Research Experience for Undergraduates Social Programs: A Key Ingredient for Success

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Abstract

This evidence-based paper assesses strategies for Research Experience for Undergraduates (REU) social program success. REU programs bring students from across the country to a university campus for the summer. These students learn how to conduct real research in their discipline by actually doing it, under the supervision of a faculty mentor. Many students who participate in REU programs remember these programs long after the program is complete. The REU experience of working with a faculty mentor on bona fide research is undoubtedly key to the educational and career planning benefits that students enjoy. The best REU experiences typically don't happen by accident. They must be deliberately planned. Despite the importance of this component of REU programs, minimal literature related REU social programs exists. This paper considers what makes a strong REU social program.

1. Introduction

This evidence-based paper assesses strategies for Research Experience for Undergraduates (REU) social program success. REU programs typically bring together students from across the country – or even around the world – to a university campus for the summer. While at this university, the students learn how to conduct real research in their discipline by actually doing it, under the supervision of a faculty mentor. Giving students exposure to conducting bona fide research allows them to determine whether they may be interested in pursuing a research career (and, to support this, continuing on to graduate-level education).

Many students who participate in REU programs remember these programs long after the program is complete. The initial experience, provided by REUs, of working with a faculty mentor on bona fide research is undoubtedly key to the educational and career planning benefits that students enjoy. However, this is not the only source of benefit from program participation. For many students – even those that don't go on to pursue careers in research – the experience with the other REU students builds friendships that can last through their college career and beyond. In this regard, the REU is effectively professional networking for pre-professionals.

The best REU experiences typically don't happen by accident. They must be deliberately planned by program directors and faculty mentors – and in some cases, even the students themselves. Despite the importance of this component of REU programs, minimal assessment of REU social programs is conducted. This paper considers what makes a strong REU social program. It reviews the literature regarding teambuilding and bonding – particularly for college and college age students. It also discusses other team-building and bonding environments commonly experienced by traditional age college students and compares and contrasts them to REU participation. The paper then continues to present examples of REU social programs used for four years of a computing-discipline REU program. Relevant student survey results for each year are juxtaposed with social program offerings and the impact of the social program decisions on student perception and outcomes is discussed. From this discussion, a template for a successful REU social program is presented that is directly applicable to many disciplines and

easily adaptable to most others. A discussion of how to adapt and implement the template follows its presentation. Focus then turns to other decisions made in the operation of a REU program that impact the social experience and student enjoyment, bonding and perceptions. Next, special considerations are discussed, such as how to best accommodate non-traditional age students and students with disabilities or special needs. Finally, the paper concludes with a discussion of the impact of the social program on student outcomes. Its long-term impact on students is discussed. Also, the impact of the social program on increasing students' interest in research careers is considered. Potential topics for future investigation are also identified.

2. Background

This section provides background on prior work in three relevant areas. First, REU sites are described. Next, prior work on experiential education, project-based learning and their assessment is reviewed. Finally, prior research on cohort-creation and team bonding for college-age students is presented.

2.1. REU sites

The National Science Foundation REU program brings together cohorts of undergraduate students to study topics within NSF supported disciplines. Many REU sites have an overarching theme to them that relates to a sub-discipline or interdisciplinary collaboration.

REU sites inherently vary from institution to institution, as each institution proposes the particular characteristics and features of its site to NSF. NSF uses panels of reviewers to select proposals for funding, out of those submitted. REU sites are expected to serve underserved populations such as under-represented minorities and students without access to research experiences at their home institution [1].

Institutions propose the length and size of their program; however, programs with lengths of 8 [2] to 12 [3] weeks are common. Student cohort sizes of as many as 12 [2] are frequently seen. Students apply to the site and some are selected for participation. Many students apply to multiple sites and must make a decision as to which offer to accept. Economy, Martin and Kennedy [4] suggest that students choose between sites based on the level of stipend provided, comparing research topics at the different institutions and by the dates that they receive their offers on.

All REU sites provide students with hands-on research opportunities with faculty mentorship [1]. Most sites offer a variety of research training programs and technical seminars (e.g., [2]) and training in technical writing (e.g., [5]). Sites are also required to offer training in research ethics [1]. Many sites also provide training about how to select and apply to graduate school (e.g., [5]), for students who choose to pursue further education. However, even with all of these programs (some of which may be offered outside of normal work hours), the bulk of student time at REU sites is spent on research activities.

