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Self-Regulated Learning in Engineering Education: A Research Experiences for Undergraduates (REU) Site Program

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Self-Regulated Learning in Engineering Education: A Research Experiences for Undergraduates (REU) Site Program

Abstract

This paper reports the most recent results of an ongoing Research Experiences for Undergraduates (REU) Site program funded by the NSF TUES-Type 1 funds. The 10-week summer program focuses on engineering education research on self-regulated learning. After a brief description of Butler and Cartier's model of self-regulated learning, which lays a theoretical foundation for this REU Site program, this paper provides an overview of the program and details of student recruitment and selection. The paper describes a variety of activities catered and designed for students, including orientation, seminar series, and the final symposium. Also described are four new REU research projects that share a common intellectual focus: self-regulated learning in engineering education. Each REU research project included two REU students, a graduate student mentor, and a faculty mentor. The lessons learned in our Summer 2014 program were applied in Summer 2015 to continuously improve the quality of this program. An independent evaluator provided both formative and summative assessments for this REU Site program. The results of program evaluation are reported in this paper.

Background Introduction

Undergraduate research has received growing attention in recent years due to its positive impact in STEM (science, technology, engineering, and mathematics) education, such as increasing students' understanding, confidence, awareness, and interest of STEM subjects. [1-4] In addition to providing supplemental funds to involve undergraduate students in existing grant awards, the National Science Foundation (NSF) provides funds to support Research Experiences for Undergraduates (REU) Site programs, which typically involve 8-10 REU students per year for three years at a hosting institution of higher learning. [5]

Lucena and Leydens [6] recently reported that more than 640 REU Site programs have been funded by the NSF REU program. The vast majority of these NSF-funded REU programs focus on a variety of disciplinary topics, such as neural engineering [7], energy [8], telematics and cyber physical systems [9], fuel cells [10], bioengineering [11], wireless integrated microsystems [12], and reconfigurable manufacturing systems [13]. Only recently has the NSF started to support REU Site programs that focus on STEM education research, i.e., education research in the context of STEM disciplines.

This paper reports the most recent results of our ongoing NSF-funded REU Site program that focus on engineering education research of self-regulated learning. Each year during a three-year program period, eight undergraduate students are recruited from across the nation to come to the authors' institution to conduct 10-weeks of summer engineering education research. The results of our program activities in Summer 2014 have been reported in the 2015 ASEE Annual Conference and Expositions. [14] This paper reports the updated results of our program activities in Summer 2015, including new REU research projects and the activities that were modified or newly designed to address the lessons learned in Summer 2014.

In this paper, the theoretical foundation of our REU site program is briefly introduced first, followed by an overview of the program. Then, student recruitment and selection methods are described. Presented next are a variety of activities focused and designed for students, including orientation, seminar series, and the final symposium. Also described are four new REU research projects that share a common intellectual focus: self-regulated learning in engineering education. The results of program evaluation are presented. Conclusions are presented at the end of the paper.

Butler and Cartier's Model of Self-Regulated Learning (SRL)

According to Zimmerman [15], self-regulated learning (SRL) is learners' "self-generated thoughts, feelings, and actions which are systematically oriented toward attainment of their goals." Extensive research [16-18] has been conducted to study its impact on student learning. Various models have also been developed for SRL. [15-16]

Our REU Site program is built upon Butler and Cartier's socio-constructivist model of self-regulation. [19-21] Butler and Cartier's model enables the investigation of the interplay between metacognitive knowledge and metacognitive control within the context of complex learning activity. Their model depicts eight features that interact with each other to shape engagement in learning: layers of context, what background knowledge and experiences individuals bring, mediating variables, task interpretation, personal objectives, SRL processes, cognitive strategies, and performance criteria. These eight features are briefly described in the following paragraphs.

- First, layers of context refer to the learning environments, such as school, classroom, and instructional approaches, in which students engage in learning.
- Second, students bring to those contexts strengths, challenges, and interests that shape their engagement.
- Third, examples of variables that mediate student engagement in a learning task include students' concepts of academic work, derived through prior experience, metacognitive knowledge, self-perceptions and emotions.
- Fourth, task interpretation shapes key dynamic and recursive self-regulating processes.
- Fifth, students set personal objectives that shape their engagement based upon their interpretation of task demands within a particular context.
- Sixth, in light of their task interpretations and personal objectives, students manage to engage in academic work using a variety of self-regulating strategies: planning, monitoring, evaluating, and adjusting approaches to learning.
- Seventh, students' use of cognitive strategies is situated in the context of cycles of dynamic, iterative, self-regulating activities.
- Eighth, as part of the monitoring effort and in an ongoing way, students compare outcomes that emerge through their activity with internal or external standards.

