national center for women & INFORMATION TECHNOLOGY

REU-IN-A-BOX:
EXPANDING THE POOL OF COMPUTING RESEARCHERS

www.ncwit.org/reubox

Photo: Todd Kulesza, 2011

REU-in-a-Box: Expanding the Pool of Computing Researchers explains the benefits of undergraduate research in computing and guides faculty mentors through the three stages of an REU: Before the REU (Deciding to Get Involved and Getting Started), During the REU (Faculty Mentor Activities and Student Activities), and After the REU (Post-REU Assessment and Next Steps for Student Researchers). With content developed by experienced computing faculty mentors and undergraduate researchers, this resource focuses on the interactions of a faculty mentor with one or a few students and the processes by which they conduct and share the outcomes of their research. Modifiable templates and handouts are included.

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Strategic Partners: National Science Foundation, Microsoft, Bank of America

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At-a-Glance

Early Research Experience Fosters Continued Participation

Hands-on research is an evidence-based way to engage students more actively in their undergraduate degree programs and to provide a pathway to graduate degrees and research careers.

Why REUs?

REUs are a powerful tool for faculty to shape the next generation of researchers while making a lasting impact on students' lives. These experiences are particularly vital for women and underrepresented groups, as they provide the close faculty mentorship known to drive student retention. This is especially critical in the computing field, where the underrepresentation of women is most pronounced in roles requiring advanced degrees; REUs bridge that gap by preparing students for graduate study.

Why *REU-in-a-Box*?

REU-in-a-Box brings together tested advice and resources for faculty as they provide research experiences to students. *REU-in-a-Box* focuses on the interactions of a faculty mentor with one or a few students involved in undergraduate research and the process by which they conduct their research. The Box is well-suited for every faculty member who wants to maximize the outcomes of undergraduate research for both herself/himself and the student researcher. For institutions with a formal REU program, *REU-in-a-Box* can complement the program and provide tools to make it even more effective.

What's in *REU-in-a-Box*?

- **Solid Rationale**
  REU-in-a-Box explains the benefits of undergraduate research in computing to the student researcher, faculty mentor, academic department, and computing community at large.
- **Guide for Processes**
  From getting students involved, to managing the experience, to evaluating the REU and helping students with their next steps, *REU-in-a-Box* provides support for every action before, during, and after the REU.
- **A Range of Approaches**
  Some activities of an REU can be structured (e.g., deliberate skills development, status reports) and others less structured (e.g., brown-bag lunches, informal hallway briefings). *REU-in-a-Box* provides examples faculty mentors and student researchers can adapt to their own preferences and personal style.
- **Sample Forms and Templates**
  REU-in-a-Box includes a variety of materials and information faculty can use for their work with undergraduates, such as a sample recruiting letter, status update forms, guidance on how to conduct a literature review, and self-assessment surveys.

Start Now

REU-in-a-Box is available for download at www.ncwit.org/reubox. You'll also find the modifiable templates and handouts as Microsoft Word documents. NCWIT is interested in your feedback. When you download *REU-in-a-Box*, please share your contact information so that NCWIT can follow-up with you regarding the resource's quality and usefulness.

Acknowledgments

ACADEMIC NCWIT& ALLIANCE

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Part 1: Introduction to REU-in-a-Box

1.1. Why Participate in an REU?

The underrepresentation of women in computing is most acute in careers requiring or best served by graduate degrees.[1] By encouraging and supporting REUs, faculty mentors are actively working to improve future professoriate and research cohorts. The visibility of students working with faculty can provide support for students considering majors in that field[2] and elevate the research profile of a department.

In a Research Experience for Undergraduates, or "REU," a student researcher engages in hands-on research guided by a faculty mentor. Hands-on research is an evidence-based way to engage students more actively in their undergraduate degree programs and to provide a pathway to graduate degrees and research careers.[3] While participating in REUs benefits all students, they may be particularly important for women and underrepresented minorities, since they provide opportunities for personalized student-faculty interaction, a strong predictor of student retention.[4]

The faculty mentors and their departments can benefit too, as explained in 1.4.

> Hands-on research is an evidence-based way to engage students more actively in their undergraduate degree programs and to provide a pathway to graduate degrees and research careers.

1.2. What is REU-in-a-Box?

REU-In-A-Box explains the benefits of undergraduate research in computing, describes ways to get students involved, outlines how faculty and students can participate, discusses how to set expectations and manage the experience, and describes typical deliverables of successful undergraduate research experiences in computing.

REU-in-a-Box focuses on the interactions of a faculty mentor with one or a few students involved in an REU and the process by which they conduct their research.

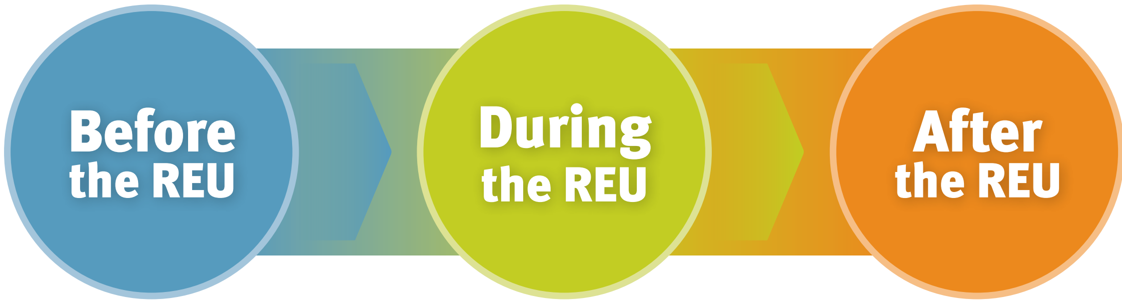
REU-in-a-Box presents a range of approaches, from structured (e.g., deliberate skills development, status reports) to less structured (e.g., brown-bag lunches, informal hallway briefings), that provide examples student researchers and faculty mentors can adapt to their own preferences and personal styles.

REU-in-a-Box includes materials and information that faculty can share with undergraduate students who are considering research experiences.

The guidelines in REU-in-a-Box are not specific to any particular program or funding source. REU-in-a-Box is not intended to support the planning or implementation of multi-student, multi-faculty summer programs (e.g., a National Science Foundation-funded REU Site).

An REU often follows the process shown in the graphic below. Variations of this graphic are used throughout REU-in-a-Box to identify the part of the process the material is describing.

STAGES OF THE REU



Before the REU

Deciding to Get Involved
- Why Participate
- What REU-in-a-Box Provides
- Student Benefits
- Costs and Benefits for Faculty Members
- Explain Research to an Undergraduate
- Put a Plan in Place

Getting Started
- A Detailed Look: Benefits, Time Costs, and Funding
- Choose a Research Topic
- Recruit Students
- Assess Student Background
- Set Up for Success: Planning Expectations and Logistics

During the REU

Faculty Mentor Activities
- Define Activities and Deliverables
- Foster Team Building and Individual Growth
- Monitor Individual Progress
- Adjust Objectives and Define Next Steps
- Provide Guidance, Encouragement, and Feedback
- Relate Student Work to Big Picture

Student Researcher Activities
- Develop Conceptual Understanding
- Review Literature
- Develop, Gather, and/or Analyze Data
- Report Findings
- Produce Deliverables: Status Reports, Paper/Poster, and/or Presentation

After the REU

Post-REU Assessment
- Student Self-Assessment
- Faculty Self-Assessment
- Post-REU Conversation

Next Steps for Student Researchers
- Update Résumé
- Present Research
- Consider Graduate School
- Apply to Graduate School
- Apply for Scholarships and Fellowships

Before the REU

1.3. What are the Benefits of REUs for Students?

Undergraduate research prepares students for careers in science, technology, engineering, and mathematics (STEM) by involving them in problem-solving experiences and exposing them to the excitement of innovation and discovery. Such experiences also add relevance to linear disciplinary study, which tends to favor gaining abstract theoretical knowledge over applied, real-world understanding.[5]

A longitudinal, large-scale impact study of undergraduate research experiences showed increased student understanding, confidence, and awareness of their field as well as increased retention in the major.[6] This comprehensive study also showed substantial research-related impacts, including gains in understanding of the research process, confidence in research abilities, awareness of academic and career options in STEM, and greater awareness of the nature of graduate school. Most undergraduate researchers also reported that their research experiences were important to their career decisions and helped them to have new expectations of obtaining a PhD.

Working with faculty mentors has been shown to be one of the most enjoyable aspects of a research experience[7] and can also bring the many benefits associated with mentoring relationships.[8] Some research shows that a mix of mentors, in background and gender, has a beneficial effect (such as plans for graduate opportunities) for all students, including women and minorities.[9] Therefore, it's important to note that faculty mentors do not have to be the same gender or racial/ethnic background as their student researchers.

It's important to note that faculty mentors do not have to be the same gender or racial/ethnic background as their student researchers.

Despite the benefits of a research experience, students are generally not aware of such opportunities, especially at institutions other than their own school. A comprehensive study[10] found that when student researchers first enrolled as undergraduates, only half were aware that the school offered undergraduate research opportunities, and, of those who were aware, only about half said that REUs were fairly or extremely important in their decision to enroll. Therefore, it is important for faculty to point out the opportunities offered by undergraduate research, helping students to become aware of the possibilities and encouraging their participation.

Even faculty who are not currently seeking to involve undergraduate researchers in their own research can encourage students to participate in REUs. The handout, *Attention Undergraduate Computing Students: YOU should consider an REU* (see p. 40) can be reviewed and distributed to students in courses or included on a departmental website.

Even faculty who are not currently seeking to involve undergraduate researchers in their own research can encourage students to participate in REUs.

Faculty who are seeking to involve undergraduate researchers in their own research will find recruiting materials and ideas in Part 2 of this Box.

1.4. Why Would a Faculty Member Choose to Work with an Undergraduate Researcher?

Both departments and individual faculty members can benefit from REU participation. Departments can use undergraduate research as a recruiting tool to attract undergraduates and to showcase the quality of their programs to the community and other departments. Advising an REU student does not have to be a "service-only" endeavor; it can benefit even pre-tenure faculty members. The key is to involve REU students in projects that will help the faculty mentor achieve existing goals; if this key factor is in place, the faculty mentor can benefit through greater productivity. Other benefits include building relationships with emerging researchers, developing a potential source of pre-trained graduate students, becoming eligible for external funding (supplements for REU students, or as "broader impacts" strategies for regular NSF grants), providing mentoring training for graduate students, and clearly making a difference in student lives.[11]

> The key is to involve REU students in projects that will help the faculty mentor achieve existing goals; if this key factor is in place, the faculty mentor can benefit through greater productivity.

The case studies to follow illustrate how several faculty mentors have worked with undergraduate researchers and the benefits of the experiences.

Case Study
Oregon State University

Adapted from NCWIT's *How Can REUs Help Retain Female Undergraduates? Faculty Perspectives* (www.ncwit.org/reufaculty)

Since her first year as an assistant professor (1991), Professor Margaret Burnett has always had one or two undergraduate researchers working for her. She describes three benefits to her own career:

1. Increased productivity: The undergraduates round out her research group. The undergraduates' contributions to research tasks otherwise done solely by graduate students help everyone get the work done faster. Further, she says that some of her undergraduates rival some of her grad students' productivity at tasks such as software development, data analysis, user studies, and interface design. Some even have writing skills as good as or better than their graduate student team-members.

