
A Theme-Based Seminar on Environmental Sustainability Improves Participant Satisfaction in an Undergraduate Summer Research Program

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ABSTRACT

We analyzed seven years of pre-program and post-program survey data to evaluate the Clarkson University Research Experience for Undergraduates (REU) Site Program in Environmental Science and Engineering, and evaluated whether our program was successful at meeting the intended outcome of increasing participants' likelihood of attending graduate school and pursuing a career in science or engineering research or education. We also evaluated how participant satisfaction in the program changed with the addition of a weekly seminar on environmental sustainability that was intended to improve participants' understanding of the societal value of their research projects. Participant satisfaction in the Clarkson REU Program was high, and increased after the addition of the sustainability seminar. Participants' intention to attend graduate or professional school increased after participating in the program, but their intention to pursue a career in science or engineering research declined. Over 60 percent of participants eventually attended graduate or professional school.

Keywords: environmental sustainability, outcomes assessment, undergraduate research

I. INTRODUCTION

Mentored summer research programs for undergraduates are a popular way to provide authentic participation in research, with the aim of encouraging participants to pursue graduate studies and ca-

reers in science or engineering (Bauer and Bennett, 2003; Kinkead, 2003; Seymour, Hunter, Laursen, and Deantoni, 2004). Typically, participants are paid a stipend, housed, and provided opportunities for recreation. In exchange, participants primarily conduct research under a faculty mentor for a period of eight to 10 weeks, but are also expected to participate in other program activities. In our experience, the ancillary program activities are perceived by participants as equally valuable as the research experience itself in terms of meeting program objectives and at increasing enjoyment (Langen and Grimberg, 2006).

The U.S. National Science Foundation (NSF) is one of the largest sources of funding for undergraduate summer research programs in science and engineering, both through awards to individual researchers and through its Research Experiences for Undergraduates (REU) Site Program. Over 120 REU Site Programs are currently funded in engineering disciplines alone. NSF's stated objective for the REU Site Program is to attract and retain promising undergraduates to careers in science and engineering research and education. This is to be achieved by funding programs that recruit a cohort of students to perform mentored research projects that share a common intellectual theme (National Science Foundation, 2005). Although the importance of outcomes assessment for undergraduate research experiences such as the REU Site Program is widely recognized, there are few properly designed studies to measure success at meeting program outcomes (Blockus, Kardash, Blair, and Wallace, 1997; Lopatto, 2004; Seymour, Hunter, Laursen, and Deantoni, 2004).

Is it necessary for a program to stress a specific and unifying theme for participants to have a satisfying and productive experience? We examine this question using seven years of assessment data on the Clarkson University REU Program in Environmental Science and Engineering. After the third year of our program, a weekly seminar focusing on environmental sustainability was added to provide a more explicit and clearly defined emphasis on the Clarkson REU Site Program's theme. This component was incorporated as a strategy to improve participants' understanding of the relevance and importance of their own research and that of other participants toward improving environmental sustainability.

Students completed a detailed survey of both expected and actual research experiences, pre- and post-program attitudes about research and graduate education, and program expectations and retrospective evaluations of the Clarkson REU Site Program. Participants were contacted periodically after completion of the program to track education and career progress. In this paper, we use the data provided by our prospective and retrospective program surveys and career tracking to evaluate the success of our program at

meeting the general program objectives: providing a rewarding and enjoyable research experience that results in a higher likelihood of participants attending graduate school and pursuing a career in science or engineering. We also assess the impact of adding a seminar to strengthen the program's focus on research for environmental sustainability. We hypothesized that overall satisfaction with the program would increase in the second four-year period relative to the first three years of the Clarkson REU Site Program, because participants had a better appreciation of the relevance of their research as a consequence of participating in the sustainability seminar. This, in turn, would result in an increased likelihood of participants attending a graduate program in science, engineering, or education.