Overview of the REU Site Program

This REU Site program aims to motivate and retain talented undergraduates in STEM careers, particularly careers in teaching and STEM education research. Each year over a three-year project period, eight undergraduate students from across the nation are recruited to participate in our program in summer. The REU students have diverse backgrounds and experiences and major in different STEM disciplines. Two REU students form a research team and work on a particular research project. Each REU team is mentored by a graduate student mentor and a faculty mentor. REU students participate in a variety of activities particularly designed to improve their technical skills as well as teamwork and communication skills. Formative assessments are administrated during the program, and summative assessments are administrated at the end of the program. The following sections describe three key elements of the program: 1) student recruitment and selection; 2) orientation, seminars, and the final symposium; and 3) REU research projects.

Student Recruitment and Selection

In Summer 2015, 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. We received a total of 57 applications among which 46 were complete with all required documents, including the application form, purpose statement, resume, unofficial transcript, and two letters of references. All documents are submitted online.

The 46 complete applicants included 27 (58.7%) females and 19 (41.3%) males. Table 1 shows the demographic locations of the 46 complete applications from a total of 22 states across the nation.

Table 1. The demographic locations of the 46 complete applications

State	Number of applicants	State	Number of applicants	State	Number of applicants
Arizona	1	Louisiana	1	Oregon	1
Alabama	1	Massachusetts	2	Tennessee	1
California	6	Maryland	2	Texas	1
Florida	3	Michigan	5	Utah	2
Georgia	3	New York	3	Vermont	1
Idaho	2	Ohio	2	Washington	2
Illinois	2	Oklahoma	1	Wisconsin	2
Indiana	2				

Figures 1 and 2 show the histograms of the 46 applicants' GPA (grade point average) and credit hours they had taken prior to applying for our REU Site program, respectively. The average GPA of the applicants was 3.43 with a standard deviation of 0.46. The applicants had taken an average of 68 credit hours with a standard deviation of 35.

The student applicants have diverse backgrounds and experiences. They major in a variety of STEM disciplines, such as aerospace engineering, biology, biomedical engineering, chemical engineering, chemistry, computer reengineering, electrical engineering, general engineering, geology, industrial and system engineering, mechanical engineering, and robotics technology. Students in STEM education majors, such as math education as well as chemistry and physics education, also applied to our program.

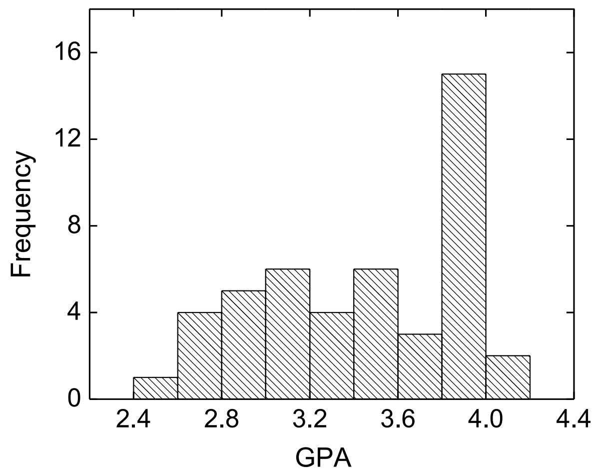

Figure 1. Histogram of the applicants' GPA

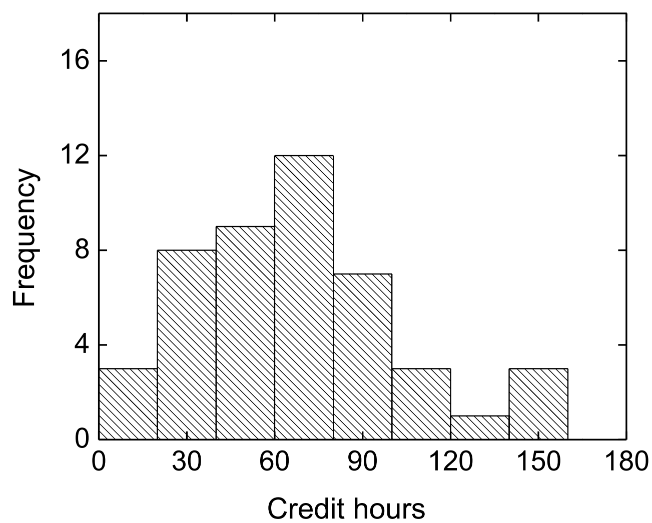

Figure 2. Histogram of the credit hours the applicants had taken prior to the application

Based on a comprehensive evaluation of student application, eight students were finally selected to participate in our Summer 2015 program. These eight students included one student from the authors' institution and seven students from outside. The internal student provided great assistance in getting outside students familiar with our institution's research facilities and local environments.