2. Strong relationships with future researchers: Because most REU students are selected from the top of their class, they are very good—in fact, some eventually rise high in their careers. They usually appreciate the extra opportunities a faculty mentor can give them, and their loyalty forges a strong relationship that can last throughout careers.

3. Making a difference in students' lives: Burnett speaks of the benefit to the REU students themselves: "Giving these students just a small amount of time can make a huge difference in their careers. Some have never thought of research, or have believed themselves unworthy of aspiring to graduate school. These experiences change their lives."

Most of Burnett's REU students have gone on to graduate study in computer science. In preparing them for this possibility, she treats the undergraduates just like the graduate students in her group. The REU students support software development of research prototypes and do everything else graduate students do: help to write, read, and review papers; attend group research meetings; help with empirical studies; and prepare posters for required presentations.

> **"Giving these students just a small amount of time can make a huge difference in their careers. Some have never thought of research, or have believed themselves unworthy of aspiring to graduate school. These experiences change their lives."**
>
> ~ Professor Margaret Burnett, Oregon State University

Case Study
Virginia Tech University

Adapted from *NCWIT's How Can REUs Help Retain Female Undergraduates? Faculty Perspectives* (www.ncwit.org/reufaculty)

Professor Scott McCrickard has worked with undergraduates since he was a PhD student at Georgia Tech. His early mentoring experiences resulted in publications for him and his students. They have also contributed to his research career at Virginia Tech, where he established the Virginia Tech Undergraduate Research in Computer Science (VTURCS) program in 2001. VTURCS peaked to include over 50 undergraduate students in 2005 and thereafter spawned several senior capstone courses and special topics courses in many areas of research.

McCrickard says he benefits as much as the students. He has published several small articles based on his partnerships with undergraduates, some of which combined nicely as case studies for journal papers. But he says the most valuable result is that it has created a research group and community around his interests.

McCrickard suggests giving undergraduates simple, focused tasks. This method allows him to see the capabilities of the undergraduates, and also helps his PhD students create focused tasks and do something with the results of those tasks. He prefers to meet with his undergraduates and graduate students as a research team; these teams are composed of four to six undergraduates and his graduate students. As the students gain confidence and experience, they can be given more complex tasks with deadlines further apart.

> **[Professor Scott McCrickard, Virginia Tech University] says the most valuable result is that it has created a research group and community around his interests.**

Case Study
University of Texas at El Paso

Adapted from NCWIT's *How Can REUs Help Retain Female Undergraduates? Affinity Research Groups* (www.ncwit.org/reuaffinity)

As tenure-track faculty and now as tenured faculty, Ann Gates and colleague Steve Roach have engaged undergraduate researchers in solving software engineering problems using the Affinity Research Group model.[12] They argue that through participation in undergraduate research, students can reach higher levels of productivity and achievement and they become leaders in the workforce. Their graduate and undergraduate students have benefited from their research experiences and the emphasis on the deliberate development of research and professional skills; the collaborations and cooperative team work have led to numerous co-authored papers.

While a common practice in many research programs is to recruit and involve the most visibly successful students (e.g., students with competitive grade point averages or high test scores), Gates and Roach encourage faculty to recruit students who show potential, but who may lack confidence to become involved in research or may not believe that they are prepared to join a research group. This practice is critical for increasing the number of students who are involved in research and who continue to advanced studies, especially women and members of other underrepresented groups. Because teaching and practicing professional skills are part of the research group's activities, students are able to learn skills within their research groups and transfer them to other environments.

Gates' and Roach's efforts have a demonstrated impact. A retrospective qualitative study[13] documents the impact of research participation on students from Gates' and Roach's research groups; a quantitative study[14] shows the impact of the model as it was transferred to six additional institutions. The articles featuring these studies also report on the impact of the model on students in the workforce and as knowledgeable and skillful members of a research community.

1.5. Why Would Undergraduates Choose Undergraduate Research?

Undergraduates engage in research for four significant reasons:

1. **More Competitive Graduate Applications.** Many students applying for top graduate programs in computing have research skills they developed while conducting research under faculty supervision as undergraduates. While research experience is not usually a prerequisite for a master's program, it is important for applying to a PhD program, particularly if the student seeks a graduate assistantship. The REU improves the application, making the student more competitive and increasing the likelihood that she or he will be funded. The faculty mentor can also write strong letters of recommendation, an important component of a graduate application. Similarly, the REU makes the student a more competitive applicant for fellowships, such as the NSF Graduate Fellowship, for which students can apply during their final year of undergraduate studies.

> While research experience is not usually a prerequisite for a master's program, it is important for applying to a PhD program, particularly if the student seeks a graduate assistantship or fellowship.

2. **Better Job Applications.** REUs bring students into personal relationships with faculty; faculty can provide strong letters of recommendation (if all goes well!) and may know about job opportunities suited for the student. Additionally, working with others in a research lab helps the undergrad develop capabilities desired by employers, such as communication, teamwork, problem solving, and critical thinking.

3. **Research is Exciting.** Being part of a larger effort or team and working with people who are smart and engaged in their work is exciting. Likewise, seeing one's name on a poster, presentation, or publication is rewarding. Exposure to faculty and graduate students can also provide exposure to other talented people in the field and their ideas.

4. **Support for Career and Research Decisions.** Participating in an REU is the best way for a student to learn what research is like and to discover if she or he would like to pursue a research-oriented graduate degree. Getting involved in research in an area a student has enjoyed in the classroom can help the student learn what research is like for that area. This experience then can help a student decide whether to continue or to explore other areas.

> Participating in an REU is the best way for a student to learn what research is like and to discover if she or he would like to pursue a research-oriented graduate degree.

1.6. How Long Does an REU Last?

An REU student can be involved for a few months (e.g., over a summer) or for much longer (e.g., during an academic year). The most common choices are summer projects, a semester in an independent research course, and academic-year projects, but the length is entirely up to the faculty mentor and student to determine. Sometimes a faculty mentor involves promising undergraduate freshman who then continue every year until graduation.

1.7. How Can a Faculty Mentor Help an Undergraduate Understand Research?

"Research" has a wide range of meanings, but when undergraduates hear the term, they typically think of library-type research or biologists with test tubes. Faculty are often so accustomed to research they may find it challenging to describe to a novice. There are three ways research can be explained to students: by example, by definition, or by process illustration.

Research ***by example*** might include

1. Providing an example of earlier undergraduate research projects.
2. Initiating a discussion of how a class project might be expanded into an undergraduate research project.
3. Providing a research paper the faculty mentor has authored for the student to read, and then following up with a discussion of the specifics of that research and how the student might contribute to future research.

Research ***by definition*** is

1. Systematic study to discover and interpret new facts and knowledge, to apply facts and knowledge to solve practical problems, to design artifacts that extend human capabilities, or to develop theories that help to explain some aspect of the natural or social world.
2. Careful or diligent search and collecting of information about a particular subject.

Research ***by process illustration*** traditionally involves the following iterative steps (see p. 23 for variations on this model within computing research):

1. Hypothesis or question.
2. Literature search for prior work or current state of field.
3. Consideration/discussion of findings with hypothesis/question.
4. Refinement of #1.
5. Design and development of artifacts to be studied — e.g., system building, data collection, experimentation.
6. Testing of system/data/experiment to see if hypothesis or question is valid or answered.
7. Conclusions and suggestions for future work.

1.8. Putting a Plan in Place

Infrastructure and Communications Support

Undergraduate research opportunities are most successful when students have interaction with others. Undergraduate research is not often a single-person effort. Instead, the REU student is often part of a team engaged in one or more steps of the research process. Therefore, space in labs, teamwork opportunities, and a variety of interaction and communication opportunities are critical. See Part 2 and Part 3 of this Box for additional detail.

Sources of Funding (Locally and Nationally)

While funding is *not* required, it is possible to secure it when needed. Funding sources can include NSF REU supplements to existing research grants; the Computing Research Association's CRA-W and the Coalition to Diversity Computing's (CDC) jointly managed CREU and DREU research programs; industrial partners; and internal university funds, such as department, school, college, or foundation funds. Additional details on funding possibilities are presented on p. 14.

Be Familiar with the Stages of the REU

The graph at the beginning of this chapter shows the stages of the REU. The process begins with the faculty mentor recruiting, interviewing, and setting expectations for the student researcher prior to the start of the REU. During the REU, the purpose of the student researcher's participation should be clear, with routine communication and guidance. Also during the experience, formative evaluation will help faculty mentors make adjustments to improve the REU for both the student researcher and faculty mentor. The student's deliverables include a report, a poster, or other types or presentation of the work. Finally, a look back to evaluate outcomes for both the faculty mentor and student researcher helps to refine the process for future REUs.

These stages are explained in more detail in the following chapters.

Part 2: Before the REU

Before a faculty member begins offering REU opportunities for undergraduates it is important to attend to practical considerations such as support mechanisms, research topics, student recruitment, and initial interactions. This section explains how to initiate the REU and provides materials for getting started.

2.1. Considering an REU: A Detailed Look

Below are elements of the process the faculty mentor should consider before beginning an REU.

Benefits. As pointed out in Part 1, the faculty mentor stands to benefit in numerous ways, ranging from feeling good about making such an important difference in students' lives to increasing personal research productivity.

Time Costs. The time costs associated with mentoring a student researcher include the time needed to structure activities and to mentor the student regularly. A rough estimate of these time costs can be expected to be 30 minutes to about an hour per week.

- *Group meetings.* If there is a research team, include the student in current group meetings. Cost: 0 (zero) additional hours per week.
- *One-on-one meetings.* The faculty mentor should meet with the student regularly, at least once per week for an hour or more frequent meetings of shorter duration. Cost: 1 hour per week or less.
- *Planning and logistics.* Often the student's project is something the faculty mentor has invested time in planning; as a result, determining the student's specific tasks is a small investment of time. Otherwise, planning will require a few hours. If there are logistics to work out, this may also take a couple of hours. Cost: Amortized over a year, the time cost is a few minutes per week.

While these costs can be shared to some extent with senior graduate students who can help with the structuring and mentoring, the ultimate responsibility for making sure these get done well is that of the faculty mentor.

Funding. Funding is not required for REU expenses. However, depending on the REU and the research undertaken, there may be monetary costs and benefits.

Some faculty offer independent study course credits instead of money. It is possible to mentor an REU experience with no direct tie to money or credit, though this can make the REU project take a back seat to the student's other deadlines.

Funding is available for REU experiences.

- NSF, CRA-WP, and others offer funding for one-on-one REU experiences.

  NSF's REU program
  www.nsf.gov/home/crssprgm/reu

  Faculty with current research funding from NSF are encouraged to apply for supplemental grants that can be used to incorporate undergraduate research into their projects. Look for the "REU Supplements" category.

CRA Undergraduate Research to PhD (UR2PHD)
http://cra.org/ur2phd

UR2PhD aims to ensure that undergraduate students have access to high-quality research opportunities, positive mentorship experiences, and information about graduate study and research pathways. This talent development programs equips students with the skills they need to excel in their careers.