II. BACKGROUND ON THE CLARKSON REU IN ENVIRONMENTAL SCIENCE AND ENGINEERING

The Clarkson University REU Site Program in Environmental Science and Engineering has been funded by the U.S. National Science Foundation for 3 three-year tenures (1998–2000, Susan Powers, director, and Stefan Grimberg, co-director; 2002–2004 and 2005–2007, Stefan Grimberg, director, and Tom Langen, co-director). The REU program was managed collaboratively as both co-directors were actively involved in all phases of the program for each of the three funding cycles. Although the director team changed somewhat between the first and second three-year funding cycle, the organization and structure of the program was unchanged except for the addition of a weekly seminar. The potential impact of changing directors on the program success was not investigated and therefore is not known. In this paper, we will focus on the first seven years of the program (1998–2005).

The theme of our REU Site Program has been solving complex environmental problems and increasing environmental sustainability through research in environmental science and engineering. Consistent with NSF's goals for REU Site Programs (National Science Foundation, 2005), our program's objectives include: (1) providing students who are traditionally underrepresented in environmental science and engineering or who attend institutions with limited research opportunities a chance to conduct independent research that is mentored by an experienced scientist or engineer; (2) teaching these students how to conduct meaningful environmental research and to communicate the results of that research to professional colleagues and the general public; (3) communicating to students the importance of graduate school as an integral part of the educational pipeline leading to successful careers in science and engineering; (4) demonstrating why integrative research is necessary for understanding and solving complex environmental problems, and therefore why multidisciplinary and interdisciplinary approaches to environmental science and engineering are important (as emphasized in Committees on Facilitating Interdisciplinary Research and on Science, Engineering, and Public Policy of the National Academies of Science, Engineering, and Medicine, 2005, and Pfirman and AC-ERE, 2003); and (5) improving students' skills for analyzing and solving complex problems by working within teams comprised of diverse members, in terms of individual perspectives and disciplinary expertise.

Similar to other NSF REU Site programs (e.g., Gonzalez-Espada and LaDue, 2006; May, 1997; Sutterer, Brenny, Pirnia, Woodward, Houghtalen, and Hanson, 2005), 10 upper-level

undergraduate students are funded to conduct 10 weeks of summer research mentored by a Clarkson University faculty member. Each year, some research mentors have supported a few additional REU participants using other funding sources resulting of an approximate cohort size of 12 students. Candidates for the program are recruited nationally resulting in a geographically diverse group of participants from both primarily undergraduate institutions and large research universities. Applicants are asked to select their first through third choice from a menu of 10 to 15 potential projects. The applicants are evaluated by the program's directors and potential mentors, and they are selected principally on academic promise and motivation to participate and secondarily on programmatic considerations. These secondary considerations include attaining a diverse pool of participants and supporting a wide variety of engineering and science research projects. Around 53 percent of participants have been women and 10 percent were underrepresented minorities. The program is highly selective; there have been over 100 applicants for the 10 NSF-funded internships each year. A total of 78 students participated in the Clarkson REU Program during its first seven years.

Researchers who mentor students include representatives from the disciplines of Civil and Environmental Engineering, Chemical Engineering, Mechanical and Aeronautical Engineering, Electrical Engineering, Chemistry, Physics, and Biology. Usually, a mentor is limited to one student supported by the REU Site Program per year. Research projects are expected to contribute toward understanding and remedying important environmental problems.

Research is the primary activity of the Clarkson REU Site Program in Environmental Science and Engineering, accounting for over 85 percent of a participant's time (assuming a typical 40 hour work week). The research experience culminates in a public research symposium at the end of the program for which each participant gives a short talk on the results of their research. Each participant also submits a written research report to the mentor and a synopsis of the research is posted on the program's Web site (www.clarkson.edu/reu).

In addition to research, the program curriculum includes several research tools seminars and a variety of community building activities. A concurrent series of special topic seminars or workshops are held to improve REU participants' skills at conducting and reporting on research and on opportunities for graduate school. Each workshop is typically a single two-hour meeting with individualized one-on-one mentoring as follow-up. Workshop topics include: framing hypotheses, statistical data analysis, presenting a scientific talk, and Web page design. As a culmination of the latter workshop, participants create individual Web pages to report their research findings, and a collective group site to present the summer's curricular and recreational activities.