2.2. Experiential education and project-based learning

REU sites implement project-based learning, which is a form of experiential education where students work on a project to learn technical, problem-solving and other skills. In the case of a REU, the project is a research project. Project-based learning has been demonstrated to be effective across a wide variety of ages of students [6]–[11]. It has also been shown to be effective both in science, technology, engineering and math (STEM) fields [12]–[14] and outside of them [15], [16]. In particular, the efficacy of project-based learning has been demonstrated in computer science [12] and in computer [14] and electrical [17] engineering.

In addition to the technical and problem-solving skills, a number of other benefits have been shown from project-based learning. Students have been shown to learn soft skills [18] from these experiences. Project-based learning has also been shown to increase creativity [19] and improve students' self-image [20]. Perhaps for all of these reasons, students who have participated in project-based learning have been shown to have enhanced levels of job placement [21].

Project-based learning can be used in the classroom environment, for multi-week or term-long class projects or in dedicated organized or extracurricular environments. Some projects can span different types of participation [22] with the potential for projects to include students, either concurrently or at different points during the project, who are participating for academic credit, personal enrichment and as part of paid employment.

2.3. Bonding and bridging activities for college-age students

An REU social program may have several key goals. Initially, social activities serve as a way to introduce participants to each other. They then serve to get the group working well together. However, for most participants the longest impact of the social program may be the bonding between cohort members.

Figure 1. REU participants engage in a group-building exercise early in the program.

Cohort bonding has numerous benefits for students both during the REU experience and after it. Bonding with peers via "co-curricular activities" has been shown to increase students self-belief, feelings of autonomy, levels of self-expression and ability to work in diverse groups [23]. It has also been shown to aid "academic identity formation" [24] and forming social networks through social interaction events [25]. Extracurricular activities have also shown association with

enhanced self-esteem and bonding [26] and reduced harmful risk-taking activities [27] in other student populations. In the academic setting, bonding can "help create a positive atmosphere" that encourages student participation [28]. It is also key to "building a discourse community" which students feel they are "bona fide members of" and have an important role in contributing to [28]. Bonding has also been shown to be helpful to under-represented minorities [29] and individuals with disabilities [30].

Lee and Lok [31] have demonstrated the importance of bonding both with peers and bridging to adult role models for the "healthy development" of youth. Both bonding and bridging activities have been shown to aid in student retention as part of an effective relationship marketing strategy [32]. Bridging with faculty has been shown to aid in "professional identity formation" [24] and to mitigate the harmful effects of partying cultures [25]. It has also been shown to reduce student dropout rates [33] and enhance academic performance [34].

3. Design of a REU program and the role of the social program

The design of a REU program typically focuses on a number of key decisions: the start and end dates, activities to prepare students for research, activities to support students during research, documentation activities, career / education preparation activities and social activities. In many cases, a single activity may serve in more than one capacity.

For the North Dakota State University (NDSU) REU program, a trip to a professional conference is included as a professional development activity. Student participants also visit a decommissioned intercontinental ballistic missile (ICBM). Both of these activities are primarily aimed at intellectual development. The former helps students gain an understanding of the intellectual interactions, publication development and presentation activities that are a key parts of being a professional scientist (in academia or the public/private sectors). The later is key to help students understand the importance of proper security and the criticality of accurate software (it is also accompanied by a discussion of Stanislav Petrov and his key role in preventing an accidental nuclear launch after a software failure [35]). Despite both of these components being primarily for research preparation purposes, they have a social component as well, as they are activities that the whole group participates in and facilitate extended periods for group bonding.

For program design for the NDSU program, the following general protocol has been used:

1. Identify the start and end dates – this is based on semester start / end dates, mentor availability, facility availability and the conference targeted (concurrent with step 2).
2. Identify the conference that the students will attend (concurrent with step 1).
3. Identify other key dates within the program such as dates when relevant speakers will be on campus and when events that several of the campus REU program will participate in (such as a combined poster session) will be held.
4. Explicitly plan time for documentation (paper / poster development activities) throughout the experience.
5. Identify dates for program-led multi-purpose / social activities.

6. Starting in a video conference before the student participants arrive and continuing once they're on-site, give the students ideas for other activities and help them fit these into free time (weekend, evening, etc.) slots. Look for opportunities to enhance student-identified social activities with programmatic elements.
7. Validate that the schedule meets all program and funding source requirements.

4. Social program outcomes

The key goals of the NDSU REU site's social programs are to:

1. Encourage cohort bonding and the development of long-term friendships and potentially beneficial professional relationships between student participants,
2. To enhance student participant excitement about the REU program, its activities and cybersecurity and cyber-physical system research, and
3. To support other REU activities with programming that fills gaps, leverages opportunities, maintains momentum and participant spirit levels and mitigates feelings of loneliness and homesickness.