CRA-WP's Distributed REU Program (DREU)
http://cra.org/cra-wp/dreu/

CRA-WP's mission is to widen participation and improve access, opportunities, and positive experiences for all people in computing research and education. DREU provides research experiences for undergraduate students early in their academic careers, supporting their interest in advanced study and careers in computing research, and education. This highly selective program matches promising undergraduates with a faculty mentor for a summer research experience at the faculty member's home institution.

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grams for R

Ronald E. McNair Postbaccalaureate Achievement Program
The program funds institutions of higher education to provide opportunities for disadvantaged and underrepresented students. Faculty can check to see if there is a McNair program on their campus.

- Many universities have in-house funding programs for REU experiences; faculty mentors should ask their university's research office.
- If the research is of value to the university or department itself, they may fund it. For example, a project at Oregon State University used the domain of a web-based student class advisor tool to work on an artificial intelligence problem. The department funded this project to improve departmental advising.
- Occasionally, funding is available from a company or other private source. For example, a consortium of independent private colleges in South Carolina funds undergraduate research. A university's research office may be able to help faculty members connect with such possibilities.

In most requests for funding, a written proposal is needed, usually requiring a brief project description and student selection criteria, as well as proposed outcomes and budget.

2.2. Why Students Might Consider an REU

Experienced REU students report common motivations for considering an REU.[15] Faculty mentors can review and share *Attention Undergraduate Computing Students: YOU Should Consider an REU* (available on p. 40) with students who are considering a research experience. To learn more about the undergraduate research experience, visit the Computing Community Consortium website: https://sparc.cra.org/students/

2.3. How to Choose a Research Topic

In some cases the faculty mentor will identify a subproject for the REU student that helps with a larger project already underway. In other cases, the faculty mentor may want to identify a separate project just for the REU student. In either case, the following guidelines are applicable.

For a win-win REU experience, the project needs to not only help the student, but also align with the faculty mentor's goals. For this reason, it is important to define the specific topic based on reasons that extend beyond providing a research experience and to make sure the topic has a reasonable scope for the time allowed.

It is important to define the specific topic based on reasons that extend beyond providing a research experience and to make sure the topic has a reasonable scope for the time allowed.

During discussions with the student, the faculty member should elicit contributions that can be incorporated in the work. It is possible to collaborate on a jointly developed research question. If a proposal needs to be written, the faculty mentor might outline the proposal and give it to the student to complete. The proposal should clearly state the research question, lay out the process to be used, and enumerate the research tasks. On the other hand, if a prepared proposal exists, the faculty mentor and student can together identify where the student contributions will be made.

Usually, undergraduates start with concrete, focused tasks.[16] These might be as varied as data collection, software testing, or observations. Then, as the students become more experienced in research and more familiar with the research culture, tasks can become more advanced.

Suggested REU research projects …

- are multi-faceted, but with a reasonable scope for the time frame
- are feasible in relation to the student's existing skills, but also build on them
- are feasible in relation to the student's available time
- have built-in difficulties that will be faced after the student has developed some confidence
- generate data or analysis that the student can present orally or in writing
- go *beyond* cookbook experiments or free programming labor

Sample Research Topics

Below are common formats of research projects and activities to which research undergraduates often contribute. Note that these projects are tied to the research questions being addressed by the research group.

Consider these overall formats and general activities for undergraduate research:

1. ***Help with the research needed to write a survey or overview paper.*** In this kind of project, students can meet as a group, divide up relevant papers to survey and summarize, and discuss progress and emerging insights each week, merging their notes into a draft survey paper.[17]
2. ***Process data.*** Data collection and analysis projects are popular. At least early forms of analysis of collected data are often done using qualitative methods, or Excel aggregations/charts. If the student has knowledge of some statistics, supervised quantitative statistical tests can also be part of the project. Sometimes this kind of work involves writing scripts to process data being collected by the student or others.

Types include:

- Scripts to initially collect logs of human subject behaviors (e.g., which features were selected). Follow-on quantitative analysis of human subject behavior data using mathematical, spreadsheet, and/or statistical software packages.

- Scripts to initially collect and later analyze hardware utilization (e.g., network loads, memory utilization). Follow-on quantitative analysis of hardware utilization using mathematical, spreadsheet, and/or statistical software packages.

- Scripts to initially collect and later analyze human subject selected "tags" against public databases such as WordNet or ConceptNet. Follow-on quantitative analysis of tag choices using mathematical, spreadsheet, and/or statistical software packages.

3. ***Help with human subjects research.*** This work is popular with Human-Computer-Interaction (HCI) faculty. Examples include:

    - Help to design experiments, help with the IRB paperwork, run the experiments with human subjects, and analyze data (see above).

    - Do qualitative HCI research (e.g., with training, the student can analyze videos, written transcripts, etc., for interesting phenomena and patterns).

    - Use analytical HCI techniques to help evaluate user interfaces to prepare them for human subjects in experiments.

4. ***Work on scientific or information visualization projects.*** REU students help design, program, and/or empirically evaluate graphics to portray interesting scientific phenomena (e.g., chemical reactions and disease spread across the country) or interesting aspects of information (e.g., propagation of supposedly "private" information across multiple websites and humans' eye movements to different parts of user interfaces).

5. ***Engage in study of topics of professional interest to the faculty mentor.*** One faculty mentor runs a term-long, one-hour research seminar (for credit) as the project. The students work on topics of interest to the faculty mentor and discuss them each week during the seminar.

See *Appendix of Example Projects* p. 52 for a list of concrete examples of projects submitted by contributors to this Box.

2.4. Recruiting Students

For the kind of REU experience described in this document— in which one faculty mentor works with one (or just a few) individual undergraduate student in research—REU students are usually local to the faculty mentor's university. Faculty mentors may wish to recruit the top students in their classes, or ask fellow faculty for lists of top undergrads in their classes. Ensure your outreach includes women and other underrepresented students, as broad and inclusive outreach helps to expand the pool of computing researchers. Diverse, cooperative teams have been shown to increase productivity and scholarship.[18]

A sample notice for recruiting locally, *Wanted: Research Experience for Undergraduates (REU) Students*, is available on p. 39. As mentioned in Part 1 and available on p. 40, *Attention Undergraduate Computing Students: YOU should consider an REU outlines for students the many benefits of an REU*; this is a piece faculty mentors may want to share with interested students.

Some universities now have an office that supports undergraduate research experiences and can be quite helpful in the recruitment process.

Additionally, CRA-W and the CDC run a summer program, called "DREU" for "Distributed REU," that matches undergraduate students and faculty mentors at different universities for summer one-on-one research experiences. To recruit a student through DREU and for more information see http://www.cra-w.org/dreu.

2.5. Getting Started Right: Setting Up a Successful Individual Research Experience

There are five important things faculty mentors can do to get started right.

1. ***Be ready to explain research.*** It cannot be assumed undergraduates understand research, either in general terms or in the context of a specific lab and its projects. Faculty mentors should take time to explain the research and the work the REU student will do within it, making sure to show the big picture of the project beyond the little part the student will play. A description of a common research cycle is available on p. 13; see p. 23 for research activities that relate to the cycle.

2. ***Choose a suitable research project.*** The suitability of the project is a defining characteristic of how good the REU experience can be. See p. 23 for sample research topics and p. 52 for a list of concrete examples. In general, the project needs to have a research component (not just a cookbook set of things to do), but still be feasible for an undergraduate student. A rough rule of thumb is that the project should be about the same amount of work as one class per term, but this can be customized to the student's course load and other commitments.

3. ***Communicate expectations early.*** At the outset of the project, the faculty mentor should discuss expectations with the REU student and what should be done if expectations cannot be met. It is important to include not only *what* the student will be working on, but also the faculty mentor's expectation of *how* she or he should work. For example, the student should be told to attend all group meetings related to the research project. Also, the faculty mentor should ask for a specific schedule (which times on which days) of when the student will be in the lab working on the project and discuss the fact that research has setbacks, making sure to discuss to whom the student should turn in these situations. The faculty mentor can review and share with the new student researcher the handout *Things for You to Think About When You Become a Student Researcher* on p. 41.

4. ***Plan how to carry out the REU process.*** If an orientation is needed for the student, the faculty mentor should decide who will be involved and the topics to be covered. For example, depending on the project and student, additional training, a review of ethical conduct standards, a discussion of intellectual property issues and confidentiality, and/or a review of lab and university research disclosure documents may be necessary. Examples of other items for the faculty mentor to consider are:

    - A communications schedule for the research team
    - Specific tasks with clear completion criteria
    - Scaffolded research tasks for the student researcher
    - Suitable tasks for the student to accomplish while the faculty mentor is traveling
    - Personality types and strengths as they relate to the research
    - Where the project may be at risk, due to research challenges or personality strengths. Part 3 of the Box addresses risk management in more detail.

5. ***Engage graduate students (if they are part of the faculty mentor's team).*** Graduate students who are or will be the under the direction of the faculty mentor should be briefed on undergraduates who will be joining the effort, particularly if the undergraduates and graduate students will be expected to interact. Graduate students will frequently guide the undergraduate students in the faculty mentor's absence, and can model appropriate behavior.

Graduate students who are or will be the under the direction of the faculty mentor should be briefed on undergraduates who will be joining the effort, particularly if the undergraduates and graduate students will be expected to interact.

Here is a list of points for faculty mentors to cover with graduate students as they prepare to have undergraduate student researchers join the research team:

- the number of undergraduates who will be joining the project, and how long they will be participating
- expectations for treating the undergraduates as potential future colleagues, while recognizing they are still undergraduate students with busy schedules, different maturity levels, midterms, finals, and the pressure to pay tuition
- ways in which this is an opportunity for the graduate students to determine if they enjoy working with undergraduates, helping them to understand whether a teaching career would be a good fit
- information about unconscious bias and stereotype threat [See NCWIT's primer on implicit bias (ncwit.org/resource/are-you-unconsciously-biased)]
- a reminder of Equal Employment Opportunity Commission (EEOC) and university norms, and that graduate student behavior towards the undergraduate student researchers will be observed, as it is an extension of the faculty mentor's professional environment
- examples of the tasks that the undergraduate student researchers might be expected to undertake
- examples of tasks which should not be delegated to undergraduate student researchers, especially if the graduate students will be permitted to supervise the undergrads
- expectations for the graduate students' mentoring practices and a reminder that mentoring undergraduates is an excellent way to develop the skills and facility they will need later as research and teaching faculty working with their own graduate students
- an explanation that an REU experience can be a major factor in an undergraduate student's continuation in graduate work
- encouragement to talk with the undergraduate student researchers about their own career pathways and how they chose a graduate program

2.6. Assessing the REU Student's Background

If the faculty mentor is unsure of the student's prior CS/IT research experience, asking some simple questions will help clarify the best starting point for the research.

Most CS/IT faculty find that students who have completed Data Structures and/or Algorithms are capable of higher-level research activities. If the prospective REU student has yet to take such courses, the research project undertaken should be appropriately tailored to match the student's skills. If specialized training is needed, make arrangements for the student to obtain it.