Besides the usual informal social activities that occur "after work" (e.g., sports leagues, barbecues), the Clarkson REU Site Program has included some formal activities for community-building and increasing awareness of the larger community. The first weekend of the program is spent at an outdoor retreat center in the Adirondack Mountains where students participate in activities designed to build trust and multicultural awareness and cause them to reflect on the leadership and collaborative skills needed to conduct research as part of a research team. Later in the program, participants are taken on three field trips to view efforts of environmental sustainability in the

field, for example large scale municipal composting in Burlington Vermont, sustainable forestry practices for the fuel generation for a wood gasification power plant, and monitoring of environmental health at a Great Lakes Area of Concern by the Environmental Division of the St. Regis Mohawk Tribe at Akwesasne.

There has been one substantive change in the curriculum of the REU Site Program, which was implemented after the first three-year period. A weekly seminar focused on environmental sustainability was added in 2002 (fourth year of the program) as a strategy to improve participants' awareness of the relevance and importance of their own research and that of others. Since all research projects focused on sustainability of environmental systems, the seminar provided a curricular center to the program that reinforced the REU Site Program theme while taking little time away from research activities (2.5 hours per week). The environmental sustainability seminar was led by William Vitek, an environmental philosopher and associate professor in Clarkson University's Department of Humanities and Social Sciences. Students read and discussed material on conceptual and applied issues related to environmental sustainability, and how multidisciplinary and interdisciplinary research in science and engineering may contribute toward attaining sustainable resource use (seminar readings have included Azapagic, Perdan, and Clift, 2004; Bednar, 2003; Capra, 2002; Costanza, Low, Ostrom, and Wilson, 2001; Dresner, 2002; Quinn, 1992; Weston, 1999). Each week one or two students were asked to lead discussions on selected readings of the assigned books. The students also discussed systems approaches to science and technology, cross-disciplinarity, and potential alternatives to current systems of science, economics, and values.

III. SURVEY INSTRUMENT AND OUTCOMES ASSESSMENT

Starting with the first year of the program (1998), student surveys were administered on the first and last day of each year's REU Site Program. The surveys provided quantitative and qualitative data on each participant's prior expectations and final subjective evaluation of the program, relative valuation of each of the program's elements, and research experiences and attitudes about research and graduate education. A total of 38 participants completed both the pre- and post-program surveys during the first period (1998–2000), and the same number of participants completed both surveys during the second period (2002–2005). The survey required about 30 minutes to complete. The survey instruments were processed so that the identity of survey respondents was concealed from the program directors and project mentors.

The pre-program survey used Likert-type scales to quantify a participant's prior research experiences (13 survey items), expectations for the REU program (7 items), attitudes toward research (4 items), opinions about the importance of research for solving environmental science and engineering problems (3 items), intent to attend graduate school (3 items), desire to pursue a research career (5 items), and importance of sustainability research (during the second period only, 3 items).

The post-program survey included the same measures and items as the pre-program survey. In addition, several other measures were employed to assess the overall effectiveness of the program including overall participant satisfaction (4 items), mentoring effectiveness (6 items), administration of the project (4 items), perceived

success of the program at meeting its stated outcomes (6 items), and the difference in knowledge of sustainability (2 items). Other items evaluated the perceived importance of different components of the REU Program, and the estimated number of hours per week occupied in research, interacting with the faculty mentor, and other activities.

We created multiple-item composite scales by summing related items to form second order constructs that indicated not only the polarity of the response, but also provided a quasi-continuous measure of the intensity (Compeau and Franke, 1990). The multi-item scales were judged reliable since Cronbach's α (an index of inter-item reliability) was at least 0.7 overall and for each item (a standard criterion for users of the index). To keep the composite scales comparable to the original item Likert-type scales, we analyzed the mean score of the included items rather than their sum.

