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# A Research Experiences for Undergraduates (REU) Site Program on Engineering Education Research*

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This paper describes a U.S. National Science Foundation-funded Research Experiences for Undergraduates (REU) Site program that aims to provide undergraduate students with experiences in engineering education research (i.e., education research in the context of engineering). This paper provides an overview of the program and briefly describes the common intellectual focus of this REU Site program. Over the past two years, a total of 16 undergraduate students, seven graduate mentors, and five faculty mentors have actively participated in the program. Four important components of the program are described in this paper, including student recruitment and selection, REU seminars, weekly reflections, and REU research projects. The results of the project evaluation show that the program has made a positive impact on increasing education research skills and communication skills of the participating REU students. Eighty percent of the participating REU students reported that the research projects they worked increased their motivation and confidence for continuing to engage in engineering education research.

**Keywords:** Research Experiences for Undergraduates (REU); REU Site program; engineering education research; self-regulated learning

## 1. Introduction

### *1.1 Undergraduate research and its impacts*

Involving undergraduate students in academic research, namely undergraduate research, has been identified as one of the most effective educational practices to have a significant and lasting impact on students' academic performance, confidence, and career paths [1–4]. Based on their extensive surveys involving 15,000 respondents (undergraduates, faculty, graduate students, and postdoctoral mentors), Russell et al. [5] reported that undergraduate research profoundly increased students' understanding, confidence, and interest in science, technology, engineering, and mathematics (STEM) education as well as the pursuit of STEM graduate degrees. Zydney et al. [6] focused a study on the impact of undergraduate research experience in engineering by surveying engineering alumni who had undergraduate research experience and who did not have undergraduate research experience. Compared to those who had no undergraduate research experience, the engineering alumni who had participated in undergraduate research reported "a significantly greater enhancement of their ability to speak effectively, understand scientific findings, know literature of merit in the field, and possess clear career goals" [6].

### *1.2 Innovations of this REU Site program*

Undergraduate students can gain their research experience either as a volunteer in a faculty member's laboratory or by participating in an undergraduate research program that his/her institution or funding agency establishes [7–11]. In the U.S., a number of federal funding agencies and professional societies, such as the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the National Institutes of Health (NIH) have established education programs aiming to sponsor undergraduate research.

The NSF, one of the primary federal funding agencies, sponsors undergraduate research in two ways [12]: (1) by 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) by providing a substantial amount of funds to establish a stand-alone Research Experiences for Undergraduates (REU) Site program to involve eight to ten undergraduate researchers each year for up to three years, i.e., 24 to 30 undergraduate researchers. Lucena and Leydens [13] recently reported that the NSF has sponsored more than 640 REU Site programs since 1987. However, REU Site programs that focus on STEM education research, i.e., education research in the context of STEM disciplines, has not become available until recently.

This paper deals with an REU Site program that focuses on engineering education research. Recent years have seen a growing trend for engineering education to become a new discipline parallel to traditional engineering disciplines, such as mechanical engineering, civil engineering, and electrical

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engineering [14]. As a result, engineering education research (i.e., education research in the context of engineering) has also received growing attention in recent years [15–17]. Research areas in engineering education include engineering epistemologies, engineering learning mechanisms, engineering learning systems, engineering diversity and inclusiveness, and engineering assessment [14].

We conducted an extensive 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 (1995–2014) to ascertain areas of undergraduate research focus within engineering. The results show that the vast majority of undergraduate research programs in engineering focuses on disciplinary research, such as electrical engineering [18], bioengineering [19], environmental engineering [20], software engineering [21], manufacturing [22], nanotechnology [23], and neural engineering [24]. The activities of our REU Site program are similar to those of other REU programs because our program also includes a set of common activities, such as weekly meetings, group discussions, and seminar series, to increase student-student and faculty-student interactions. However, the intellectual focus of our REU Site program is significantly different from that of other REU programs because our program provides undergraduate students with engineering education research experience, rather than engineering research experience.

In addition to providing undergraduate students with engineering education research experiences, another innovation that our REU site program makes concerns integrating research with practice. The undergraduate students involved in our study not only conducted engineering education research on self-regulated learning, but also practiced self-regulated learning via weekly reflections during their research.