The following questions would be useful during a discussion between the faculty mentor and a prospective student researcher:[19]

- Have you completed any research methods courses?
- Have you completed any statistics courses?
- Have you completed any math courses, such as Differential Equations or Linear Algebra?
- Have you completed any computing courses? If yes, which ones?
- What programming or scripting languages have you worked in?
- Have you been required to make any presentations? If yes, briefly describe the topic of the presentation(s) and your experience.
- Have you been involved in any research projects? If yes, briefly describe your role in the project.
- Do you have any knowledge of plotting or visualization tools?
- How long have you been interested in research? Describe any particular event or individual that initiated your interest.
- What would be the best outcomes for you?
- How much time can you dedicate to this REU?
- What do you want to learn?
- Which faculty members can I contact as references for you?

2.7. REU Logistics: Meetings, Lab Space, Computers, Housing, and More

There are several practical considerations to address when arranging the REU. Here is a good sampling.

Set up a meeting and research log schedule

Group meetings. Students need to be treated as a contributing member of a team. Thus, REU students should be told that they should come to all project/group meetings. This will help them to understand how their own work fits into the larger picture, and to understand the value they are contributing.

Individual meetings. In addition, the REU student needs regular one-on-one meetings with the faculty mentor, or with a designated graduate student who is helping to mentor the undergraduate student researcher. These meetings are usually once a week, and may be more frequent at the start of the project.

Research log. Some faculty like their students to log regular status updates tracking their progress. A shared, communal resource, such as a Google Site or Wiki, permits all group members to access the information and provides an opportunity for the faculty mentor to edit and contribute. If the faculty mentor wants the research students to keep such logs, it's important to communicate expectations regarding the frequency of updates and the level of detail.

Lab Space/Computer/Library

At a minimum, the faculty mentor needs to make sure the student researcher has access to whatever computing and library facilities they need to be able to contribute to the project. It is best if the student researcher can work where the rest of the team works, such as the lab or graduate office space where other team members work.

The Visiting Student (Housing, etc.)

If the student is a visitor to campus, the faculty mentor should have a plan to connect them with resources like housing and a social group. A great way to do this is to have the student enroll in enough credit to qualify as a local student, e.g., 1 hour of independent study. (The faculty mentor is probably the right one to pay the bill for this. In any case, use the minimum number of hours possible.) Being enrolled gives the student the ability to live in a dorm, use campus facilities like the library and the workout center, attend on-campus events for students, and generally have access to the things local students have available.

If there isn't a good way for the visiting student to enroll minimally, the faculty mentor should attend to the details of getting the student access to housing and other resources they'll need, like the library.

Housing ideas for the visiting student:

- Residence hall on campus (see above)
- Roommate arrangement with other students in the research group — This helps keep the visiting student connected with other students on the team.
- Roommate arrangement with other visiting students — These students will be in a common situation.

2.8. Key Takeaways from Before the REU

1. **Benefits of REUs for Students**
    - Preparation for careers in science, technology, engineering, and mathematics (STEM)
    - Involvement in problem-solving experiences
    - Exposure to the excitement of innovation and discovery
    - Added relevance to coursework
    - Experience that can lead to more competitive graduate school and job applications
    - Support for career and research decisions
2. **Benefits of REUs for Faculty**
    - A recruiting tool to attract undergraduates and to showcase the quality of programs to the community and other departments
    - Achievement of existing goals, such as greater productivity
    - Building relationships with emerging researchers
    - Developing a potential source of pre-trained graduate students
    - Eligibility for external funding (supplements for REU students, or as "broader impacts" strategies for regular NSF grants)
    - Mentoring training for graduate students
    - Making a difference in students' lives
3. **Important Steps for Getting Started**
    - Be ready to explain research
    - Assess the student's background
    - Communicate expectations early
    - Plan how to carry out the REU process
    - Engage graduate students (if they are part of the faculty mentor's team)
4. **Logistics**
    - An REU student can be involved for a summer, a semester, or an academic-year
    - Plan for both group and individual meetings
    - Senior graduate students can help with structuring and mentoring
    - Funding is not required for REU expenses, but it is available

Part 3: During the REU

3.1. Research Activities

The **research activities** that can take place during an undergraduate research effort are known by faculty and may include one or more of the following: a literature review, Institutional Review Board (IRB) approval, data gathering, system or software development, measurement, and analysis. An undergraduate student is likely unaware of these research steps, and it is important that the faculty member discuss them with the student.[20]

A **conceptual understanding** of the research the undergraduate will be participating in will help the student see how the research project relates to the undergraduate curriculum, to faculty research interests, and, if applicable, to the big picture of other team members' work in the area. Considering the use of applied mathematics, or theory learned in the classroom, or implementation of specific approaches or algorithms discussed in a computing core course encourages both the conceptual understanding of the curriculum and the larger discipline topics, while moving the research agenda forward.

A conceptual understanding of the research the undergraduate will be participating in will help the student see how the research project relates to the undergraduate curriculum, to faculty research interests, and, if applicable, to the big picture of other team members' work in the area.

Individual research projects do not always include all research activities — usually, some activities are called for and others are not needed. Here are examples of some of the research activities that *might* be associated with a specific research area:

A **theoretical research** topic might include a literature review, hypothesis development, testing, and analysis. Another example would be literature review, algorithm design, proof of correctness, and complexity analysis.

A **software engineering or systems** research project might include system requirements analysis, software design, implementation, testing, and performance analysis.

A **human-computer interaction (HCI)** research project might include a literature review, research question development, experimental design, IRB application submission and approval, testing, and results analysis.

A **cross-disciplinary effort** in an area such as bioinformatics, the application of statistics and computer science to the field of molecular biology (data intensive projects such as DNA sequencing), would include a literature review, research questions, experimental process design, data gathering, and analysis.

These examples are not meant to be comprehensive or all-inclusive. They are provided to show how research can take different forms even in topics that are part of the same scientific area.

The faculty mentor may wish to share the stages of research activity with the undergraduate researcher:

Literature review. Students joining the research group need to become aware of the work that has taken place in the research group, the steps that were followed, and the context and motivation for undertaking the current research project. One way to accomplish this is to give the student the task of reviewing work published by the group and other work that has been informally distributed (via the web or other methods). The faculty mentor can review and give the student researcher *What Is a Literature Review and How Do I Do One?* (See p. 42.)

In addition, the student researcher should become familiar with other research efforts. To help the student get a feel for how the research community works together, the faculty mentor may consider having the student do a citation search to see who has cited other published research.

The faculty mentor can provide the student with a complete project literature review or assign readings on a weekly basis during the early parts of the REU, making sure the student understands the structure of a research paper and how to read it and identifying useful journals and conference sites for the student.

Despite their importance, literature reviews can be very isolating. The faculty mentor may consider putting a time limit on the literature review ("Let's set aside Monday and Tuesday for your literature review, and plan to discuss what you've found on Wednesday morning."), or present it as an opportunity to introduce the undergraduate to the research team with a briefing to the research group as a whole ("See what you can find during a literature review Monday and Tuesday and provide your results and a short briefing to the rest of the team during our weekly meeting on Wednesday."). This will provide a structure and outcome for the literature review and give the faculty mentor an early opportunity to see how the student handles this task.

The faculty mentor may also want to consider the following ideas:

- Plan literature discussions with the student researcher and others.
- Set an expectation that the undergraduate researcher will participate more fully as she or he becomes familiar with the review process.
- Advise the student to keep careful notes, so that the information gathered can be included in a research paper or in the background section of a poster.
- Consider introducing web-based bibliographic tools to keep track of sources, such as Zotero (http://www.zotero.org/), whether or not a formal literature review is necessary.

IRB approval. If the research project requires IRB approval, as is often the case in Human Computer Interaction (HCI), social computing, and other research involving human subjects including cross-disciplinary projects, the faculty member should be sure to explain the IRB process to the student. The faculty mentor should prepare and submit the IRB application well in advance of the proposed research, so that IRB approval will be granted in time to conduct the research. If time permits, the faculty mentor can work with the student to prepare the IRB request, so the student learns more about the proposed research and the process of receiving authorization for research involving human subjects. Furthermore, the student researcher can earn a Certificate of IRB Tutorial Completion. For campuses that do not have their own educational materials, the NIH has a free site (http://phrp.nihtraining.com/users/login.php) through which anyone can be certified. Most IRBs will accept these certificates. Another good training website is the Collaborative Institutional Training Initiative (CITI): https://www.citiprogram.org/Default.asp.

Data gathering and software development. Undergraduates can develop their research skills through data gathering, using techniques ranging from user surveys or interviews to system observation and measurement. Developing software — which students are familiar with — to use for experiments or testing is another research activity. Faculty mentors can consider having their student researchers prepare surveys that are administered to others. The Government Accountability Office has a useful website of survey/questionnaire development: http://archive.gao.gov/t2pbat4/150366.pdf. Faculty mentors can also make an existing system available that the student researcher then uses to provide data for further analysis. Or, faculty mentors can have student researchers modify existing software in order to try out a new algorithm and test against the original. Most importantly, faculty mentors should make sure the student researchers understand how their tasks fit into the larger research process.

Measurement, experimentation, testing, analysis. This step in the research process is highly variable depending on the research question being investigated. Analysis, or the review and consideration of data gathered during measurement, experimentation, or testing is an important part of research. The faculty mentor can review the different steps associated with measurement, experimentation, and testing, as well as the situations in which each is the appropriate approach. The student researcher needs to understand how important it is to keep a lab notebook for accurate reporting and to make sure the project timeline includes time for analysis and checking for accuracy.

3.2. Team-building and Individual Growth

Once an REU is underway, different techniques can be used to develop the undergraduate as an independent researcher.

Team Building

An important facet of any REU is creation of an environment in which group members share common research goals (including goals for academic and professional development), group members work toward the success of the project, and each member flourishes. While it is possible that faculty may work with undergraduates exclusively in a one-to-one manner, the student is also part of a larger team of researchers, whether co-located at the host university or college or in the larger external research and sponsored projects community. Attending group meetings and teleconferences will help the undergraduate gain skills in teamwork and communication, as well as improve the student's contributions to the team and the team's effectiveness as a whole. Outlined below are team-building approaches which may be useful to the faculty researcher as the student conducts research, prepares presentations, and works towards presenting research results effectively, to other students or at a conference.

When building a research team, consider the cooperative team approach developed by David and Roger Johnson[22] and expanded in the Affinity Research Group Model (ARG).[23] Based on social-psychological theories of learning, this paradigm has been extensively applied in classrooms and for team building in business environments. In this approach five basic elements must be present in the activities within the group for it to function as a cooperative team:

1. ***Positive interdependence.*** Each member knows that she or he contributes to the success of the others and the group. When positive interdependence is present, each member of the group has a personal stake in the success of the group and believes that the group values her or his contributions. Positive interdependence can be structured for the research group in a variety of ways, such as through assigning roles and creating shared goals. For example, students may name their project within the group; members of the research group could participate in defining or refining the group's mission or goals; and students can participate in creating and maintaining a research group website.