We verified that data distributions were normal and homoscedastic before applying parametric statistical tests, and we applied data transformations if warranted; otherwise, we used nonparametric statistical tests. Effect sizes are reported as the mean plus/minus standard deviation ($\bar{x} \pm sd$).

To test for differences between periods (1998–2000 vs. 2002–2005) and test administration (pre- vs. post-program), we used repeated measures ANOVAs. With this analysis, (1) the main effect period tested whether the two periods differed in mean response level, (2) the main effect pre-post tested whether the mean difference in a participant's response between the pre- and post-program differed from zero, and (3) the interaction term *period x pre-post* tested whether the mean difference between the pre- and post-program responses differed in magnitude between the two periods.

Approximately once each year, the program directors attempted to contact by e-mail all past participants with a request to contact the directors with updated information on current academic or occupational status. Past participants' project mentors were also contacted in cases where there was no response. We have information on post-collegiate activities of all past participants. We present data through 2004 only because some 2005 participants have not yet finished their undergraduate degrees.

IV. EVALUATION OF THE PROGRAM

Responses to single survey items measuring student satisfaction with the Clarkson REU Site Program in Environmental Engineering was near the ceiling of our scale during both periods of our program (for examples of survey items, see Table 1). Overall success of the program was assessed by generating summated scores of related survey items (see section III). The post-program participant assessment of the overall success of the program was slightly lower than the pre-program (prospective) assessment, which was near the ceiling of the scale (Table 2; repeated measures ANOVA: period $F_{1,74} = 3.6$, $p = 0.07$; pre-post $F_{1,74} = 21.9$, $p < 0.0001$; period x pre-post $F_{1,74} = 0.003$, $p = 0.96$). Overall participant satisfaction with the REU Site Program was significantly higher during 2002–2005 than the previous three-year period, although there was no difference between periods in the perceived success at achieving the program's stated outcomes or in project execution, nor in mentoring quality (Table 3). Participants' overall satisfaction correlated with perceived success of the program at

Survey Statement	Period	
	1998 - 2000	2002 - 2005
I am glad that I participated in this program.	6.7 ± 0.63	6.8 ± 0.58
I would recommend the program to other students.	6.6 ± 0.73	6.8 ± 0.46
If I had to do it all over, I would choose to participate in this program	6.6 ± 0.68	6.7 ± 0.55
I worked with a diverse group of students and faculty.	6.0 ± 1.22	6.2 ± 1.17
Overall, I learned a lot from participating in this research project.	6.6 ± 0.72	6.2 ± 1.13
I learned a lot from my mentor.	6.2 ± 1.10	6.1 ± 1.42

Table 1. Participants' judgments ($\bar{x} \pm sd$) of the overall success of the Clarkson REU Site Program in Environmental Science and Engineering, assessed on the last day of the program, as indicated by representative survey items. There are no significant differences between the two periods in median score for any survey item (Mann-Whitney Test, all $p > 0.1$). Response scale: 1 = Strongly Disagree, 4 = Neither Agree nor Disagree, 7 = Strongly Agree.

meeting stated outcomes, the quality of mentoring, and whether the program was fun (Table 4). Interestingly, during the second three-year period (after the sustainability seminar was incorporated into the program), the participants' judgments of the success of the program were significantly correlated with their evaluation of the importance of environmental sustainability research at the program's end (Table 4). This association emerged during the program as there was no correlation between a participants' evaluation of the importance of environmental sustainability upon entering the program and their evaluation of the program's success at its end (Table 4).