### *1.3 The structure of this paper*

In the reminder of this paper, an overview of our REU Site program is provided. Then, the central intellectual focus of our REU Site program—self-regulated learning in engineering education—is briefly introduced. Four important components of the program are described next, including student recruitment and selection, REU research projects, REU seminars, and student practiced self-regulated learning via weekly reflections. The results of project evaluation are also presented, followed by concluding remarks.

## 2. Overview of the REU site program

The overall goal of our REU Site program is to motivate and retain talented undergraduates in STEM careers, particularly careers in teaching and engineering education research. The objectives of the program are:

- Expose REU students, especially those who might not otherwise have the research opportunity as well as those from historically underrepresented groups in STEM (female and ethnic minority), to cutting-edge engineering education research.
- Stimulate participating REU students to pursue graduate degrees and careers in teaching and engineering education research.
- Develop each REU student's technical, communication, and teamwork skills by actively engaging him/her in all aspects of educational research—from literature review, research methods, data collection and analysis, to technical writing and oral presentations.
- Create a supportive educational community that involves REU students, graduate students, faculty mentors, and education professionals and administrators to promote STEM education in general and engineering education in particular.
- Evaluate the effectiveness of this REU Site program and broadly disseminate student research findings as well as the program results to the STEM research and education community nationwide.

Over a three-year program period, 24 REU students (eight students per year) from across the U.S. are selected to come to the authors' institution to conduct engineering education research for 10 weeks during summer (June, July and August). REU students work with a group of faculty mentors and graduate student mentors on a series of ongoing research projects that share a common intellectual focus—self-regulated learning in engineering education. REU students participate in a series of seminars specifically designed to increase their education research skills and communication skills. REU students also participate in weekly reflections designed to integrate research into practice. At the end of the program, REU students present their research results at the final symposium and submit a written project report.

To date, the program has been held twice: in Summer 2014 and Summer 2015. Table A1 in the appendix shows an example timetable of the Summer 2015 program, including advertising and recruitment, application deadline, student selection, and 10-week summer activities. The detailed time-

table of the 10-week summer activities is shown in Table A2 in the appendix.

Note that our vision is not merely to involve REU students in emerging engineering education research, but also to train students to become active scientific contributors through independent, high-quality research that can lead to publishable discoveries. ''Independent'' does not mean without any guidance from mentors. Instead, each REU student is assigned a faculty mentor and a graduate student mentor to provide the correct research direction and focus, so all students have the opportunity to produce meaningful results. Our faculty mentor team is diverse, including senior and junior faculty, male and female faculty, and both engineering and educationally trained researchers. All REU research projects are part of ongoing, active research programs, so each REU student becomes part of an existing research team.

## 3. A Brief introduction to self-regulated learning

As mentioned above, the common focus of our REU Site program is research on self-regulated learning in engineering education. Self-regulated learning is broadly defined as a complex repository of knowledge and skills for planning, implementing, monitoring, evaluating, and continually improving the learning process. When confronted with a problem or task, a learner usually begins by generating thoughts, feeling, and actions to attain the best solution to that problem. Ideally, those self-generated thoughts, feelings, and actions support effective forms of self-regulated learning. Studies suggest that the enhancement of self-regulated learning skills strengthens a learner's cognitive learning skills [25] and improves academic success [26–30]. Students with good self-regulation are more knowledgeable and responsible for their cognition [31] and accomplish cognitive actions more successfully [32]. According to Zimmerman [33], self-regulated learners are ''meta-cognitively, motivationally, and behaviorally active participants in their own learning process;'' therefore, self-regulated learners are skilled in goal-setting, self-monitoring, self-instruction, and self-reinforcement [34].

As a metacognitive control process, self-regulated learning is closely tied to metacognition. Emphasizing the use of the terms ''metacognition'' and ''self-regulation,'' Dinsmore, Alexander, and Loughin [35] stated that ''We see a clear cognitive orientation of metacognition, while self-regulation is as much concerned with human action rather than the thinking that engendered it.'' Furthermore, researchers have maintained that one of the most important goals in self-regulation and metacognition research is to understand ''the correspondence between metacognition and action and how thoughts and feelings of learners guide one's thinking, effort, and behavior?'' [36].