2. ***Face-to-face promotive interaction.*** All members of the group work in ways that promote each individual member's success, as well as the success of the group as a whole. Faculty mentors support and encourage members' progress and involvement so that the students feel comfortable exchanging and sharing ideas and resources with each other, with the explicit goal of making each other and, therefore, the group successful. It is important to acknowledge and recognize each member's contribution to the group. Consider building a structure by which you regularly recognize students' accomplishments, such as at monthly meetings.

3. ***Individual accountability.*** Each person must be responsible for her or his fair share, defined generally in terms of tasks and deliverables. This is critical for developing strong individuals and well functioning teams. Individual accountability allows students to assess their own abilities and areas of weakness and to seek help so that they can improve their performance. Structure individual accountability by assigning concrete tasks, along with deliverables, to every group member.

4. ***Group and professional skills.*** Developing effective group participation and professional skills makes for more productive and successful interaction among group members and is key to maintaining positive interdependence. Never assume that students come with the necessary skills to work effectively in research groups. Explicitly teach group and professional skills in activities designed around technical topics, such as the discussion of journal articles or critiques of technical presentations.

Group and professional skills include basic skills such as active listening, active participation, and recording minutes, as well as more advanced skills such as summarizing, providing directions, synthesizing ideas, asking questions, facilitating brainstorming sessions, and offering constructive critique. Faculty mentors can teach group skills by asking students to identify and describe the aural and visual cues of someone modeling or practicing a particular skill. For example, the faculty mentor might encourage students to listen for and identify statements that support a constructive critique, such as the following: "I think your example was effective. It might be more effective if you presented it earlier in the talk."

5. Group processing. Structure meetings so team members regularly reflect on how well they are achieving their goals and how well the group is functioning. Based on the results, determine whether programmatic changes need to be made, and ask team members to identify the changes that need to be made in their group.

The five elements of a cooperative framework can be structured into weekly group meetings, the day-to-day functioning of the group, and throughout the life of the research group. Team-building and interaction tools, such as Meyers-Briggs Type Indicator (MBTI) or the Keirsey Temperament Sorter, are useful to build a sense of team belonging, while also helping people appreciate the differences of others on the team. Improved communication, conflict management, and time management are just a few of the outcomes of these tools. The tools may be very useful for multi-year on-going team projects and certainly for smaller teams of two to three members which may take on new members after the departure of others due to graduation or other pursuits. Acknowledging changes in the team composition can be very useful for making the most of the new team members, while assisting the veteran team members with new roles.

Team-building methods can be easily included in research projects, even those with smaller timelines, such as 10-week summer or single-semester projects, by structuring meetings so that cooperative team skills are practiced and modeled by the faculty mentor. Research teams can also adopt midterm reflection discussion (held during week six or seven, for example) and a final assessment.

Improving the Team and Individual

Process improvement. Process improvement is the identification of strengths and weaknesses in processes and the resulting revision of processes that address any discovered weaknesses. The faculty mentor can create a mechanism for assessing how well the team is functioning by evaluating the progress of the research, students, and any subgroups. Student researchers benefit from self-assessment that helps them examine how well they are functioning in the research group. This can give them a medium to evaluate their progress and interactions as part of the team and allows them to adjust their behavior accordingly.

It is important to include risk identification, assessment, and mitigation when defining research tasks. Typical risks that should be identified include:

- **When undergraduate and master's level students are involved in the group for a limited period.** Task turnover and project continuity might suffer from different talent levels, non-overlapping time schedules, and communication problems. This risk can be overcome by making one (often the graduate student) or both students aware that this is a difficult transition which should be managed carefully. With extra attention, such as additional detail in the research log or extra briefing time before or after the weekly meeting, this risk can usually be navigated successfully.

- **When a student decides not to continue in the research program.** An approach for mitigating this type of risk is to have students work as pairs or trios, particularly when their tasks are on a critical path, and to structure meetings in which each member describes her or his efforts. Another approach is to define deliverables is such a way that information can be transferred among members of the group and to new members, preserving continuity and productivity.

- **When one student dominates and in effect limits participation (and learning) by others.** This is another problem that can be mitigated by defining and assigning individual deliverables and then monitoring the activity of the team.

In addition to observing the researchers as they are working and discussing research in meetings, faculty mentors can consider asking students to complete a questionnaire and then use the responses to make adjustments. Example questions follow:

Personal tasks

- What successes have you had in your research project?
- What obstacles have you encountered?
- What help do you need to meet your research goals?
- What can you do to improve your efforts to meet your goals?

Team

- What has worked well in the research team?
- What can be improved?

Member relationships

- Do you have effective working relationships with your team members?
- What member actions do you find helpful?
- What member actions could be improved?

Individual improvement and growth. In addition to conversations about the research underway and the research process, more organic conversations may take place. One of the most important interactions with the undergraduate researcher will be those with the faculty mentor, who is modeling what it means to be a research professional and introducing the undergraduate to the culture of computing and information technology research. Topics such as ethics, how publication works (posters, conferences, journals), peer-review, providing research results to the research community, and career opportunities in research will all be shared, either explicitly or implicitly. These conversations will contribute strongly to individual growth and development of the undergraduate student as a result of this research experience. Although less measurable in the short-term, this interaction is very important in the long-term assessment of the importance of research experiences for undergraduates. Part 4 presents additional topics which faculty mentors can discuss with the student researchers at the conclusion of the research and as plans are made for post-graduation life.

One of the most important interactions with the undergraduate researcher will be those with the faculty mentor, who is modeling what it means to be a research professional and introducing the undergraduate to the culture of computing and information technology research.

3.3. Monitoring Individual Progress and Giving Feedback

In addition to team building and individual accountability, discussed above, structuring accountability into the group allows individual students to make self-assessments about their own abilities and areas of weakness, and to seek help so that they can improve their performance in those areas. These are traditional aspects of project management and are discussed in software engineering courses, usually taken in the junior or senior year. Undergraduates should be made aware of the critical path for project completion, if there is one, and the significance of iteration to the research process, particularly in computing. Critical path tasks and dependencies should be identified.

There are numerous strategies for structuring individual accountability:

- asking students to explain a particular aspect of the group's effort or work
- impromptu questioning in the student's area of study
- calling on the student to explain their research, and assigning distinct tasks to students along with deliverables
- constructing timelines (Gantt charts) and explicitly showing the dependencies among individual and group tasks (Pert charts)

These are also good ways to help the student to understand how their part of the project relates to the project as a whole. Students should be encouraged to identify the research skills they have and the skills they would like to develop. For example, a student who considers reading and analyzing research papers to be strengths, but would like to be more experienced at presenting research, might be asked to analyze a research paper and then to present it to the rest of the group for discussion. This would complement the student's strength (research analysis) while providing room for further development and experience (research presentation).

Group meetings, which should be held frequently, are an effective mechanism for students to discuss the status of assigned tasks and encountered problems. This is another good way to keep the student apprised as to how their part of the project fits into the project as a whole. Status reporting ensures individual accountability and keeps other members informed. More importantly, it provides the means for identifying problems early enough to prevent lost time. In addition to an informal oral report at a small group meeting, status reporting can be achieved through submission of reports and formal presentations. The faculty mentor can also define a variety of deliverables that can be used to monitor student progress. Example status report forms are provided on p. 30.

3.4. Adjustment and Planning

As research projects proceed, the faculty mentor's objectives may have to be adjusted depending on available time, equipment and resources, the skills of undergraduate students, and personnel. The faculty mentor should clearly communicate adjustments to the team, as changes may be perceived as failure rather than logical realignment based on new information. Undergraduate students are frequently accustomed to all or nothing results in terms of assignment completion. The faculty mentor needs to communicate new objectives, schedule changes, or other adjustments with all, and explain that this is what researchers do — adjustments are not failures, but corrections based on updated information.

The faculty mentor should clearly communicate adjustments to the team, as changes may be perceived as failure rather than logical realignment based on new information.

The faculty mentor should also help the undergraduate researcher define the next steps or research goals to be accomplished in daily or weekly increments. An incremental focus helps students understand what needs to be done next, and shorter goals are easier to tackle than the longer-term goals. This approach mimics the week-by-week steps in a course outline, which is familiar to undergraduates.

3.5. Communication and Status Reports

As mentioned in Part 1, several approaches, both informal and formal, can be used to manage an REU. With an informal approach, status reports can take the form of hallway chats or short email updates. Creating a Google Site or other wiki allows the team, both faculty and undergraduates, to keep each other up-to-date. This is especially helpful when team members work different hours or are in different locations. With a Google Site or wiki, everyone can share status updates, papers, data, and other project information.

In the case of a more formal reporting requirement, such as a funder's requirement, or if the goal is to provide the student(s) with a more realistic feeling of a industrial research group or larger academic team, a status report form can be used, such as the two shown on p. 30. (Download modifiable versions of these reports and other customizable documents at www.ncwit.org/reubox).

Project Status Report

Project Name:

Date:

Student Name:

Task Description: ______% Complete

Problems Encountered:

Completed Deliverables: Stored Locations:

Other Project Successes: Factors that support or hinder success:

A sample status report.

Presidential Scholars Research

Weekly Report ______ Midterm Report ______ Final Report ______

Project Title:

Period: **Today's Date:**

Name of Student Researcher: **Email:**

Name of Faculty Researcher: **Email:**

Research Question(s) being considered:

Accomplishments this week:

Plans for the coming week:

List any literature, websites, or other research groups that have been consulted and found useful (on the web or in journals or books):

List any resources you need to move ahead:

List any challenges or concerns:

An example of a more-detailed undergraduate project status report.

3.6. Defined Deliverables

Results from an REU can be reported through a variety of defined deliverables. Deliverables provide the tangible evidence that tasks have been completed and, more importantly, it archives knowledge to be shared while expanding the capacity of the group. Deliverables provide documentation of the project and help advance the research because fallacies or weaknesses in design or reasoning are more quickly exposed when explanations are written and presented in a cohesive document. Defining deliverables is one strategy for minimizing risks, developing domain expertise, and honing technical and communication skills.

Deliverables provide the tangible evidence that tasks have been completed and, more importantly, it archives knowledge to be shared while expanding the capacity of the group.

Deliverables include products, presentations, reports, and other documentation that can be used to determine progress on a project and document discoveries. Specific examples of deliverables include:

- **Abstract or summary of a technical paper or journal article**
- **Research poster**
- **Trip report**
- **Meeting documentation**
- **Critical review of a journal or conference article**
- **Technical report or archival paper**
- **Development of a product, e.g., a design, program, and associated documentation (user manual, software requirements specification, design document)**

The faculty mentor should review deliverables with the team and ask members to provide the "owner" of each deliverable with constructive criticism that will help him or her improve the work.

Completing deliverables is often an iterative process, especially when a student lacks experience. The faculty mentor should be sensitive to the time commitment and capabilities required for students to complete a deliverable. Indeed, there is a balance between effort and return on investment.

The use of research results for publication and/or conference presentation is discussed further in Part 4.

During the REU

3.7. Key Takeaways from During the REU

1. **Research Activities to be Explained to the Student Researcher by the Faculty Mentor Include:**

    - Conceptual explanation of the research.
    - Literature review.
    - IRB approval (if required).
    - Data gathering and software development.
    - Measurement, experimentation, testing, analysis.