Participants rated all major elements of the program as similarly important (Figure 1). The research project was the most important element of the program, as would be expected for a program such as ours for which research is the principal activity. Adding the sustainability seminar did not change the relative importance ranking of the research project category but it proportionately lowered the other five categories (Figure 1). Categories directly associated with

research (i.e., the project, communicating results, mentor interactions) were allocated a cumulative 50 percent of the ranked importance; equal in importance were other program activities (i.e., seminars, field trips, interactions with other participants). The Clarkson REU Site Program significantly increased participants' self-assessed experience at conducting research and there was no change in the magnitude of the increase with the addition of the sustainability seminar (Table 5; repeated measures ANOVA: period $F_{1,70} = 3.1, p = 0.08$; pre-post $F_{1,70} = 81.5, p < 0.0001$; period x pre-post $F_{1,70} = 1.4, p = 0.2$). During the second period of the program, after the addition of the sustainability seminar, participants' subjective evaluations of the importance of research on environmental sustainability increased between entering and completing the REU program (Table 6; paired $t_{36} = 2.1, p = 0.047$; pre-survey = 6.2 ± 1.17 , post-survey = 6.6 ± 0.58). This is not entirely surprising since the students' knowledge with respect to sustainability increased significantly during the REU program due to the seminar program.

Participants entered the program with strong positive opinions of the importance of research, and their assessment was unchanged at the end of the program (Table 6; repeated measures ANOVA: period $F_{1,73} = 0.8, p = 0.38$; pre-post $F_{1,73} = 0.05, p = 0.8$; period x pre-post $F_{1,73} = 1.3, p = 0.3$). Participants' intentions of attending graduate school increased after participation in the REU program (period $F_{1,73} = 0.6, p = 0.5$; pre-post $F_{1,73} = 6.3, p = 0.01$; period x pre-post $F_{1,73} = 0.007, p = 0.9$). However, participants' intentions of pursuing a career in research declined after participation in the REU program (Table 6; period $F_{1,74} = 0.4, p = 0.5$; pre-post $F_{1,74} = 6.4, p = 0.01$; period x pre-post $F_{1,74} = 0.08, p = 0.8$). There was a negative correlation between the number of hours spent working on a research project and the intention to attend graduate school as assessed at the end of the program ($r_s = -0.29, p = 0.02, n = 65$).

A high proportion of Clarkson REU Site Program participants have eventually attended graduate school in science, engineering, education, or other professional careers such as medicine or law (1998–2000, 63 percent; 2002–2004, 64 percent). We cannot

	Period	
	1998 - 2000	2002 - 2005
Pre-Survey	6.4 ± 0.45	6.6 ± 0.47
Post-Survey	6.0 ± 0.61	6.2 ± 0.69

1 = Very Poor; 4 = Neutral; 7 = Very Good

Table 2. Participants' ($\bar{x} \pm sd$) prospective (before program commenced) evaluation and retrospective (last day of program evaluation) of the overall success of the Clarkson REU Site Program in Environmental Science and Engineering. Response scale: 1 = Very Poor, 4 = Neutral, 7 = Very Good. Difference between Pre-Post survey responses for each time period were statistically significant ($F_{1,74} = 21.9, p < 0.0001$).

Scale Item	Period		Mann-Whitney test Z, p
	1998 - 2000	2002 - 2005	
Program Satisfaction	6.6 ± 0.53	6.9 ± 0.28	2.1, 0.03
Meeting Outcomes	5.9 ± 0.64	6.2 ± 0.78	1.7, 0.08
Project Execution	5.6 ± 1.16	5.5 ± 1.05	0.4, 0.7
Mentoring	6.0 ± 1.12	6.0 ± 1.06	0.02, 0.99

Table 3. Summated scores ($\bar{x} \pm sd$) for measures of program success of the Clarkson REU Site Program in Environmental Science and Engineering during the two periods. The two periods were compared via a Mann-Whitney test (normal approximation of the test statistic). Response scale: 1 = Very Poor, 4 = Neutral, 7 = Very Good.

compare fairly recent graduate program attendance rates of the first three-year program period to the second because some participants defer several years before enrolling, thus the first three-year period is advantaged over the second simply because they have had a longer period in which to enroll.

