotated bibliography (synopsis) • Learn qualitative research methods • Learn how to code	A report containing at least five synopses of articles on problem solving and think-aloud methodology
3	• Attend seminar No. 5 • Code relevant transcripts	A report containing what the REU student has learned during the last three weeks
4	• Code relevant transcripts	
5	• Attend seminar No. 6 • Code relevant transcripts	
6	• Attend seminar No. 7 • Analyze the codes, revisit the coding, review and discuss implications and conclusions	A report containing the preliminary research results
7	• Conduct seminar No. 8 • Analyze the codes, revisit the coding, review and discuss implications and conclusions	
8	• Attend seminar No. 9 • Analyze the codes, revisit the coding, review and discuss implications and conclusions	
9	• Analyze the codes, revisit the coding, review and discuss implications and conclusions Make a PowerPoint presentation about the research results at the final symposium	
10	• Write the final project report	The final project report

In this research project (i.e., project #2 described above), qualitative research methods including coding and analysis were employed. Our method of training REU students to conduct qualitative research is "learning by doing." Weekly meetings were held throughout the summer program to discuss research results. The REU students were able to form strong relationships with their faculty mentor and graduate student mentors through consistent, professional interactions

V. Student comments

At the end of the program, REU students provided positive comments on their experience with this REU Site program. The results show that the program achieved its intended outcomes. The REU students not only learned how to conduct rigorous research on self-regulate learning, but also practiced self-regulated learning while conducting research. Representative student comments are listed below.

Student #1: "One valuable experience that I encountered was learning the process of research. This experience made me consider going into educational research after doing a few years of teaching. Another valuable experience that I encountered was learning about self-regulated learning. ... I also liked that we had to self-regulate ourselves during the process of doing the research."

Student #2: "One of my most valuable experiences didn't exactly directly come from the research part of the program, but instead it came from meeting the people I was surrounded by. Both the other researchers and the people I met out here in Utah have molded me into more of who I am. I was able to discover some real things about myself and my life and have experiences I never even imagined I would have this summer being so far from home."

Student #3: "I have learned an incredible amount about research in general, and specifically qualitative research, about myself, and about working with others on a team. Before coming here, I had read many research papers for my physics and education studies, some qualitative and some quantitative, but I never understood what exactly qualitative research entailed....I loved being able to feel comfortable talking to [my mentors]. It is one of the best experiences I have ever had working with a professor. They were interest in me, my learning, and our research."

Student #4: "The first thing I learned from this project was how to do conduct qualitative research. I learned that I should always back up my claims, methods, and results. The second thing I learned about research, and specifically qualitative research, is that I should be open to seeing the project from other peoples' points of view. This will allow me to get a better overall feel for the research and improve the quality of my work… I also realized that coming to know my coworkers outside of work helped me to understand how to work more effectively with them at work."

Student #5: "I learned a lot about what self-regulated learning is and how to apply self-regulated learning to my own learning to help me improve as a student. I also learned a great deal about the research process and how all of the steps of that process work. I especially learned a lot about qualitative research and how to accurately code data related to a qualitative research project....Among all of these things, I also learned a great deal about myself and how well I work in various situations, as well as how good I am at working hard on a project and putting my all into what I am doing."

Student #6: "I have realized that Educational Research is more than just observing how students learn. When I first arrived, I thought that I would be interviewing students in order to see how they learned a particular topic. Counter to my initial belief, Educational Research involves scrutinizing responses, and coming to a tough agreement with a research partner. It involves so much more communication than I previously thought."

Student #7: "The process of educational research is very rigorous and systematic. It is very important to interpret the results and the findings of educational research within the context they were discovered... Being involved in a research project allows you to learn so much not only about your field, but also about yourself."

Student #8: "I learned that engineering education is fun, fascinating, relevant, important, and approachable. I definitely want to go into engineering education research!"

VI. Concluding remarks and future work

This paper has described an innovative practice to provide undergraduate students with research experiences. Our REU Site program is innovative due to its focus on STEM education research rather than STEM disciplinary research on which tremendous literature is available. REU students have provided positive comments on their experience with our REU Site program.

In this work-in-progress study, assessments of student learning outcomes primarily relied on student comments. No analysis was yet conducted to assess student learning outcomes in pre-post tests. Future analysis will be focusing on using pre-post tests to determine to what extent REU students have learned to conduct STEM education research.

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