2. **Improving the Team and Individual**

    - Cooperative teams include the elements of positive interdependence, face-to-face promotive interaction, individual accountability, group and professional skills, and group processing.
    - Identify strengths and weaknesses in processes and revise to address discovered weaknesses.

3. **Numerous Strategies for Structuring Individual Accountability for Undergraduate Students Include:**

    - Asking students to explain a particular aspect of the group's effort or work.
    - Impromptu questioning in the student's area of study.
    - Calling on the student to explain their research, and assigning distinct tasks to students along with deliverables.
    - Constructing timelines and explicitly showing the dependencies among individual and group tasks.
    - Clearly defining student deliverables such as reports, presentations, and posters.

4. **Adjustment and Planning**

    - The faculty mentor should clearly communicate adjustments to the team, as changes may be perceived as failure rather than logical realignment based on new information.

5. **Communication and Status Reports**

    - Formal and informal approaches can be used to monitor an REU.

Part 4: After the REU

Any REU effort should have a clear point of conclusion. With summer REUs, students usually present a final paper or demonstration project. With academic year REUs, a student's one- or two-semester effort usually concludes with a similar deliverable — a paper, poster, demonstration, or software.

After the conclusion of the REU, the faculty mentor and student researcher should assess the experience, identifying what worked and what might be improved in the future.

4.1. Post-REU Assessment and Next Steps for Student Researchers

There are three parts to post-REU assessment:[23] a conversation between the faculty mentor and student researcher, a self-assessment by the faculty mentor, and a self-assessment by the student researcher.

Conversation between the faculty mentor and student researcher

In preparation for a post-REU conversation, the faculty mentor should review and print out *Student Post-REU Self-Assessment* (found on p. 44) and *Beyond the REU: Next Steps for REU Student Researchers* (p. 47); both documents should be given to the student researcher to reflect upon before the meeting. The faculty mentor may want to review the *Faculty Post-REU Self-Assessment* (found on p. 34) as well.

These are questions the faculty mentor can ask the student researcher as part of the conversation. The answers may lead to understanding about managing the next REU experience.

A. Were your expectations met or exceeded? Please explain.

B. Did you feel challenged? Why or why not?

C. Do you feel better prepared to work on a future research project in your major? Why or why not?

D. Did you have…

- adequate direction and structure to your learning?
- adequate guidance when you needed it or asked for it?
- adequate support and encouragement?
- feedback on how you were doing?
- adequate time and involvement with me?
- good communication?
- good listening?

In the long term, it would be ideal to determine whether the REU experience encouraged the student researcher to stay in the major (retention), enroll in a graduate program, and/or complete a PhD. REU students who are most successful in their graduate programs often show signs of their future success during their REU, through their:

- self-motivation (i.e. not waiting for tasks to be assigned on a research project, but moving forward on their own)
- skill in drafting final reports, conference papers, or journal papers
- time management (meeting deadlines and not procrastinating)

The faculty mentor can ask the student researcher to stay in touch as she/he completes her/his degree and offer to provide reference letters in support of applications to graduate programs. It is also beneficial to inquire about the student researcher's success as graduation approaches, or shortly afterwards. Usually, students are happy to keep in contact with the faculty mentor and share how their future plans are developing, initially every month or so until their path is identified (industry or graduate school) and often annually after that, if they work on a graduate degree.

The faculty mentor can ask the student researcher to stay in touch as she/he completes her/his degree and offer to provide reference letters in support of applications to graduate programs.

At the end of the discussion, the faculty mentor can ask the student if there are any other topics the student researcher would like to discuss, perhaps based on *Beyond the REU: Next Steps for REU Student Researchers* (p. 47).

Faculty Post-REU Self-Assessment

After each REU, the faculty mentor should assess her/his own experience, the REU research project, and any outcomes –not only research outcomes, but also individual outcomes, such as the retention of the student in the discipline and the potential for the student to continue on to graduate study. An REU experience may identify that a research career would not currently suit a student, which is a valid outcome in itself. The same student may find research suitable sometime later in their post-graduate career.

For **faculty mentors,** the post-REU self-assessment might include the following:

- Was the project(s) selected of the right size and effort for the student(s)?
- How much effort did the REU contribute to my faculty workload?
- Did I, the faculty mentor, enjoy the REU?
- In my faculty opinion, was the REU a good experience for the student?
- What might be done in the future to encourage further success?
    - longer/shorter time period?
    - more/less of my availability?
    - more/less guidance for the student?
    - larger/smaller student team?

The ***Student Post-REU Self-Assessment*** is available on p. 44 to be printed and given to the student researcher. (The questions appear here as well for the faculty mentor's easy reference.)

For **student researchers,** a post-REU self-assessment might include the following:

- What did I learn about research?
- Am I more interested/less interested in a research career in CS?
- What questions do I still have about research in CS?
- Am I done with this research, or is it a topic I'd like to investigate further, either as a basis for an independent study course or a larger project?
- How can I use my experience in applying for a graduate program?
- Were there specific aspects of the REU I really enjoyed or really disliked? What were they?
- What suggestions can I give the faculty to make future REUs even more successful?
- Would I like to continue working in this research area in graduate school?

Note: A more comprehensive self-evaluation tool is available, which is useful for determining specific research skills the student acquired, the student's self-perception as a researcher, and the student's plans for graduate study. See *Comprehensive Post-REU Student Self-Assessment Survey*, p. 45.

4.2. Key Takeaways from After the REU

1. **Any REU effort should have a clear point of conclusion**

2. **The post-REU Assessment Includes**

   - A conversation between the faculty mentor and student researcher
   - A self-assessment by the faculty mentor
   - A self-assessment by the student researcher

3. **The faculty mentor should ask the student researcher to stay in touch as she/he completes her/his degree and offer to provide reference letters in support of applications to graduate programs.**

Part 5: Additional Resources

Links to additional materials and resources are available on the Box's landing page, www.ncwit.org/reubox.

Part 6: Templates and Handouts

The templates and handouts that follow are downloadable as Microsoft Word documents at www.ncwit.org/reubox *(where this Box was downloaded); faculty mentors can modify them as needed.*

Wanted: Research Experience for Undergraduates (REU) Students

As referenced in 2.4, this is sample text for a letter, poster, or flyer to be used for recruiting locally. It can be modified by the faculty mentor to include specific details of the research assignment. In particular, the text between < > will need to be customized to the specific situation.

Attention Undergraduate Computing Students: YOU Should Consider an REU

As referenced in 1.3, 2.2, and 2.4, this handout for students describes the benefits of REUs and how students can find a faculty mentor. Even faculty who are not seeking a student researcher can share the handout with students. Faculty can print it to share "as is" or modify as needed.

Things for You to Think About When You Become a Student Researcher

As referenced in 2.5, this handout is for new student researchers. The faculty mentor can review the handout and then share it (as is, or with modifications) with the new student researcher.

What Is a Literature Review and How Do I Do One?

As referenced in 3.1, this handout gives the student researcher guidance on conducting a literature review. The faculty mentor can review the handout and then share it (as is, or with modifications) with the new student researcher.

Sample Status Reports

As referenced in 3.5, these sample status reports can be modified by the faculty mentor and used for formal reporting.

Student Post-REU Self-Assessment

As referenced in 4.1 on p. 35, these questions, along with *Beyond the REU: Next Steps for REU Student Researchers*, should be reviewed by the faculty mentor and then given to the student researcher so that she/he can prepare for a post-REU conversation.

Comprehensive Post-REU Student Self-Assessment Survey

As referenced in 4.1, this is a more comprehensive self-evaluation tool for the student researcher. The faculty mentor should review the survey and then share it with the student researcher, explaining that it may be helpful for self-evaluation.

Beyond the REU: Next Steps for Student Researchers

As referenced in 4.1, this handout, along with *Student Post-REU Self-Assessment*, should be reviewed by the faculty mentor and given to the student researcher to reflect upon before the post-REU conversation.

6.1. Wanted: Research Experience for Undergraduates (REU) Students

What follows is text for a sample recruiting letter, poster, or flyer. It can be modified to include specific details of the research assignment. In particular, the text between < > will need to be customized to the specific situation.

Wanted: Research Experience for Undergraduates (REU) Students

We are looking for sophomores or juniors who are interested in participating in research projects on the cutting edge of computing! We have openings for paid undergraduate research assistants to assist in research on <topic>. This is an opportunity to learn about research by doing research. It pays as well as most student jobs, and looks very good on your résumé.

This experience is intended for students who are interested in research or are considering the possibility of going to graduate school. An REU assignment can make a big difference in helping you get into a good grad school and in winning fellowships and scholarships to pay for it.

JOB DESCRIPTION

- The Pay: <insert the pay, if this is funded, or hours of credit available >
- The Project is summarized here: <url>
- Responsibilities: <This is a one-year experience: The research assistant is expected to work together with the grad students on the project for about 200 hours/month during this summer (e.g., 10 weeks half-time, 5 weeks full-time, etc.), and about 10 hours a week each term next year. (Other arrangements are also possible.) Your responsibilities will include helping to implement the prototype as well as helping with user studies.>

REQUIREMENTS

We are looking for a student who is <a good communicator, hard worker, and good learner.>
In addition:

- You must be an undergraduate student enrolled at <university> until at least <date>. Preferably, you are currently a sophomore or junior.
- Your grade point average should be above < 3.0 > in the major.
- < Insert any other eligibility requirements here as needed, e.g., funding source requirements>
- You must have a desire to learn about research!

CONTACT US

We are happy to talk to you about the position, even if you are not yet sure whether you want to officially apply. Contact: <email address>.

To apply: Send an email and a short résumé to <email address> by <date>.

Tell us why you want to be the candidate we choose.

Please give us the name of one faculty member we can contact as a reference for you.

6.2. Attention Undergraduate Computing Students: YOU Should Consider an REU

WHAT DOES REU STAND FOR?

Research experience for undergraduates

WHY CONSIDER AN REU?

1. REU experiences are a way you can get a glimpse at what research in computing is like as a future career.
2. Because computing research occurs in graduate school, it gives you an advanced look at what graduate school might be like, to see if it is a good fit for you.
3. REU experiences are prestigious, and having had one will look good on your résumé. Also, the result of the research experience may provide additional items that look good on your résumé, such as interesting projects and publications. These strengths can help you get into graduate school or get a job in industry.
4. REU experiences give you a chance to work one-on-one with a computing researcher such as a faculty mentor or graduate student.
5. Many REU experiences pay a salary or provide other concrete benefits, such as hours of credit in your major.
6. An REU lets you work more intensely in an area that interests you and/or allows you to make a contribution to society.

If you are ready to learn more about the undergraduate research experience, visit the Computing Community Consortium website: https://sparc.cra.org/students/.

HOW CAN YOU FIND A FACULTY MENTOR?

Most mentors for individual research experiences are your local professors (academic year and/or summer). National Science Foundation (NSF) REU Sites, the Computing Research Association's Committee on Widening Participation (CRA-WP)/Distributed REU (D-REU) program, and CRA's Undergraduate Research to PhD (UR2PHD) program also connect students with mentors.

