Board 201: Assessing change in research perceptions following participation in an REU site focused on converting biological wastes into products of value

Prof. Brendan Higgins, Auburn University

Brendan Higgins is the director of the NSF REU site: Research experience through collaborative teams in bioprocessing for conversion of waste into products of value. His research focuses on using algal-bacterial processes to upcycle food and agricultural wastes into products of value. He also conducts research on sustainability modeling of food and agricultural systems.

Laura Parson, North Dakota State University

Laura Parson, PhD is an Associate Professor of Educational and Organizational Leadership. Her Ph.D. is in Teaching & Learning, Higher Education from the University of North Dakota. Laura's research seeks to identify where and how institutional disjunctures occur in higher education for women and members of minoritized groups. She is a qualitative methodologist, with a focus on ethnographic and discourse methods of inquiry.

Dr. Sushil Adhikari, Auburn University

Dr. Sushil Adhikari is a Professor in the Biosystems Engineering Department and the Center for Bioenergy and Bioproducts Director at Auburn University. He is the Co-Principal Investigator of the NSF REU site: Research experience through collaborative teams in bioprocessing for conversion of waste into products of value. Adhikari devotes his efforts to teaching and research in the area of bioenergy and bioproducts and circular economy. He teaches Heat and Mass Transfer, Renewable Energy and Biomass and Biofuels courses for both undergraduate and graduate students.

Fredricka Saunders, North Dakota State University

Fredricka Saunders, M.Ed., is a doctoral candidate at North Dakota State University, specializing in institutional effectiveness in higher education. Her research focuses on underrepresented groups' experiences, supported by qualitative methods. She's also managing editor of the Journal of Women and Gender in Higher Education and a research assistant.

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Introduction

The overall goal of this project was to establish an NSF REU site that integrates undergraduate students in team-based research projects focused on converting biological wastes into products of value. This site has operated for two summers at Auburn University and has graduated 19 REU fellows. Each fellow was paired with a faculty mentor, with the goal of being a part of an interdisciplinary team-based research project. We hypothesized that this team-based approach would improve the confidence and knowledge of participating fellows regarding effective team and research practices. Our project evaluation aimed to determine how the REU site affected fellow confidence in effective team and research practices.

Our site has served a diverse cohort of students, including 13 students who identified as women, six students from minority groups traditionally underrepresented in engineering, and five students from institutions with limited research opportunities, as shown in Table 1. Undergraduate research has been proven to improve retention at the undergraduate level and increase the likelihood of attaining an advanced degree [1]; this is particularly true for students traditionally underrepresented in higher education [2-4]. This site supports REU student projects in four research areas: 1) converting lignocellulosic biomass into adhesives and polymers, 2) upgrading aquaculture wastewater for hydroponic plant production (aquaponics), 3) converting cellulose into sensors for antigen detection, and 4) upgrading nutrients in anaerobic digestate into fish feed using algae and zooplankton. These research areas aim to solve global and societally relevant problems in the areas of environmental protection, health, food production, and renewable resources. Engagement of communal and altruistic goals such as these have been shown to appeal particularly to women [5-7] and some racial/ethnic groups that have been traditionally underrepresented in engineering [8]. Our site also offers three weekly professional development workshops: 1) Best practices in research and teamwork, 2) a writer's workshop focused on technical communication, and 3) a journal club where REU students present an article on their project area to the group. All of the workshops involve hands-on activities to maximize engagement and relevance.

Table 1. Demographic characteristics of REU cohort (n=17)

Demographic Group	*n*	%
Women	13	76.5
Minority Groups (Traditionally Underrepresented in Engineering)	6	35.3
Students from Institutions with Limited Research Opportunities	5	29.4

Note. 2 students did not sign the consent letter to participate in the IRB-approved evaluation research.

Evaluation Methods

Evaluation of the project consisted of a pre-post survey instrument focused on perceived self-efficacy in universal teamwork and research skills. This instrument was an adaptation of the Research Self-efficacy scale [9]. Questions focused on things like the perceived ability to "engage in effective team practices," "follow ethical principles of research," "identify my own strengths within a team setting," and "present research ideas in oral or written form." This pre-post survey was augmented by weekly surveys aimed at understanding fellow engagement in the program. A final focus group was held with the project evaluator to further elucidate the results of the surveys.

Evaluation Results and Discussion

Of the 19 REU participants to date, 17 signed the letter of consent to participate in the IRB-approved evaluation research. However, only 10 chose to complete both the pre- and post-assessment instruments. In the first year, we found that fellows scored lower or showed no meaningful change in self-efficacy in multiple aspects of research after participation in the program. This was somewhat surprising because qualitative feedback (i.e., focus groups and weekly surveys) indicated that fellows had learned a lot from the program. We traced this apparent disconnect to the vague and sometimes misaligned statements in the Research Self-efficacy scale used in the pre-and post-test survey. It was apparent from the focus group that fellows had gained enough knowledge of research that they also realized they had a long way to go before they could master research. We therefore modified the statements in the test to better reflect the more realistic learning that was likely occurring at our site instead of measuring broader research goals more appropriately assessed over the course of a degree or program. For example, rather than the statement, "I know when to quit generating research ideas based on a literature review," we created more realistic statements like "I can find relevant articles for a research question." The former might be appropriate for an experienced graduate student but was overwhelming for an undergraduate student with only 10 weeks of research experience. Averaged across all summative questions, we saw score increases of 12% in year 1. The percent improvement was determined as the change in score divided by the total possible score for the question, so it was not a percent improvement for the individual (which would be biased toward those who gave low initial scores). In year 2, with the revised set of questions, the average score increase across all questions was 19%. The questions showing the greatest increase in fellow confidence in years 1 and 2 are shown in Tables 2 and 3, respectively. Also, a complete list of the pre-and post-test questions (and average scores) from years 1 and 2 are shown in Appendix A and Appendix B, respectively.