To this end, the NDSU program conducts a very limited number of purely social activities, team/cohort building activities with an inherent social component and social activities incidental to other REU site activities.

5. Social program components

The NDSU REU program makes use of on-campus and local resources. It also incorporates social elements into the free and travel time during the conference trip. Figure 2 illustrates both.

Team / cohort building exercises, on campus – the program starts with a team / cohort building activity that is designed to help everyone learn everyone else's name and a little about them. It also gets everyone up, moving and interacting. One of two field areas on campus is used for this purpose.

Visit to museum, local location – a visit to a local museum serves a dual purpose. It helps student participants to consider the evolution of various technologies including those that create visual and moving visual mediums. The need for various types of security solutions is discussed. The visit also makes a nice short outing for the group and gets everyone out of the office and interacting.

Visit to decommissioned ICBM site, local location – one of the most memorable things that student participants get to visit during the program is a decommissioned missile silo and command center (shown in the upper left, in Figure 2). The professional development benefits of this dual-purpose trip have been discussed in Section 3. The trip is also an exciting experience for the students and an opportunity to spend most-of-the-day bonding with the group.

Camping opportunity – for student participants that enjoy camping – or want to try it, because they haven't ever before – there are typically several opportunities for local camping.

Figure 2. Student participants visit a decommissioned ICBM site (top left), attend a conference (top right), eat lunch together in a local park (lower left) and visit a local museum (lower right).

The social program includes a limited number of purely social activities, multiple team/cohort building activities with an inherent social component and social activities incidental to other REU site activities. Components of the social program include:

Visit to other departments on campus – the program had the opportunity to take the REU participants to several other locations on campus to learn about interesting computational technologies in these areas. The student participants got to visit the Architecture Department to see how virtual reality, augmented reality and 3d printing are used to support their work. An augmented reality sandbox that the students got to try is shown in the lower left of Figure 3.

The student participants also got to visit the research computing department and the Information Technology Division's primary data center and network connectivity location and be introduced to high end server and networking hardware at both locations. The research computing department also presented on how computing clusters could be used to support research activities.

In addition to the technical learning, these were also fun outings for the students. Visiting the Architecture Department took them to our second campus location and provides an opportunity to introduce them to the city transportation system, which the participants get free access to because of an agreement between the university and the city.

Figure 3. Student participants visit a local technical landmark (top left), go camping (top right), visit another department on campus to learn about a technology they use (bottom left) and attend a local air show (bottom right).

Visit to KVLY tower – in the local areas, there is a unique attraction, which is conveniently located between campus and several different locations that the student participants will visit during the experience. The KVLY Tower was once the tallest structure in the world [36] and is still the tallest structure in North America. The KVLY tower visit provides an opportunity for student participants to learn, think about and discuss wireless data transmission security and physical security concerns. It is also exciting, because most people don't know that the KVLY tower is located just outside of Fargo, North Dakota.

Free time activities on conference trip – while on the way to the conference and in the free time in the evenings, the student participants have the opportunity to explore the conference city and locations on the way and on the return.

Local air show – the Department of Computer Science chair sponsored a trip for the students and some of the faculty mentors to attend a local air show in Fargo, North Dakota that is located just beyond the north end of NDSU's campus. The student participants get to spend one day of their weekend (the show is open both Saturday and Sunday), if they want, and see the flying demonstrations from local enthusiasts, touring acts and military craft. They also can tour the ground exhibits. This has fallen towards the end of the REU, so it is a nice group outing.

Street fair – Fargo, North Dakota has an annual street fair. This makes for a short, no cost (as the no-cost-to-us city busses can be used to get to and from it) outing for the program. The fair has lots of food vendors and a variety of other attractions. It typically makes for a good dinner and activity.

6. Site results and social component contribution

The NDSU REU site is assessed in a variety of ways. Part of this assessment is a survey (discussed in [37]) that asks student participants to, at the end of the program, characterize their pre-participation and post-participation levels in several key areas. Table 1 shows this data for the first year of the NDSU site.

Table 1. Improvement of Skills from participation [37] (highlighting added).