V. DISCUSSION

Satisfaction with the Clarkson REU Program in Environmental Science and Engineering has been consistently high for participants during each year of the program. However, our assessment data indicated that participant satisfaction in the program increased in the period (2002–2005) over the first (1998–2000). This increase was not due to perceived improvements in mentoring or project success. Although it is possible that the increase in student satisfaction that occurred after instituting the weekly seminar series was merely due to increased interactions among the program participants, we think this reason is unlikely; the extra 2.5 hours per week the participants were together during the seminar was small compared to opportunities to interact while living together in adjacent apartments, during weekly social sports events, and during field trips organized by the program directors. Instead, it appears to have been due to an increase in the value that participants place on research on environmental sustainability, which emerged during the program experi-

ence as a direct consequence of the sustainability seminar. Participants indicated that the sustainability seminar was helpful (in decreasing order of magnitude) at increasing general knowledge about science and engineering, understanding how to conduct research, and at decisions related to graduate school and career. They also agreed (mean score 6.3 on a scale 0 = strongly disagree to 7 = strongly agree) that they came to understand how their particular research project contributed to environmental sustainability (Langen and Grimberg, 2006). We conclude that a weekly seminar program that reinforces a summer research program's theme can make an important contribution to a program's success, by helping participant's appreciate the relevance of their particular research project to a broader program theme and to understand why the theme is important. Similar conclusions about the usefulness of weekly seminars in summer research programs are reported in Lax and Van Epps (2005), and Shachter (2003).

Participant satisfaction with the Clarkson REU Site Program was associated with participants' judgment of the quality of faculty mentoring, success of the program at meeting stated outcomes, perception that the program was fun, and, during the second period, how highly they valued environmental sustainability. These results are consistent with other findings and recommendations about undergraduate research experiences (Gonzalez-Espada and LaDue, 2006; Lopatto, 2003; Mabrouk and Peters, 2003; Shellito, Shea, Weissmann, Mueller-Solgar,

Scale Item	Period	
	1998 - 2000	2002 - 2005
Mentoring	0.43**	0.34*
Project Execution	0.18	0.32 [†]
Meeting Outcomes	0.39*	0.51**
Fun Experience	0.60***	0.60***
Value of Sustainability Before Program	N.A.	0.09
Value of Sustainability After Program	N.A.	0.44**

Table 4. Correlates (Spearman rank correlations) of overall satisfaction with the Clarkson REU Site Program in Environmental Science and Engineering. Significance of correlation coefficients at each time period: $^{\dagger} = p \leq 0.1$, $* = p < 0.05$, $** = p < 0.01$, $*** = p < 0.001$.