Table 2. Questions in Y1 with the greatest change in response score

Year 1 Question	% Increase
Train assistants to collect data	30%
Organize your proposed research ideas in writing or presentation format	28%
Organize collected data for analysis	23%
Identify implications for future research	23%

Present your research idea orally or in written form to an advisor or group	20%
Synthesize results with regard to current literature	18%
Perform experimental procedures	17%
Synthesize current literature	17%
Identify and report limitations of study	16%

Table 3. Questions in Y2 with the greatest change in response score

Year 2 Question	% Increase
I know the tools used in collecting data.	39%
I know how to gather data.	36%
I know what to do at an academic conference	36%
I know what kind of research I am interested in.	36%
I know how to support claims with supporting evidence in an academic paper.	32%
I can work independently on a research project.	32%
I can create a scientific poster presentation.	29%
I can instruct others on the components of a research proposal.	29%
I am proficient at analyzing data.	29%

In both years, fellows showed strong improvement in their ability to collect and analyze data, skills that flowed directly from their laboratory research. Generally, the responses also reflect positively on the professional development workshops in which fellows learned about and practiced 1) constructing a PowerPoint research proposal presentation, 2) rigorous evaluation of scientific articles, 3) making a poster, and 4) participating in a poster symposium at the end of the summer program. It was interesting that "training assistants to collect data" resulted in a lot of improvement in fellow confidence in year 1. The fellows were the trainees, but their responses in year 1 might have resulted from a general boost in confidence surrounding collecting and analyzing data. The questions in year 1 with the smallest change in confidence were "Follow ethical principles of research" and "Use existing computer software package to analyze data." In the former case, the fellows already expressed a high confidence (pre-score of 90.8 out of 100), whereas in the latter question, it could be due to limited opportunity to work with statistical software packages during the experience. The questions in year 2 with the smallest improvement were "I am confident writing the different components of an academic paper (i.e., abstract, introduction, method, results, and conclusion)," followed by "I feel at ease asking my mentor for assistance." Although paper construction was discussed, the REU fellows never had an opportunity to write a paper during their 10-week experience. Thus, it is not surprising that little improvement was shown in this area. The second question was strongly biased by one student who gave a very low ranking.

In addition to the pre- and post-summative assessments, we also sought weekly feedback from fellows on their level of engagement with the REU program. These weekly surveys focused more on feelings of engagement with different activities within the site rather than their assessment of research knowledge and skills. Here, we found that fellows felt most engaged when working in their research labs and felt particularly affirmed when being taught or helped by their graduate student mentors. In the first year, fellows felt most disengaged with our site's journal club. In year 1, the journal club entailed having each fellow present an article on their research topic to the group. The idea was to give them an opportunity to teach their group about their area of research while also learning how to break down a scientific article into its components. However, most fellows were overwhelmed by the prospect of reading articles from so many different fields of study; their feedback suggested that they found the articles difficult to understand and that the activity lacked focus. As a result of this finding, we modified the journal club format in year 2 so that fellows would focus on answering questions about "universal" aspects of articles rather than be responsible for reporting on the specifics of any particular article. This reframing, at the very least, led to a decline in feelings of disengagement, which we determined because there were no specific comments about journal club in the comments from year 2.

Conclusions

Based on the qualitative weekly surveys and focus groups, it is clear that the students learned a great deal about themselves as researchers from this REU experience. In particular, they showed meaningful increases in confidence related to data collection, presenting their work, and reading scientific articles. However, it was also clear that focusing the pre-and post-test questions on what the fellows are realistically learning is also important if the goal is to measure progress in a more quantitative way. We will continue to tweak the site's professional development components in year 3 based on the feedback we have received from years 1 and 2.

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Appendix A. Y1 summative questions (100-point scale where 100 is complete confidence in ability, n = 6).