	Pre-participation	Post-Participation	Increase
Technical Skill	2.8	5.7	2.9
System Design	3.5	5.9	2.4
Excitement	7.5	7.7	0.2
Presentation Skills	5.5	6.1	0.5
Presentation Comfort	5.8	6.3	0.5
Leadership Skills	5.4	6.1	0.7
Leadership Confidence	5.3	6.4	1.1
Project Management Skills	5.4	6.5	1.1
Time Management Skills	4.9	6.7	1.8

The areas that the social program may contribute to include excitement, leadership skills, leadership confidence, project management skills and time management skills. The areas of the social program that may be responsible for driving potential gains in each area include:

Excitement – Many social program activities are designed to create student engagement and excitement. Excitement can come from the location visited (such as the ICBM site) or the nature of the event (such as the air show). The opportunity to explore a new city, learn a new skill or have a new experience can also be exciting for REU participants.

Leadership Skills and Confidence – REU participants can certainly gain leadership skills through their research project. The social program provides an opportunity to do this in a different context. Through the social program, participants have the opportunity to lead their team (usually taking turns or through collective decision-making) and help design and run events for the group. Participants have planned group meals, camping trips, trips around town and other group experiences.

Project and Time Management Skills – Participants, similarly, gain project and time management skills through their research project. Their work on planning and leading group excursions also helps develop project and time management skills. Most importantly, however, participants learn how to fit together their project activities, social program activities, personal time commitments and other required activities into a schedule and project plan that leads

towards project success.

In each of these categories, student participants have shown an increase. In time management, this increase is 20% of the 9-point Likert-style scale. Notably these increases are not as high as the technical and system design skill increases, which of course are core components of the program. Also, the core components of the program contribute to the identified areas as well and no mechanism exists for differentiating between the impact of the core program and social program as to the level of contribution.

The excitement gain is not as pronounced as the others and the reason for this is not entirely clear. Excitement started with the highest average score (7.5) and also ended with the highest average score (7.7), among all of the categories. Given this, there was less scale-room for it to show gain. However, even considering the amount of gain relative to the gain possible (given the starting score and scale maximum), excitement still increased, as a percentage, the least of all categories. Arguably, producing additional gain may be non-linear and thus smaller gains, given a similar level of activity, could, prospectively, be expected at higher scale values because of this.

Table 2. Improvement of Skills as a Percentage of Possible Gain.

	Possible Gain	Increase	Percentage Gain
Technical Skill	6.2	2.9	47%
System Design	5.5	2.4	44%
Excitement	1.5	0.2	13%
Presentation Skills	3.5	0.5	14%
Presentation Comfort	3.2	0.5	16%
Leadership Skills	3.6	0.7	19%
Leadership Confidence	3.7	1.1	30%
Project Management Skills	3.6	1.1	31%
Time Management Skills	4.1	1.8	44%

Participants were asked as to the impact of the program on increasing excitement (shown in Figure 4) and all but one answered in the strongly agree, between strongly agree and agree and agree categories. Given the attribution of increasing excitement to the program, it is possible that some unknown confounding factor is impacting the data in Tables 1 and 2.

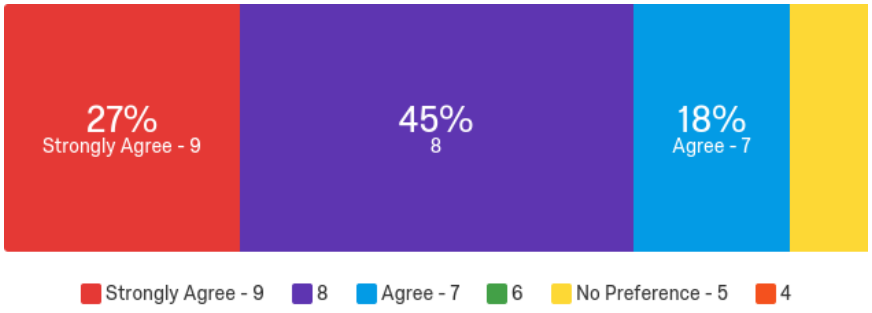

Figure 4. Participation increased excitement [37].

Perhaps more pronounced, but not assessed, was the demonstrable bonding of the participants leading to them spending time outside of organized activities together. The student participants created their own mini-trips around the city from time-to-time. The students were also very sad to part in the final days of the program.

7. Template REU social program

The idea of this template is to provide those running a REU site for the first time – or those proposing for one – with an idea of what an excellent social program entails. It is important to note that doing this effectively takes a lot of work on the part of site leadership (and faculty mentors and possibly department staff). An effective social program can dramatically enhance a REU site. Alternately, blunders with the social program can create bad feelings among participants and undermine the comradery that is so critical to build.