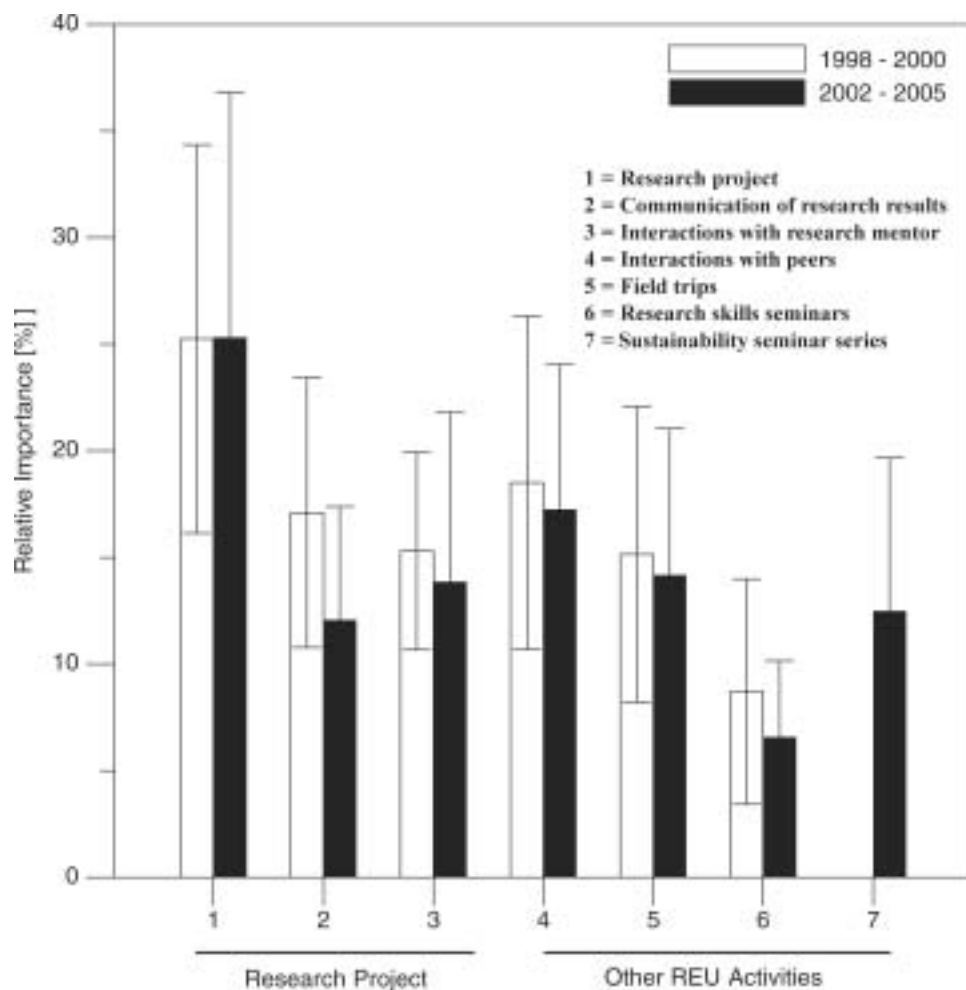


Figure 1. Participants' judgements (mean \pm sd) on the ranked importance (sum = 100) of the seven principal elements of the Clarkson REU Site Program in Environmental Science and Engineering.

and Davis, 2001; Sutterer, Brenny, Pirnia, Woodward, Hough-talen, and Hanson, 2005). There was a small decline between participants' expected satisfaction in the program (measured on the first program day) and their retrospective evaluation (measured on the final program day), which was nevertheless still highly positive. This slight decline may be a "ceiling effect", and

may also be due to the timing of the second survey; students' evaluations of program satisfaction can increase between the end of a program and a later time after they have had time to recover from the stress of the experience and reflect upon it (Langen and Welsh, 2006).

In terms of one of the principal objectives of NSF-funded undergraduate summer research programs, convincing students to attend graduate school in science, engineering, or education, the Clarkson REU Site Program appears to have a mixed success. Participant intention to attend graduate school was already high at the start of the program, as might be expected given how participants are recruited and selected, and the intention increased after the program experience; over 60 percent of participants have eventually entered graduate or professional school programs. One study similar to ours also found an increase in intention to attend graduate school after participation in an undergraduate research program (Gonzalez-Espada and LaDue, 2006); numerous other studies have claimed success at increasing graduate school attendance but are inconclusive because the intentions of participants were only surveyed at the completion of a summer research program, and therefore lack a measure of the incremental improvement caused by the experience, or proportion of participants that eventually attended graduate school was tracked without similarly tracking a comparable control group (Bauer and Bennett, 2003; Hathaway, Nagda,

	Period	
	1998 - 2000	2002 - 2005
Pre-Survey	3.0 \pm 1.7	3.7 \pm 2.21
Post-Survey	5.5 \pm 0.08	5.7 \pm 1.05

Table 5. Participants' ($\bar{x} \pm sd$) research experience before and after participation in the Clarkson REU Site Program in Environmental Science and Engineering. Response scale: 1 = No Experience, 7 = Much Experience (repeated measures ANOVA: period $F_{1,70} = 3.1, p = 0.08$; difference between pre-post surveys $F_{1,70} = 81.5, p < 0.0001$; increase in research experience between program periods, period \times pre-post $F_{1,70} = 1.4, p = 0.2$; 70 degrees of freedom).