- Local professors: In this case, usually the faculty mentor initiates the contact, through advertising, making announcements in class, or contacting a student who seems like a good fit for the work.
- If you hear about opportunities from advertisements or announcements, respond to the ad or visit the professor during office hours. You can do this to find out more; you do not have to be sure you are interested.
- If you are in a class taught by a professor with a specialty of interest to you, you could consider visiting during office hours to discuss whether that professor offers research experiences for undergrads. However, this approach is less usual than the cases above. The best approach is to check the faculty member's webpage. If the faculty member's homepage encourages you to come visit with your REU ideas, then you should do so; otherwise, faculty need to have already made up their minds that they have the time and resources to sponsor such a project, and they usually initiate the process once they have done so. That said, it doesn't mean you shouldn't ask; just be aware that your professor may not have the resources or time to work with you right now.
- CRA-WP Distributed REU Project (http://www.cra-w.org/dreu) — In this case both the faculty and the student take initiative, and then the sponsoring organization performs a "matchmaking" to match up interests and skills. This program focuses on students from groups underrepresented in computing. It allows students to travel to research universities and experience grad student life, even if the student is from a non-research college.
- Keep in mind that you must be a good student for professors to include you in their research. Doing a very good job in a class is a good way to land an opportunity to do research.

6.3. Things for You to Think About When You Become a Student Researcher

WHAT TO EXPECT, HOW TO PROCEED

General expectations. The goal is to have you do some work that has continuing value in the project. Your immediate "managers" might be one or more of the graduate students in the group, or might be the sponsoring faculty mentor.

Why a research project is not like a class project. Someone else will likely pick up your work in the near future, so you should hold your results to a high standard, and think about how to make it understandable and useful to the next person to work on.

Managing the project. Be realistic about your own time constraints: do not promise more than you can deliver, and do not procrastinate. If you hit roadblocks, you should tell the other people in your group immediately. Expect to encounter problems; if it were not full of unknowns, it would not be research!

TIPS FROM REU STUDENTS

Here is a set of tips gathered from several undergraduate research students:

On choosing a project. Often the faculty mentor will choose the project, but you will then have the choice of applying for it or not. In a few situations, you might actually define the project yourself. In either case, this is a choice you need to make carefully because it will affect the quality of your experience. You want to be selective but open to new ideas, too. Here are some questions to ask yourself when deciding on a project:

- *Does this project have a clear-cut goal?* When will your project be considered finished? Make sure you understand this, before taking it on.
- *How much time is this going to take?* From a professor's perspective, it's better for undergraduates to not take on an ambitious project, if they will not be able to finish it. You would have worked hard, without producing anything that's very useful to the group. If possible, try to pick a project that you have enough time to finish. This will give you and everyone else a sense that you have accomplished something significant.
- *Is this something I'm going to enjoy working on?* If not, it may be better to wait for a better project or look in another professor's group. If you do not like what you are doing, it may affect your motivation and interest, especially when the project hits some obstacles.
- *Will I learn something significant from this project?* The answer to this question may be "no" if you get a grunt-work project to start out with. In subsequent projects, you want to pick a project that will challenge you in some way, if at all possible.

On expectations. It is important to have realistic expectations. It takes a long time to acquire enough knowledge to be able to do really groundbreaking research, so what you will probably be doing as an undergraduate is smaller tasks that fit into a professor's or graduate student's overall scheme.

On gaining skills. Try to learn by observing other people in research. For example, try to observe the graduate students, to gain from their experience doing research. What do they do when they get stuck? How do they do research in a systematic way? If you can, even try to observe the way they think. When they have an idea, how do they talk about it with other people? When and why do they decide to give up and try something else? Thinking about these kinds of things will greatly add to your experience.

On setbacks. Rarely does research go according to plan. You are likely to run into more obstacles doing a research project than you would doing a class project because there's a lot less structure. No one has tested the project out beforehand to iron out the technical problems. Expect things to go wrong when you are doing research work; if it was not uncharted territory, it would not be research.

6.4. What Is a Literature Review and How Do I Do One?

Literature review is a necessary step in any research project; without this step, it is not possible to know what related research is already underway or if the research problem has been solved. By examining available literature, researchers are able to determine if there is already a solution to the problem. While there may be solutions to your proposed research problem, existing solutions do not always explain new observations. An existing solution might require revisions or may have to be discarded if another solution is found. If the literature review identifies a solution to the research problem which works, you have found a solution to your problem! If the literature review does not identify a solution to your research problem, then your research project is needed!

A *literature review* typically follows these steps:

1. **Search professional journals or conferences. The faculty mentor can provide you with a starting list of names.**
2. **Begin with the most recent articles you can find. Your faculty mentor may have research papers or articles she/he has published with students; these are a logical starting point.**
3. **Keep track of relevant articles in some way, usually by adding the article citations to a bibliography. Use the citation format your faculty mentor recommends.**
4. **As you read or scan each article, develop a short summary of the research problem, approaches taken, and results, if any. Pros and cons of the research should be briefly noted.**
5. **As your review proceeds, you should be able to organize the articles in some way by methods used, or by chronological date (i.e. earlier efforts which then provided a basis for later research). This organization will provide both a context and a guide map for your research project.**

IEEE (IEEE Computer Society) (www.ieee.org) and ACM (Association for Computing Machinery) (www.acm.org) digital libraries are good places to begin looking for literature. Your university library or faculty mentor should be able to provide you with access to any articles you would like to read.

Don’t be discouraged if research work on the topic is already underway.

Be careful to check your sources when conducting your literature review. For example:

- Peer-reviewed publications, such as those found in major conferences and journals, have been reviewed by multiple people before being published and are therefore the most trusted sources of information.
- Many trade magazines are not peer-reviewed and internet sites are not always reliable information sources.
- Generative AI can be used to discover peer reviewed sources. However, AI summaries alone should not be relied on. You need to access the original source to make sure it exists and is accurately summarized by the AI.

A literature review is an important first step in qualifying a research problem — that is, making sure the research problem is a ‘good’ one — one that has not been solved and one to which you can contribute. The detailed notes and observations of a literature review are often used as the basis for references in conference and journal publications.

6.5. Sample Status Reports

Project Status Report

Project Name:

Date:

Student Name:

Task Description: ______% Complete

Problems Encountered:

Completed Deliverables:

Stored Locations:

Other Project Successes:

Factors that support or hinder success:

Presidential Scholars Research

Weekly Report ______ Midterm Report ______ Final Report ______

Project Title:

Period:

Today's Date:

Name of Student Researcher:

Email:

Name of Faculty Researcher:

Email:

Research Question(s) being considered:

Accomplishments this week:

Plans for the coming week:

List any literature, websites, or other research groups that have been consulted and found useful (on the web or in journals or books):

List any resources you need to move ahead:

List any challenges or concerns:

6.6. Student Post-REU Self-Assessment

As a **student researcher**, you can ask yourself these questions after the REU. They will serve as a good preparation for your post-REU conversation with your faculty mentor.

- What did I learn about research?
- Am I more interested/less interested in a research career in CS?
- What questions do I still have about research in CS?
- Am I done with this research, or is it a topic I'd like to investigate further, either as a basis for an independent study course or a larger project?
- How can I use my experience in applying for a graduate program?
- Were there specific aspects of the REU I really enjoyed or really disliked? What were they?
- What suggestions can I give the faculty mentor to make future REUs even more successful?
- Would I like to continue working in this research area in graduate school?

6.7. Comprehensive Post-REU Student Self-Assessment Survey

Note: This is a more comprehensive self-evaluation tool[25] which is useful for determining specific research skills you, the student researcher, acquired, your self-perception as a researcher, and your plans for graduate study.

SECTION 1: RESEARCH SKILLS

Did the REU help me to…

- Understand contemporary concepts in computing?
- Make use of others' research in computing (e.g., from journal articles)?
- Develop better research skills?
- Select a research topic?
- Identify a specific question for investigation based on existing research in computing?
- Formulate a research hypothesis based on a specific question?
- Design an experiment or theoretical test of a hypothesis?
- Write programming code for testing?
- Observe and collect data?
- Understand how to synthesize existing research on a subject?
- Statistically analyze data?
- Reformulate the original research hypothesis (as appropriate)?
- Relate results to the "bigger picture" in computing?
- Prepare a poster or presentation for a professional conference?
- Orally communicate the results of research projects?
- Write a research paper for publication?
- Deal with setbacks (e.g., participants leaving study)?
- Deal with unexpected findings?
- Clarify career options?
- Find other research opportunities?
- Identify fellowship opportunities?
- Select a graduate school?
- Apply to graduate school?
- Understand the qualifications for applying to graduate school?

SECTION 2: PERCEPTIONS AS A RESEARCHER

Can I confidently say that because of the REU…

- I feel like I belong to a community of researchers?
- I feel more confident of my computing knowledge in general?
- I feel more confident of my understanding of research and what researchers do?
- My project was challenging to me?
- It is important to me that my project solves a real-world problem?
- I feel a stronger commitment to finish my computing degree?
- Over the course of the summer/semester/year, I felt greater responsibility for the project?
- The research topic was interesting to me?
- I had the support I needed to make a contribution to the project?
- I am proud of my contribution to the project?

SECTION 3. PREPARATION FOR ENROLLMENT IN A GRADUATE PROGRAM

Can I confidently say that because of the REU I will take the following steps toward enrollment in a graduate program?

- Peruse websites to find relevant programs?
- Study for entrance exam (e.g., GRE or other standardized test)?
- Take entrance exam?
- Complete and submit application?
- Visit graduate program campus?
- Talk to graduate advisor/director?
- Talk to other faculty in the department?
- Seek letters of recommendation?
- Write an admission essay or personal statement?
- Seek academic transcripts?

You may wish to discuss with the questions you did not feel were satisfied by your participation in the REU with your REU faculty mentor.

6.8. Beyond the REU: Next Steps for Student Researchers

There are many different avenues for activity beyond the REU. You may want to discuss these options with your faculty mentor who may be able to help you plan your next steps.

You can leverage your participation in an REU to increase your competitiveness for undergraduate research awards, fellowships and scholarships, and for graduate school admissions. Consider the following approaches:

Present Your Research. By presenting your research, either in person or in print, you will gain valuable experience in placing your work in the appropriate context, discussing it with people who may or may not know much about it, and understanding next steps for your research.

After your research project has concluded, make a poster or write a paper describing your research results. Once completed and reviewed by your faculty mentor, you can send the poster or paper to a conference or journal for peer-review. You can find details about preparing materials to submit and dates for submission on the website of the conference or journal you are considering.

Poster Presentations. Research poster presentations are often part of larger academic conferences. Many involve a submission process, so check on the conference website for submission guidelines. Here are some to consider:

- The Association of Computer/Information Sciences and Engineering Departments at Minority Institutions (ADMI)
  www.admiusa.org
- The ACM's (Association for Computing Machinery) Special Interest Group on Computer Science Education (SIGCSE)
  www.sigcse.org
- Consortium for Computing Science in Colleges (CCSC)
  http://www.ccsc.org/events/conferences.htm
- Grace Hopper Celebration of Women in Computing
  www.gracehopper.org
- Society of Hispanic Professional Engineers (SHPE)
  www.shpe.org
- Tapia Conference on Diversity in Computing
  www.tapiaconference.org

Conference and Institution Meetings. Many specific subgroups in computing have their own conferences to which you can submit a poster or paper. The IEEE Computer Society, Association for Computing Machinery (ACM), or Society for Industrial and Applied Mathematics (SIAM) professional societies, among others, sponsor a range of meetings throughout the year. Formats and length can vary, so make sure you check the specific requirements of the event you are considering.