## 4. Student recruitment and selection

### *4.1 Advertisement*

To ensure the size and quality of applicant pool, we advertised this REU Site program in early November (see Table A1 in the appendix), three months earlier than the application deadline. The advertisement was done via a variety of channels, including email distributions to targeted institutions, a variety of list serves, and personal contacts. Each applicant was required to submit a set of items listed in the appendix.

### *4.2 Demographic and profile of the applicants*

For our programs in Summer 2014 and Summer 2015, we received a total of 143 applications, among which 21 (14.7%) applications were incomplete (missing some required documents such as reference letters) and 122 (85.3%) applications were complete. Table 1 shows the genders and ethnicities of the 122 applicants. As can be seen from Table 1, female applicants accounted for more than 55% of all applicants. A significant percentage of ethnical minorities (Asian/Pacific Islanders, African Americans, and Hispanics) also applied to the program. In the most recent annual report by the U.S. National Science Board [37], women and ''historically underrepresented racial and ethnic groups'' (African Americans, Hispanics, American Indians and Alaska Natives) accounted for only 29% and 11.3% in the nation's science and engineering workforce in 2013 [37]. A number of national education initiatives have been proposed to increase the number of women and minority students to diversify the science and engineering workforce.

**Table 1.** Gender and ethnics of the applicants

| | Gender | | Ethnics | | | | |
|---|---|---|---|---|---|---|---|
| REU program | Male | Female | White | Asian/Pacific Islander | African American | Hispanic | Other |
| Summer 2014 (n = 76) | 34 (44.7 %) | 42 (55.3%) | 35 (46%) | 11 (14.5%) | 15 (19.7%) | 11 (14.5%) | 4 (5.3%) |
| Summer 2015 (n = 46) | 19 (41.3%) | 27 (58.7%) | 26 (56.5%) | 10 (21.7%) | 5 (10.9%) | 3 (7.5%) | 2 (4.3%) |

**Table 2.** The average GPA of the applicants and the credit hours they completed prior to application

| REU program | Average GPA | Standard deviation | Average number of credit hours | Standard deviation |
|---|---|---|---|---|
| Summer 2014 (n = 76) | 3.42 | 0.42 | 69 | 42 |
| Summer 2015 (n = 46) | 3.43 | 0.46 | 68 | 35 |

The 122 applicants were from higher learning institutions across the U.S.: 43 institutions in Summer 2014 and 34 institutions in Summer 2015. Table 2 shows the average GPA (grade point average) of the applicants and the credit hours they completed prior to application. As seen from Table 2, the applicants are generally of good quality, with the average GPA of 3.42 (on a scale of 4.0) for the Summer 2014 program and 3.43 for the Summer 2015 program. The average credit hours they have completed prior to applying is 69 (Summer 2014) and 68 (Summer 2015), slightly more than half of the total credit hours (120–130) that are required for a undergraduate student to earn a BS degree at a university in the U.S. The data included in Table 2 provided useful information for our future recruiting efforts. It may also be used as a reference by other REU programs for student recruitment. Based on a comprehensive selection rubric, a total of 16 students were finally selected to participate in our program: eight students for Summer 2014 and eight students for Summer 2015.

## 5. REU research projects

Research projects are an essential element of our REU Site program. Because the purpose of this paper is to describe how our program was designed and implemented, so other programs at other institutions may be similarly developed, this section provides a brief description of a series of research projects particularly designed for our REU Site program. These research projects are part of ongoing research activities undertaken by our faculty members who served as faculty mentors for the REU students.

Over the last two summers, five faculty mentors who worked on this program designed a total of eight REU research projects (four projects per summer) for a total of 16 REU students. Each project involved two REU students, a faculty mentor, and a graduate student mentor. These eight projects were designed based on the ongoing research of each faculty mentor and share a common intellectual focus on self-regulated learning. These projects are briefly described below.

REU research project 1 aimed to develop a self-regulation survey instrument to measure how well students regulate themselves in solving ill-defined engineering problems. This project particularly focused on three important constructs of self-regulated learning: task value, task interpretation, and planning strategies. REU students chose a targeted SRL construct, designed problems and interview questions for initial study, lined up and interviewed participants, gathered and analyzed data, and developed survey items.

REU research project 2 aimed to understand how students' self-regulation strategies are used while solving a problem. This research particularly focused on the use of computational thinking strategy in problem solving. The hypothesis of this research is that students with experience in applying a computational thinking strategy use different self-regulation strategies than less experienced students. REU students learned to collect and analyze data of undergraduate and graduate student participants solving daily computational problems using a verbal protocol technique.