Category	Example statement	Period			
		1998 - 2000		2002 - 2005	
		Pre Survey	Post Survey	Pre Survey	Post Survey
Attitudes towards research	Conducting research makes an important contribution to our society.	5.7 ± 0.65	5.8 ± 0.67	5.6 ± 1.06	5.5 ± 0.95
Importance of research for the environment	Without research, our environmental problems will only get worse.	5.8 ± 1.08	5.7 ± 1.12	6.0 ± 1.44	6.3 ± 0.79
Intentions for graduate school	I will attend graduate school.	5.7 ± 1.20	6.0 ± 0.99	5.8 ± 0.99	6.2 ± 1.05
Intentions for a career in research	I will pursue a career in basic or applied research.	5.5 ± 0.84	5.2 ± 1.14	5.6 ± 0.84	5.3 ± 1.11
Importance of sustainability research		N.A.	N.A.	6.2 ± 1.17	6.6 ± 0.58

Table 6. Attitudinal changes ($\bar{x} \pm s$) resulting from participation in the Clarkson REU Site Program in Environmental Science and Engineering. Response scale: 1 = Strongly Disagree, 4 = Neither Agree nor Disagree, 7 = Strongly Agree.

and Gregerman, 2002; Zydney, Bennett, Shahid, and Bauer, 2002; Kemer and Bringle, 1990; Morley, Havlick, and May, 1998; the last four were reviewed in Seymour, Hunter, Laursen, and Deantoni, 2004). Creating a valid control group is difficult since research program participants are self-selected (as applicants) and selected (as top candidates in a large candidate pool) through a process that is likely to result in choosing students that are inherently interested in attending graduate school. Pre-post program matched surveys may be the best way to measure the value-added of an undergraduate research experience (Lopatto, 2004; Kardash, 2000; Seymour, Hunter, Laursen, and Deantoni, 2004).

Although intention to attend graduate school increased, the intention to pursue a research career declined between the pre-program and post-program surveys. This result may have reflected some participants' realistic self-evaluations of interest and aptitude at research, or increased awareness of non-research track career options that require graduate degrees such as law, medicine, or education (each of which has been pursued by past participants); other studies have indicated that each of these may contribute to outcomes such as ours (Gonzalez-Espada and LaDue, 2006; Lopatto, 2004). A substantial fraction of doctoral scientists with degrees in environmental science are working in a sector other than research (Campbell, Fuller, and Patrick, 2005). It would be interesting to assess whether participation in a program such as ours results in a better understanding of the career options available to holders of graduate degrees. Based on post-program participant tracking, some participants eventually pursued higher degrees in preparation for non-research track careers in education, medicine, law, business, engineering management and other fields. It would also be very interesting to examine why participation in undergraduate research programs causes some students to turn away from research careers, and whether this is in fact beneficial in that it prevents these students from pursuing a vocation for which they don't have sufficient aptitude or interest.

In a highly-selective program such as ours, most participants arrive with a strong intention to eventually acquire a graduate degree. It would be worthwhile to evaluate whether summer research programs such as ours increase the likelihood that participants are accepted into high-quality graduate and professional school programs. We suspect that the added value for most participants of a summer research program such as the Clarkson REU Site Program is in developing the experience, skills, knowledge-base, and mentoring network that facilitates acceptance and success in higher-quality graduate programs, and hence contributes to eventual success in a career of science and engineering research or teaching (as shown in Bauer and Bennett, 2003).

VI. CONCLUSIONS

The addition of an interdisciplinary seminar program on environmental sustainability to our summer research program increased participants' satisfaction apparently because it made them aware of the value and greater context of their own and other participants' research. The benefits of the seminar series appear to be considerably greater than the cost in lost research time. Our REU Site Program increased participants' interest in pursuing graduate studies but it also shifted some participants' career track away from research. Overall, our results have demonstrated that this type of seminar, focused on reinforcing the relevance and importance of student research in a broader context, can have a very positive impact on student response in an REU program. In addition, a stated outcome of this NSF education program, to encourage undergraduates to pursue higher degrees in science and engineering research and education, appears to be met, with the caveat that we have not established that the increase in intention to attend graduate school is for programs in science and engineering.

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