Question	Average Pre	Average Post	Change	% Change/ total
Q2_1 Follow ethical principles of research	90.8	89.3	-1.5	-1.5%
Q2-2 Brainstorm areas in the literature to read about.	70.3	79.0	8.7	8.7%
Q2_3 Participate in generating collaborative research ideas.	74.2	79.2	5.0	5.0%
Q2_4 Work interdependently within a research group.	79.3	87.2	7.8	7.8%
Q2_5 Identify my own strengths within a team setting.	73.2	81.5	8.3	8.3%
Q2_6 Identify the strengths of other team members when working in a team setting.	80.2	86.7	6.5	6.5%
Q2_7 Articulate effective team practices.	77.8	86.7	8.8	8.8%
Q2_8 Engage in effective team practices.	83.5	88.0	4.5	4.5%
Q2_9 Discuss research ideas with peers.	80.5	81.3	0.8	0.8%
Q2_10 Consult senior researchers for ideas.	85.3	94.8	9.5	9.5%
Q2_11 Decide when to quit searching for related research/writing.	56.7	66.2	9.5	9.5%
Q2_12 Decide when to quit generating ideas based on your literature review.	61.3	73.3	12.0	12.0%
Q2_13 Synthesize current literature.	68.2	85.5	17.3	17.3%
Q2_14 Identify areas of needed research, based on reading the literature.	65.3	77.3	12.0	12.0%
Q2_15 Develop a logical rationale for your particular research idea.	68.3	79.2	10.8	10.8%
Q2_16 Generate researchable questions.	71.5	86.8	15.3	15.3%
Q2_17 Organize your proposed research ideas in writing or presentation format.	67.8	95.7	27.8	27.8%
Q2_18 Effectively edit your writing to make it logical and succinct.	80.0	94.0	14.0	14.0%
Q2_19 Present your research idea orally or in written form to an advisor or group.	76.8	97.0	20.2	20.2%
Q2_20 Utilize criticism from reviews of your idea.	76.0	89.5	13.5	13.5%
Q2_21 Choose an appropriate research design.	66.5	74.7	8.2	8.2%
Q2_22 Be flexible in developing alternative research strategies.	72.3	76.2	3.8	3.8%
Q2_23 Choose appropriate data analysis techniques.	62.7	68.8	6.2	6.2%
Q2_24 Obtain appropriate subjects/general supplies/equipment.	71.8	80.5	8.7	8.7%
Q2_25 Train assistants to collect data.	52.8	82.3	29.5	29.5%
Q2_26 Perform experimental procedures.	72.5	89.8	17.3	17.3%
Q2_27 Ensure data collection is reliable.	70.0	83.8	13.8	13.8%
Q2_28 Supervise others in research.	54.3	69.3	15.0	15.0%
Q2_29 Attend to all relevant details of data collection.	64.5	77.7	13.2	13.2%
Q2_30 Organize collected data for analysis.	68.7	91.3	22.7	22.7%

Q2_31 Use a computer for data analysis.	75.5	84.7	9.2	9.2%
Q2_32 Use an existing computer software package to analyze data.	79.3	80.0	0.7	0.7%
Q2_33 Interpret statistical analyses.	67.3	74.0	6.7	6.7%
Q2_34 Synthesize results with regard to current literature.	67.2	85.3	18.2	18.2%
Q2_35 Identify and report limitations of study.	64.8	80.5	15.7	15.7%
Q2_36 Identify implications for future research.	65.7	88.2	22.5	22.5%

Appendix B. Y2 summative questions (7-point scale where 7 is high confidence in ability, n = 4).

Question	Average Pre	Average Post	Change	% Change/ total
Q3#1_1 I understand the work that goes into beginning a research project. Scale: 1 is not at all true and 7 is very true	4.6	6.0	1.4	20.0%
Q3#1_2 I understand the work that goes into completing a research project.	4.4	6.0	1.6	22.9%
Q3#1_3 I can identify the different components of a research project.	5.2	6.8	1.6	22.1%
Q3#1_4 I can create a scientific poster presentation.	5.0	6.8	1.8	25.0%
Q3#1_5 I know what to do at an academic conference.	4.4	6.5	2.1	30.0%
Q3#1_6 I can find relevant academic articles for a research question.	6.0	6.5	0.5	7.1%
Q3#1_7 I know how to cite academic work in a written publication.	5.8	6.3	0.5	6.4%
Q3#1_8 I can instruct others on the components of a research proposal.	3.8	5.8	2.0	27.9%
Q3#1_9 I feel comfortable conversing with others about scientific ideas.	5.6	6.3	0.7	9.3%
Q3#1_10 I am capable of conducting real-world scientific studies.	5.0	6.3	1.3	17.9%
Q3#1_11 I know how to design an experiment with appropriate controls to answer a research question.	4.4	6.0	1.6	22.9%
Q3#1_12 I feel at ease asking my mentor for assistance.	4.8	5.0	0.2	2.9%
Q3#1_13 I know what kind of research I am interested in.	3.4	5.8	2.4	33.6%
Q3#1_14 I am confident writing the different components of an academic paper (i.e., abstract, introduction, method, results, and conclusion).	5.4	5.5	0.1	1.4%
Q3#1_15 I know how to support claims with supporting evidence in an academic paper.	4.0	6.0	2.0	28.6%
Q3#1_16 I am proficient at analyzing data.	4.0	6.0	2.0	28.6%
Q3#1_17 I can work independently on a research project.	4.4	6.5	2.1	30.0%
Q3#1_18 I know how to gather data.	4.2	6.5	2.3	32.9%
Q3#1_19 I know the tools used in collecting data.	3.8	6.5	2.7	38.6%