Travel Scholarships. Scholarships for student travel to these conferences are often available. You will find instructions for applying on the conference websites. The funding source for the REU program you participated in, if it was a funded research experience, may offer conference travel funding. Also, organizations such as the Coalition to Diversify Computing and ACM-W have programs that provide travel support for students to attend conferences, even if the student is not presenting a poster or paper.

Awards. If your research has been well received and your faculty mentor is supportive, consider applying for award consideration.

- The Computing Research Association (CRA) (www.cra.org) offers annual undergraduate student research awards. A faculty member who has first-hand knowledge of your research contribution must make the nomination.
- Honor societies, such as Phi Kappa Phi (www.phikappaphi.org) and Sigma Xi (www.sigmaxi.org) have national chapter awards, as well as those offered by their local chapters, many of which may be based at your college or university. Local chapters of IEEE and ACM also offer student awards.
- Many universities and some departments offer undergraduate research awards.

Undergraduate Scholarships. Scholarships for undergraduates pursuing computing degrees are available.

- Goldwater Scholarships for Undergraduates (http://www.act.org/goldwater) is one source for scholarships: Three hundred highly competitive scholarships are awarded (maximum of $7500, based on financial need) annually to college sophomores (two years of support) and juniors (one year of support). A faculty nomination is required. Four undergraduates per year can be nominated from a given school.
- Ronald E. McNair Program (http://www2.ed.gov/programs/triomcnair/index.html) cultivates promising undergraduates for graduate education. Many colleges and universities have this program available.

Other REU experiences. A second REU experience, sometimes with a different faculty mentor or at a different location, can broaden your perspective, help you compare your educational progress with that of students from other schools (who are also visiting), and give you a chance to interact with graduate students if you haven't already had such a chance. There are a number of REU experiences that can double as (paid) summer jobs. Many of these are away from your home institution, but travel to the summer location is usually covered for you. To consider this possibility, watch for advertisements for summer REU experiences with US government labs and through CRA and NSF. (See also http://www.cra-w.org/undergraduate or http://www.nsf.gov/crssprgm/reu/reu_search.cfm.)

Graduate School Applications. If you have enjoyed the REU, your faculty mentor may encourage you to consider graduate school. Bring the subject up yourself if you would like to know more about graduate school. Also consult the Computing Research Association's *Graduate School Information Guide for Women and Minorities in Computer Science and Engineering* (click on "Publications" at http://cra-w.org/Resources or search for "CRA Graduate School Information Guide") for more details on graduate school. As you enter your senior year, arrange to take the GRE exam if the graduate programs you are applying to require it. You may want to also take the CS subject exam, if the graduate programs you are applying to require or recommend it. Fee reductions and waivers are available to cover the cost of the exam; financial eligibility criteria and restrictions on the distribution of fee waiver certificates are explained in the GRE guidelines at the GRE website.

The graduate school application process is probably unfamiliar to you, unless you have talked to your faculty mentor or graduate students in the department. Find out all you can about graduate applications from your faculty mentor, your department, and graduate students. Graduate applications are usually completed and submitted during fall of your senior year. Resources such as Donald Asher's *Graduate Admissions Essays*[26] are useful; the Graduate Admissions and/or Career Services Office at your university should also be able to assist you.

Prepare your personal statement. If you are applying to graduate school, this will be a part of your graduate school application. Much like a résumé or curriculum vitae, a personal statement is an evolving document that you can refine and add to throughout your undergraduate career. It is a key document for admission to graduate school. Ask your faculty advisor, academic advisor, or graduate students for advice on writing a personal statement.

Your résumé. List your REU experience on your résumé. Also, if you (with or without co-authors) submitted or published a research paper on the work, also include that on your résumé. REU experiences are highly regarded by some potential employers and by others who read your résumé (e.g., scholarship committees, graduate school admission committees). Here is an example statement you might edit and include on your résumé or application:

<REU project name>

<University name>

Over the past two years, I have been working with <name of faculty mentor> and recent PhD graduate <name of grad student mentor> on how information foraging theory can be used to help in debugging tasks. When people debug, they can use bug reports to find scent that can lead them to the bug in the source code. I co-led, with <name of faculty mentor or other collaborator>, a team of three students in developing and refining the code set used to categorize 12 verbal transcripts of professional programmers while they debugged, categorizing their utterances according to principles of information foraging theory. I also co-authored two papers, which are listed in the Publications section of this résumé.

Publications:

1. <Be sure to use the standard citation methods for your field of study, to include authors, title, conference/journal, date, pages (if already published), status (if it hasn't appeared yet. e.g., "under review", "to appear" ...>

2. ...

Graduate Scholarships and Fellowships. Graduate scholarship and fellowship applications are usually due early in the fall semester prior to the academic year for which you are seeking admission. Scholarship applications can be due before graduate applications, so pay careful attention to the deadlines.

A range of graduate scholarships and opportunities are available on these websites:

- American Society for Engineering Education (www.asee.org)
- Computing Research Association (http://www.cra.org/for-students)
- NSF Graduate Research Fellowship (http://www.nsfgrfp.org)

NOTE. At the close of your REU experience, pause to reflect: you are the face of the future of computing and information technology. Research in this field, to which you have just contributed, is unique in that much of the innovation comes from the ground up (newcomers to the field), not just from the top down (established researchers). Examples abound: Facebook, Google, and early PC operating systems are just a few well-known products that were initially developed by students.

Your faculty mentor and everyone who contributed to REU-in-a-Box hope that your experience has helped you to discover the excitement of computing research and perhaps will even lead you to a future you did not imagine before.

Part 7: Endnotes

1. Barker, L. (2009). Student and faculty perceptions of undergraduate research experiences in computing. *ACM Transactions on Computing Education, 9*(1), Article 5.

2. See Endnote 1.

3. Russell, S.H., Hancock, M.P., & McCullough, J. (2007 April 27). Benefits of undergraduate research experiences. *Science, 316,* 548-549.

4. Pascarella, E.T., & Terenzini, P. (1983). Predicting voluntary freshman year persistence/withdrawal behavior in a residential university: A path analytic validation of the Tinto model. *Journal of Educational Psychology, 52*(2), 60-75.

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Part 8: Appendix of Example Projects

The following is a list of concrete example projects as submitted by contributors to REU-in-a-Box. They are arranged roughly in order of increasing complexity under each topic heading. (See http://cra-w.org/dreu for additional examples.)

A. Crime-solving, privacy, security projects

A1. Financial Fraud Detection with Data Mining: Data Mining provides efficient techniques to uncover useful information hidden in the large data repositories. In this project, you will help investigate the unique features that distinguish data mining techniques from traditional analytic techniques for fraud detection and prevention.

A2. Graph Mining of Private Data: Help build a variety of graphs from our data set, then use our current set of graph analysis tools to parse, navigate, visualize and synthesize the findings. One central challenge is to devise graph-building methods from this kind of data that are privacy preserving.

A3. Game Theoretic Aspects of Homeland Security: The effort to protect our country form the threat of smuggled weapons is a non-zero sum game, in which the opponent's estimates of the value of a success are different from our own estimates of the cost of failure. The problem is known under the name "Inspector Game." The project will examine this problem in the context of an ongoing research program on the problem of optimal detection of weapon smuggling threats at borders.

B. Education projects

B1. Parsing PDF Documents for Educators: Evaluate the effectiveness of an existing algorithm for parsing PDF educational assessments (e.g., exams and quizzes) on a large body of assessments. In order to evaluate it both in terms of precision and recall, two standard metrics are used in the information retrieval/processing domain. This parsing algorithm is part of an application that will be used to support educators.

B2. Computer Science Class Schedule Advisor: Help design and build a web-based interface that helps undergraduate CS students understand the impacts and choices of their class schedule possibilities.

C. Graphics/animation/computer vision projects

C1. Annotate videos for the gestures found within them, then using statistical software to identify patterns.

C2. Algorithm Animation for Bioinformatics Algorithms: Use an open source software system written in Python to animate bioinformatics graph algorithms to show their dynamic behavior. Example bioinformatics algorithms that could be considered include those that align two DNA sequences to assess their similarity, assemble complete genomes from fragments produced by sequencing, and answer questions about the origin of species by constructing phylogenetic trees.

D. Helping populations in need, i.e., domains such as health care, disaster relief, charities

D1. Applied Research: Students develop a tracking program for donations to a local food bank, including bar code scanning and inventory management.

D2. Robotics in Healthcare: In healthcare applications, hands-on research with autonomous mobile manipulating robots — robots that move around and physically interact with their surroundings. Project areas include systems engineering (e.g., physical fabrication or software systems), programming, machine learning, and human factors (user studies and evaluations).

E. Investigating how people use computers (today and tomorrow)

E1. Social Computing: This project examines evidence of the social and financial impact of social computing, and will examine Facebook, one of the nation's most-used social networks available to the public. The project will study how and why Facebook is used, and will explore its use in the context of academia.

E2. Gender Human Computer Interaction project: Help implement prototypes and conduct experiments with human subjects to understand how males and females use software differently.

E3. End Users Meet Machine Learning: Help with algorithm development, interface design, prototype building, and human subjects experiments to evaluate which algorithms and interface approaches help human end users understand and communicate with systems based on machine learning, such as an automatic email sorter.

E4. Bringing Robotics to Communities: Projects include developing design and arts-based learning materials for youth and adults to explore robotics in community contexts, conducting interviews with community members to discover new roles for sensing and robotics, and helping develop a robotic device that responds to environmental data.

F. Search projects

F1. Understanding Search: Two students analyze real traces from search engines to produce enough statistical data that people could create synthetic, realistic benchmarks for further research in datacenters.

F2. Multimedia Retrieval Methods: Using tag clouds composed of less frequently used tags (such as non-English words), determine if photo, video, or other image retrieval is significantly enhanced.

G. Software/hardware that creates, maintains, or is infrastructure for other software

G1. Architecture: Implement the hardware for a component that was designed for a computer architecture research effort. The results were passed to a graduate student who could optimize it.

G2. Software Engineering Testing and Debugging: Help with algorithm development, interface design, prototype building, and human subjects experiments to evaluate which methods help human testers find and fix software bugs most efficiently.

G3. Modeling Software Engineering Behavior: Help to implement algorithms and analyze their performance at modeling how humans navigate around code when they are debugging.

G4. Anomaly Detection: Finding persistent patterns in networks. The central question is finding patterns that can be used as the basis to detect anomalous activities in time-evolving networks.

H. Systems design, performance problems

H1. Characterize Sources of Delay in a Transportation System (i.e., Seattle ferries). This project involved fieldwork, data collection, and data analysis.

H2. Real-time Information Gathering: Implement a commercial sensor network to gather environmental or other data; archive data gathered in a database, and provide data and analysis to users via web interface.