Both REU research projects 3 and 4 aimed to study the effect of computer simulation and animation (CSA) on students' meta-cognitive skills in a foundational engineering dynamics course. Project 3 involved a CSA learning module on the Principle of Work and Energy, and Project 4 involved a CSA learning module on the Principle of Angular Impulse and Momentum. One important research question is: How does CSA affect students' meta-cognitive skills in learning and problem solving in engineering dynamics? REU students conducted qualitative research including data transcription, coding, and analysis.

REU research project 5 aimed to identify student-oriented activities, within the Mathematics, Engineering, Science Achievement (MESA) program, that have a positive influence on underrepresented students' engineering self-efficacy, interest in engineering, perceptions of engineering, self-regulation, and cognitive strategies while they are engaged in MESA' hands-on activities. REU students designed research questions, performed statistical analysis on relevant data collected through the MESA program.

REU research project 6 aimed to develop protocols for exploring engineering design knowing and thinking. The project measured and compared the design thinking of engineering students and expert engineers through a study of their cognitive processes while designing. REU students studied trends in cumulative design issues of freshmen, seniors,

and professional engineers, and designed coding based on requirements, function, expected behavior, structure, behavior derived from structure, and documentation. The project utilized the protocol analysis method, where videos are transcribed, segmented, coded, and analyzed to produce the base data. These coded protocols provide a very rich data source from which the design cognition can be determined and understood.

REU research project 7 aimed to explore the strategies employed by undergraduate students undergoing 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. 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.

REU research project 8 aimed to understand correlations among Conceptual Design Blending (a teaching intervention delivered in engineering graphics solid modeling courses), creativity, mindsets, 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. REU students conducted quantitative research to study if any relationships exist among Conceptual Design Blending, a student's perception of their potential to succeed in engineering (mindset), creativity, and spatial thinking.

In order to ensure that REU students can learn from their research, and that each project can be completed by the end of the program, each faculty mentor designed a time schedule for the project he or she supervised. Table A3 in the appendix shows an example schedule of REU research project 2 in the first two weeks. Note that all REU students attended the same seminars and training activities in the first two weeks in order to better prepare them for subsequent research. However, students in different research groups collected and reviewed different literature that was most relevant to their own research projects.

## 6. REU Seminars

In addition to REU research projects, a series of events were held for REU students to increase their education research skills and communication skills. These events included orientation, seminars, and a final symposium. Table A4 in the appendix shows the topics of these events.

In the first week of the program, we held an orientation session to introduce the four REU research projects as well as all people involved (REU students, graduate students, and faculty and staff members). Particularly, we conveyed our expectations to the REU students, that is, what they were expected to accomplish by the end of the program. Each REU student team presented their research results at the final symposium in the 9th week of the program and submitted a written project report in the final week of the program.

In the first three weeks of the program, the faculty mentors held five seminars on a variety of topics. Then, in Weeks 5–8 (see Table A4 in the appendix), each of the four REU student teams took turns and delivered a seminar sharing their research findings with each other. Because each REU research project was different, REU students learned how different research methods and data analysis methods could be used in education research. The five seminars held by the faculty mentors are described in the following paragraphs.

### *6.1 Seminar No. 1: Self-regulated learning: what is it?*

This first seminar presented background knowledge about self-regulation as a psychological construct. Students were introduced to a common definition, elements, and a model of self-regulated learning as well as its implication on learning. This seminar took a hands-on learning approach. Students formed several groups to solve a given problem and were asked to identify their own self-regulation while solving the problem.

### *6.2 Seminar No. 2: Educational data analysis with SPSS*

SPSS (Statistical Package for the Social Sciences) is a computer software program widely used for statistical analysis in education and social sciences research. The goal of this seminar was to introduce to the REU students how to use SPSS to perform basic statistical analysis on education data. The seminar covered topics such as descriptive statistics (mean, standard deviation, standard error), correlation analysis, regression, *t*-tests, and analysis of variance (ANOVA). Each REU student was provided three sets of data to practice using SPSS to conduct relevant statistics analysis.