Orientation, Seminars, and the Final Symposium

After REU students arrived at the campus, we offered an orientation session to introduce the REU program activities (such as REU research projects) 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. During the program, a series of seminars were held either to prepare students for education research, or to provide additional opportunities for REU students to practice their communication skills. At the end of program, REU students orally presented their research results in the final symposium, and each REU student submitted his/her final report to his/her respective faculty mentor.

The weekly activities for orientation, seminars, and the final symposium are listed in Table 2. We applied one important lesson we learned from the Summer 2014 activities to the 2015 activities by moving the five faculty-hold seminar series to the first three weeks of the program, as indicated in Weeks 1-3 in Table 2. In Summer 2014, the five faculty-hold seminar series were offered every other week, and REU students reported that these seminars were offered too late for them to know how to best conduct education research.

Another important activity added to the Summer 2015 program was a seminar that each REU student team offered on their research project (see Weeks 5-8 in Table 2 on next page). The purpose was to provide students an opportunity 1) to share research methods and findings, so they could learn from each other; and 2) to improve their verbal communication skills.

Four REU Research Projects

The central key component of our REU Site program is REU research projects. The following paragraphs describe four new REU research projects we particularly designed for Summer 2015.

REU Research Project 1: The Role of Self-Regulation in Problem-Solving Activities using Computational Thinking Strategies: A Preliminary Study

This research provides REU students authentic experience conducting engineering education research and a deeper understanding of self-regulation in problem-solving. The goal of this research is to understand how students' self-regulation strategies are used while solving a problem. The specific focus of this research is on the use of self-regulation strategies commonly applied to solve problems requiring "recursive and non-recursive mechanism." Thinking recursively is one of the strategies of computational thinking. Computational thinking is popularly defined as a way of solving problems, designing systems, and understanding human behavior that draws on concepts fundamental to computer science. The hypothesis of this research is that students with experience in applying a computational thinking strategy will use different self-regulation strategies than less experienced ones.

REU Research Project 2: Effect of Computer Simulation and Animation on Students' Motivation, Self-Regulation, and Cognitive Strategies in Engineering Dynamics

The research focuses on a particular computer simulation and animation (CSA) learning module

Table 2. Weekly activities for orientation, seminars, and the final symposium

Week	Activities	Speaker
1	Orientation: Welcome, introduction to four REU research projects, and expectations	All faculty mentors
1	Seminar 1: Self-regulated learning: What is it?	Faculty mentor 1
1	Seminar 2: Educational data analysis with SPSS	Faculty mentor 2
1	Seminar 3: Developing an educational research question	Faculty mentor 2
2	Seminar 4: A brief introduction to qualitative methods	Faculty mentor 3
3	Seminar 5: Responsible research	Faculty mentor 4
5	Seminar 6: The role of self-regulation in problem-solving activities using computational thinking strategies	REU student team 1
6	Seminar 7: Conceptual design blending and its impact on creativity, spatial ability, and mindset	REU student team 2
7	Seminar 8: Computer simulation and animation: Metacognition during learning and problem-solving	REU student team 3
8	Seminar 9: Design heuristics: A qualitative research study in engineering education	REU student team 4
9	Final symposium: Oral presentation of results of each REU project	All four REU student teams
10	Final project report: Witten report submitted to faculty mentors	Each individual REU student

on the Principle of Angular Impulse and Momentum, which was particularly designed for Engineering Dynamics, a foundational yet difficult undergraduate engineering course. The overall goal is to study the effect of computer simulation and animation (CSA) on students' metacognitive skills in engineering dynamics. One important research question is: How does computer simulation and animation affect students' meta-cognitive skills in learning and problem solving in engineering dynamics? REU students, working in a pair with a graduate student mentor and a faculty mentor, conduct qualitative research including data transcription, coding, and analysis.

REU Research Project 3: Mindsets and Spatial Thinking in Engineering Mechanics

The target of this REU project involves the understanding of correlations between Conceptual Design Blending (a teaching intervention delivered in engineering graphics solid modeling courses), creativity, mindsets (i.e., students' perception of their potential to succeed in engineering), and spatial thinking in engineering mechanics. Spatial thinking refers to thinking that finds meaning in the shape, size, orientation, location, direction or trajectory, of objects, processes or phenomena, or the relative positions in space of multiple objects, processes or phenomena. In one application, mindsets focus around an individual's desire to persist working towards a goal when faced with adversity. Mindsets have impacts upon success. This REU project aims to target and discover any relationship that may exist between Conceptual Design Blending, student mindsets, creativity, and spatial thinking.