Creating an effective social program can also be an exercise in fundraising and frugality. Securing institutional funding for side trips, entry fees and other expenses that are not part of the core program may be more difficult at some institutions than at others. NDSU's Department of Computer Science has been very generous in supporting several social program costs each year.

This plan is based on a ten-week duration. For sites with durations of eight or nine weeks, it is probably prudent to remove a weekend activity. For a twelve-week site, it may be desirable to add an additional weekend activity.

The below plan shows the primary activities (in the left column) and suggested social activities (in the right column). This is not an exact match to any year of NDSU's activities (or activities at the precursor University of North Dakota site), nor will it likely be possible for a new site to follow it precisely. The template in Table 3 should be adapted based on local attractions (paying particular attention to local events), where holidays fall and program requirements.

Table 3. Social Program Template.

Week	Research Goals	Social Activities
1	Topic selection, background research	Team / cohort building activities, activity in the local community (museum visit) or elsewhere on campus
2	Background research, experimental design	Student planned activity in the evening or on one weekend day, student-planned small group activities
3	Experimental design, system* / experiment implementation	Group activity such as the missile site tour
4	System / experiment implementation	Student-planned small group activities, group meal
5	System / experiment implementation, system / experimental design testing	Group activity in the local community (street fair)
6	Implementation, experimentation & analysis	Student-planned small group activities, group meal
7	Implementation, experimentation & analysis	Group activity, such as camping, on-campus tours

8	Experimentation & analysis	Student-planned small group activities, group meal, on-campus tours, meeting with graduate students, graduate advisors / program directors
9	Wrapping up experimentation, beginning write-up	Group activity (air show, etc.), student-planned small group activities, group meal, preparing for conference trip
10	Final write-up, presentation	Conference trip (if possible**), presentation at campus poster session***, group meal towards the end of the week

* As a computer science site, many of our projects require software development or integration, so system design takes more time than might be allotted in other disciplines.
** Ideally the conference would fall at the end of week 9, over the weekend and into the beginning of week 10. Of course, there may not be a conference at this time that is relevant to a site theme, so this would need to be re-positioned accordingly.
*** This is not really a portion of the social program, but has a distinctly social component as it is a key point of interaction between the students in our program and other REUs at NDSU.

We typically have group meals on holidays like the 4th of July where some of the closer-by students may be returning home while the others (who flew to NDSU) cannot. This helps prevent homesickness.

8. Operational decisions impacting student enjoyment and learning

Two key decisions have been very effective in enhancing student enjoyment and promoting learning. The first is to arrange some initial activities for the student participants to get them interacting with each other. The introduction of this at the beginning of the NDSU REU site made a markable difference compared to the previous University of North Dakota (UND) site. While program leaders observations indicated that students from both programs eventually ended up becoming very close friends, the students in the newer NDSU program got to a point of effective interaction and cohesiveness much faster because of the initial team / cohort building exercises. While the students work alone on their projects (sometimes collaborating on related projects), so that they each have a demonstrable personal outcome from the REU, they interact in numerous other ways. Getting them to the point of comfortable interactions quickly enhanced first week (in particular) productivity.

The second key decision, which was actually brought over from the older UND site, was to have the student participants plan out most of the social program. Items that are purely social are entirely the students' responsibility (with mentoring) to schedule and plan. Items that can be easily moved, such as the missile site visit, are scheduled in conjunction with the student participants, with discussions of how different scheduling decisions impact other aspects of the program. This exercise gives students ownership of this key portion of the program, leadership and planning experience. It also results in a program that is tailored to their needs and wants, because they planned it.

9. Special Considerations

Special considerations are presented by students that may be outside the typical age range of undergraduate students as well as students that may have disabilities or medical conditions. We ask students to tell us, initially, about any disabilities or medical conditions that they believe may impact program participation so that we can arrange appropriate accommodation. We also ask participants to let us know, at the time, if any activities may bring up other unexpected medical or disability concerns.

10. Conclusions and future work

This paper has discussed the social programs at the NDSU REU site, the contributions that these programs make to overall site goals and their implementation. It has provided a guide that can be used by those planning (or proposing) future sites. Hopefully it may spark additional ideas for social program elements in those that have even run sites for some time.

Minimal assessment has been conducted on the impact of REU social programs or differentiating their outcome contributions from other parts of REU site activities. Further study of REU social program design, implementation and impact is clearly required to enhance the understanding of how to best design REU social programs for maximum benefit to the participants.

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