### *6.3 Seminar No. 3: Developing quality questions for education research*

Education research often involves research questions. The quality of research questions usually determines the quality of research because research methods, data collection, and analysis are all centered around answering research questions. The

goal of this seminar was to help REU students develop quality questions for their research projects. Prior to the seminar, each REU student was provided with and asked to read a relevant paper published in a highly regarded journal. During the seminar, REU students were asked to report their findings: Did the paper he or she had read contain a research question or questions? If not, what research question(s) should be presented? How did the authors develop the research question(s)? What research methods were used to address the research question(s)? What were major research findings of the paper? Did the research results answer the research questions?

### *6.4 Seminar No. 4: Qualitative methods in engineering education*

One of the caveats behind educational research is that all research methods are theoretically grounded to address important research questions. The goal of this seminar was to present REU students with an encompassing view of qualitative research methodologies surrounding qualitative research. Additionally, the seminar was designed to help students appreciate the complexity and power of qualitative research and how it can complement quantitative data. This seminar consisted of a lecture and active learning discussions. The lecture focused on an overview of the qualitative research writing cycle spanning the identification of research questions, the identification of theoretical frameworks, and the development of comprehensive discussions about their coded data. REU students were asked to situate their research into a potential qualitative research methodology. Once the methodology was identified, different methods that could apply to that methodology were discussed among REU students.

### *6.5 Seminar No. 5: Publication and authorship in the academy: responsible research*

Scientific research often results in publications. The way credit is partitioned within a publication typically takes the form of authorship, one of the most visible forms of academic recognition. With credit for publication being an important focus in disputes and allegations of research misconduct, it is worth considering why authorship credit is so important. The goal of this seminar was to help REU students understand what constitutes authorship and how to negotiate the authorship process. This seminar focused on best practices for preventing authorship problems and investigated several case studies used to exemplify different authorship dilemmas.

## 7. Weekly reflections

As the common intellectual focus of our REU Site program is self-regulated learning (SRL), we expect all REU students to not only conduct SRL research but, moreover, to *practice* and be consciously aware of their own SRL during the program. We asked all REU students to participate in a series of reflective activities that were particularly designed and conducted throughout this program.

### *7.1 Weekly individual reflections*

Every Friday, each REU student was asked to complete an online weekly reflection. The purpose was for REU students to build a habit of linking current experience to previous experience. Through this weekly reflection, REU students were required to act upon and process information and to synthesize and evaluate their work experience. Each week, they were asked to respond to five questions:

(1) What did you do this week?
(2) What was your result for this week?
(3) What did you learn this week?
(4) What was the most significant learning experience that you had this week?
(5) What did you learn about yourself as you worked on this week research tasks?

The first two questions were asked to help REU students build a habit of identifying tasks they had earlier engaged in and any outcomes associated with each of those tasks. The last three questions focused on reflecting on how those tasks had impacted themselves, from the perspectives of their knowledge and personal growth.

### *7.2 Weekly group debriefing*

This activity was designed and conducted to discuss the status of the project of which each REU student was responsible. Thus, it was a project group activity and the session was usually short, no more than 45 minutes long. During the session, the faculty and graduate student mentors and REU students went over the previous tasks and accomplishments, discuss potential future challenges and the next or new directions or plan needed to take to complete the project.

### *7.3 Mid- and end-program group reflections*

To gather a wealth of detailed information and deep insights into REU students' research experiences, focus group interview sessions were conducted at the middle and the end of the program. Group reflections were intended for validating information collected through individual weekly reflections. Students were asked to respond to eight core questions divided into three categories: engagement, exploration, and exit questions. Example questions were: What does research mean to you? And what do you like and not like about doing research?

## 8. Program evaluation

An external evaluator conducted independent evaluations of this REU Site program through questionnaire surveys (administrated in the middle of the program) and interviews at the end of the program to confirm the survey results and solicit additional thoughts from REU students. Both Likert-type and open-ended questions were designed and used in surveys and interviews, including (1) two logistics-related questions: Did you receive sufficient information about the summer REU program prior to coming to Utah State University? How would you evaluate your lodging and accommodations? and (2) three learning-related questions described as follows:

- How would you rate the quality of your experience with the Summer REU Program that you are working on? (i) It exceeds my expectations, (ii) It meets my expectations, (iii) I have some concerns, iv) The quality of the research project is lacking.
- 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? (i) Increased my motivation and confidence, (ii) Decreased my motivation confidence
- Describe one or two things that you have learned from this Summer REU Program.