REU Research Project 4: Use of Design Heuristics to Identify Creative Blocks during Problem-Solving of Engineering Design Student Projects: A Qualitative Study

The goal of this research was to understand how design heuristics (mental representation of design approaches) impeded or improved ideation of engineering design projects for a service learning project. The research questions to be studied were as follows: What influence does the use of Design Heuristic Cards have on freshmen engineering students' design strategies? What aspects blocked creative processes during engineering students' design strategies? The research exposed to two undergraduate students to the principles of qualitative research, the concept of coding for inter-reliability of interpreted information, the importance of Institutional Review Board considerations and ethical handling of information, and ensured that the REU students were communicating and cross-talking ideas and concepts during emergent themes.

Assessment of Students' Experiences

An independent evaluator assessed students' experiences with the REU Site program as well as the impact of this program on students. The overall purpose of the evaluation was to provide insights into what students had learned from this unique program that focused on engineering education research (rather than on engineering research), and what other engineering educators and education researchers could take away from the program results to assist with their efforts. Both formative and summative assessments were conducted, involving the use of electronic questionnaire surveys (via Survey Monkey) and face-to-face interviews. The assessments focused on both non-technical (e.g., logistic) and technical (i.e., learning) aspects of students' experiences with this program.

In the non-technical aspect of students' experiences, students reported that they received sufficient information regarding the program, housing, and technical and financial details prior to arriving on the Site. The students were very glad to have a student from the host institution as part of the group, and this person was very helpful in acclimating students to the campus and community. Regarding to lodging and meal accommodations, students' responses to likert-type scale questions (Great, Acceptable, Mostly Acceptable, and I have concerns) were: great (five students), acceptable (two students), and mostly acceptable (one student). A few students commented on the limited meal options available on campus during the summer and especially on the weekends.

In the technical (i.e., learning) aspect of students' experiences, one open-ended survey item was, "Do you feel that the Research Project you are working on has served to increase or decrease your motivation and confidence for continuing to engage in educational research?" Seven of the eight students responded to this item and indicated that the research project increased their motivation and confidence. One student was particularly excited about continuing to do education research when starting graduate school. Several students expressed their interest in teaching in a STEM (science, technology, engineering, and mathematics) field.

Students were also asked to "describe one or two things that you have learned from this Summer REU Program thus far." Four of the eight students reported that they learned a lot about working with other people in an "agreeable and efficient" way, as one student phrased it. Other students talked about learning the steps of the educational research process and expressed that they had learned the skills necessary to work with qualitative data analyses. They learned the importance of having a theoretical framework, drawing meaning from the data, and telling a coherent story.

Representative student comments are provided in the following paragraphs. These comments describe a variety of program activities in which the students participated, such as how to conduct education research and how to work on a team.

- "I never thought I would enjoy conducting research as much as I did this summer while learning about different aspects of research - developing research questions, selecting research method (i.e. qualitative, quantitative, mixed method), designing research questions and/or selecting tests, surveys to use, IRB approval, and grant proposal for funding."

- "I had worked on team projects prior to this experience; however, none were quite as in-depth and long-lasting as this one. …... By working with a partner and realizing the difficulties of dealing with two, sometimes opposing, opinions, I developed many traits in myself that I didn't previously recognize any use for."

- "I also have learned a lot about myself through this experience, which I find incredibly valuable. ….. At first, I was very overwhelmed by all of the literature that I was reading and how I felt like I forgot all that I read immediately after I put the paper away. Through practice, I was able to learn to read articles differently and more quickly, looking for the main points."

- "Seminars at the beginning of the research project were very informative; I learned a multitude of things about research in general….. I, throughout the summer, learned many valuable things about myself. This experienced opened my eyes to my strengths, weaknesses, likes, dislikes, and much more. I discovered things about myself I had not known or reflected upon before."

Concluding Remarks

This paper has reported the most recent results of our ongoing REU Site program that focuses on engineering education research on self-regulated learning. In Summer 2015, eight talented students were selected from a total of 46 complete applicants to participate in our program. Based on lessons learned from Summer 2014, we moved the five faculty-held seminar series to the first three weeks of the program to better prepare students for education research. In addition, each REU student team offered a seminar on their research projects, so they could learn from each other by sharing research methods and findings. This paper has also described four new REU research projects designed for Summer 2015 and the results of the program evaluation. Students provided positive comments on their experiences with our program.

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