Of a total of 16 REU students who participated in either the Summer 2014 or Summer 2015 program, 15 REU students responded to questionnaire surveys and participated in interviews. The results show that seven (47%) students rated their experience with this program as "exceeding" their expectations, and eight (53%) students rated their experience with this program as "meeting" their expectations. Twelve (80%) students reported that the research projects they worked "increased" their motivation and confidence for continuing to engage in engineering education research. Students indicated that the research projects provided them a good balance of structure and freedom in most stages of the projects. Some students were excited about continuing to do education research when starting graduate school. Other students were interested in teaching in a STEM (science, technology, engineering, and mathematics) field.

Nine (60%) students indicated that they learned a lot about working with other people in an "agreeable and efficient" manner, as one student phrased it. Students reported that they had learned skills to work with qualitative data analyses, and had learned the importance of having a theoretical framework, drawing meaning from the data, and telling a coherent story. They also reported that they had learned the importance of reflections and considering different perspectives when drawing conclusions. One student commented that "One of the other things I will try to incorporate while teaching my students is patience, diligence, genuineness, enthusiasm, and respect my faculty adviser and graduate student mentor showed while interacting with us."

In addition to independent evaluations by the program evaluator, the faculty mentors also evaluated what scientific contributions REU students had made to the research projects. Their contributions were enormous. For example, an REU student team helped develop a survey instrument that could be used to measure how well post-secondary students self-regulate within problem solving. The development of the instrument involved multiple steps from developing an understanding of self-regulatory features associated to the problem-solving process to developing, validating, and fine-tuning the survey items. Approaching the ninth week of the program, the REU student team was able to complete the entire process of the survey development project and presented their findings to their fellow students and mentors.

Finally, the faculty mentors asked REU students to describe their experience in their final project reports. Representative comments from students are provided in the following paragraphs:

- A Sumer 2014 student: "My time spent this summer at Utah State University campus has been filled with many wonderful, incredible, and intelligent people. I have appreciated the experience of spending time with so many people from so many different backgrounds and cultures and with so much to offer. I have gained a new appreciation for the world of academia."
- A Sumer 2014 student: "This project has impacted my life in a variety of positive ways. All of the outcomes from the last ten weeks have reinforced my want to attend graduate school in some type of educational field. Learning so much about SRL has also made me want to incorporate more self-regulating strategies into my own life."
- A Sumer 2015 student: "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."
- A Sumer 2015 student: "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.''

## 9. Concluding remarks

This paper has described a REU Site program that provides undergraduate students with experiences in engineering education research on self-regulated learning. The program includes a variety of activities, such as orientation, seminars, weekly reflections, a final symposium, and research projects. The results of the project evaluation show that the program has made a positive impact on increasing education research skills and communication skills of the participating REU students. Eighty percent of the participating REU students reported that the research projects they worked increased their motivation and confidence for continuing to engage in engineering education research.

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## Appendix

**Items that each student applicant was required to submit online:**

1. The application form
2. A statement of one to two pages that describe:
   - The applicant's career goal and professional interest
   - Why the applicant is interested in this REU Site program
   - The applicant's previous research experience (if any) and academic accomplishments (such as awards and honors)
   - What the applicant expects to learn from this REU Site experience
   - Was there anyone who inspired the applicant to participate in this REU Site? If "yes", what was applicant's relationship with him or her?
3. Resume listing prior study and work experience and accomplishments
4. A copy of the applicant's recent unofficial transcript of all college course work
5. Two letters of recommendation. The letters must be from professionals (rather than personal friends or relatives) who can comment on the applicant's accomplishments or potential as an undergraduate researcher.

**Table A1.** Timetable of our REU Site program in Summer 2015

| Date | Activity |
|---|---|
| Nov. 1, 2014—Feb. 1, 2015 | Advertising and recruitment |
| Feb. 2, 2015 | Application deadline |
| Feb. 3, 2015—Mar., 2015 | Selection of REU students |
| Mar. 2, 2015 | Official acceptance letter |
| Apr. 1, 2015—Apr. 15, 2015 | Initial determination of research project for each student |
| June 6, 2015 | Students arrive at the university campus |
| June 8, 2015—Aug. 14, 2015 | 10-week REU summer activities (see Table 2 for details) |
| Aug. 15, 2015 | REU Summer 2015 program ends |

**Table A2.** Timetable of 10-week REU summer activities

| Week | Research | Seminars | Weekly reflections and debriefing | Internal focus group interviews | Independent project evaluation |
|---|---|---|---|---|---|
| 1 | √ | Nos. 1, 2, 3 | √ | √ | |
| 2 | √ | No. 4 | √ | | |
| 3 | √ | No. 5 | √ | | |
| 4 | √ | | √ | | |
| 5 | √ | No. 6 | √ | | √ |
| 6 | √ | No. 7 | √ | | |
| 7 | √ | No. 8 | √ | | |
| 8 | √ | No. 9 | √ | | |
| 9 | √ | Final symposium | √ | √ | √ |
| 10 | Final project report | | | | |

**Table A3.** The example schedule of REU research project 2 in the first two weeks

| Week | Activities (seminars, training, research, weekly debriefing) | Documents |
|---|---|---|
| 1 | *Seminars:*<br>• Seminar on "self-regulated learning: what is it?"<br>• Seminar on "educational data analysis with SPSS"<br>• Seminar on "developing quality questions for education research"<br>*Training:*<br>• Institutional Review Board (IRB)<br>*Introduction to research:*<br>• Searching for academic literatures: EBSCO and ERIC<br>• Enhancing search query: Boolean operators and wildcard<br>• Best practice: research log book<br>• Taking notes: annotated bibliography<br>• File naming and version convention<br>*Literature collections and reviews:*<br>• Self-regulated learning<br>• Computational thinking<br>*Weekly debriefing:*<br>• Issues and suggestions<br>• Connecting self-regulated learning with computational thinking<br>• Connecting seminars, training, and Literature<br>• Planning for next week | At the end of the week, each student needs to submit to the faculty mentor:<br>• Three summaries of seminars<br>• IRB training certificate<br>• Five annotated bibliographies of the literature |
| 2 | *Seminars:*<br>• Seminar on "a brief introduction to qualitative methods"<br>*Learn Programming:*<br>• Completing Light Bot stage 1–3 (http://lightbot.com/hocflash.html)<br>• Completing Code—Elsa Frozen puzzle 1–20 (http://code.org/api/hour/begin/frozen)<br>*Literature collections and reviews*:<br>• Verbal protocol<br>• Application of verbal protocol<br>• Constructs within computational thinking<br>*Verbal protocol familiarity:*<br>• Watch videos of conducting verbal protocol<br>• Discuss possible issues on conducting verbal protocol<br>*Weekly debriefing:*<br>• Issues and suggestions<br>• Connecting self-regulated learning, computational thinking, and verbal protocol<br>• Connecting seminar, learning programming, and literature<br>• Planning for next week | At the end of the week, each student needs to submit to the faculty mentor:<br>• One summary of the seminar<br>• One screen shot which showed the completion of all Light Bot stages<br>• One screen-shot which showed the completion of all Elsa Frozen puzzles<br>• Five annotated bibliographies of the literature<br>• A note about possible issues of conducting verbal protocol. |

**Table A4.** Topics of 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 No. 1: Self-regulated learning: what is it? | Faculty mentor 1 |
| 1 | Seminar No.2: Educational data analysis with SPSS | Faculty mentor 2 |
| 1 | Seminar No.3: Developing quality questions for education research | Faculty mentor 2 |
| 2 | Seminar No.4: Qualitative methods in engineering education | Faculty mentors 3 & 4 |
| 3 | Seminar No.5: Publication and authorship in the academy: Responsible research | Faculty mentor 5 |
| 5 | Seminar No.6: The role of self-regulation in problem-solving activities using computational thinking strategies | REU student team 1 |
| 6 | Seminar No.7: Conceptual design blending and its impact on creativity, spatial ability, and mindset | REU student team 2 |
| 7 | Seminar No.8: Computer simulation and animation: metacognition during learning and problem-solving | REU student team 3 |
| 8 | Seminar No.9: Design heuristics: A qualitative research study in engineering education | REU student team 4 |
| 9 | Final symposium: Oral presentation of all REU project results | All REU student teams |

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