Improving Retention and Graduate Recruitment through Immersive Research Experiences for Undergraduates

Teresa Dahlberg, Tiffany Barnes, Audrey Rorrer, Eve Powell
UNC Charlotte, 9201 University City Blvd, Charlotte, NC, USA
1-704-687-8553
{Teresa.Dahlberg, tbarnes2, arorrer, empowell}@uncc.edu

Lauren Cairco
Winthrop University
lcairco@gmail.com

ABSTRACT
Research experiences for undergraduates are considered an effective means for increasing student retention and encouraging undergraduate students to continue on to graduate school. However, managing a cohort of undergraduate researchers, with varying skill levels, can be daunting for faculty advisors. We have developed a program to engage students in research and outreach in visualization, virtual reality, networked robotics, and interactive games. Our program immerses students into the life of a lab, employing a situated learning approach that includes tiered mentoring and collaboration to enable students at all levels to contribute to research. Students work in research teams comprised of other undergraduates, graduate students and faculty, and participate in professional development and social gatherings within the larger cohort. Results from our first two years indicate this approach is manageable and effective for increasing students' ability and desire to conduct research.

Categories and Subject Descriptors
K.3.2 [**Computers and education**]: Computer and information science education. – *computer science education.*

General Terms: Design, Management

Keywords: Undergraduate research, education

1. INTRODUCTION
Alarming declines in computing enrollments in the last seven years [1] have inspired increased efforts to increase the number of students entering computing degree programs. By also increasing participation by students from historically underrepresented groups, it is hoped that we can achieve an infusion of talent, creativity, and diverse perspectives that will shape the future of computing and information technology. Participation in research experiences for undergraduates (REU) cohort is a proven strategy for increasing student retention and encouraging undergraduate students to continue on to graduate school [2-5]. Managing an REU cohort, however, can be challenging for faculty. The time needed to carve out meaningful research projects for several students with varying levels of preparation and to sustain a successful student's newly developed interest in research, long-term, can seem to outweigh the benefits of an REU program as a graduate school recruitment tool.

SIGCSE'08, March 12–15, 2008, Portland, Oregon, USA.

At the University of North Carolina at Charlotte, we have completed the second year of a Computing Research Experiences for Undergraduates Site that is designed to create an environment of situated learning, facilitate peer and faculty interactions, and connect research to real world application with the explicit goal of recruiting and retaining underrepresented students in computing. Our program is funded by the National Science Foundation (NSF) as a computing REU Site. NSF REU Sites typically support an in-depth research experience for a cohort of 8-12 undergraduate students working in a research lab during the summer, and occasionally during the academic year. General information about REUs can be found in [6] and online through www.nsf.gov.

Herein we describe our program design and implementation. We employ a situated learning pedagogy that includes mentoring and social engagement to build a community of research practice. Additionally, we emphasize socially relevant aspects of computing through augmenting research with diversity training and outreach. The results promise a manageable, effective means for retaining undergraduate students and recruiting diverse, domestic students to graduate computing programs.

2. PROGRAM STRUCTURE
Our REU Site program (www.cs.uncc.edu/reu), provides undergraduates with a full-time summer research experience for 8-10 weeks. We encourage students to live on campus, and provide team-building and social activities to welcome students and build community. Our NSF grant provides support for 10-12 students annually, but through the Computing Research Association's Distributed Mentoring Project (CRA-DMP), McNair Scholars, and other funding sources, we extended the program to include 15 students in year 1 and 19 in year 2.

Our REU Site structure supports situated learning by providing a realistic setting for lab research. Each summer cohort is organized into four REU teams, each working within a research lab: the Charlotte Visualization Center, the Future Computing Lab, the Games + Learning Lab, and the Networking Research Lab. Each team includes three to six REU students, one to three graduate students, and at least one faculty advisor. REU students participate in all activities within their labs and have many informal and formal opportunities to interact with the diverse graduate students and junior and senior faculty in the program.

The UNC Charlotte Diversity in Information Technology Institute, http://www.cci.uncc.edu/diti, of which the first author is the Director, administers the program, handling recruiting,

housing, scheduling, and engaging other campus resources. This separation of administration and research direction enables faculty to focus on providing students with a quality research experience.

2.1 Recruitment

Our recruitment efforts focus on reaching students from groups that are underrepresented in computer science and from local undergraduate institutions. Because our situated learning approach encourages an apprentice-like model, we focus on rising sophomores and juniors (i.e. 2nd -3rd year students), and encourage students to participate with their research labs for two consecutive summer REUs, or through other academic year programs.

Our recruiting efforts were performed through websites, flyers, email, and personal visits and contacts at regional institutions. In campus visits, UNC Charlotte students shared their excitement about participating in our research. Similarly, we leveraged our role as leaders of the STARS Alliance, a Southeastern Partnership to Broaden Participation in Computing (www.starsalliance.org) to personally recruit students during our annual conference.

Applications and lab descriptions were online at our REU website. The application required: name, address, university, major, GPA, awards and honors, extracurricular activities, questions on academic plans, selection of the research area, previous experience, a transcript, 2 reference letters, and a personal statement. The essay should describe how the student would contribute to the program, and how it ties in with his or her career and academic goals. Recipients were selected by 1) preferred lab, 2) reference letters, 3) essay, and 4) GPA and experience.

2.2 Community & Professional Development

At the beginning of the summer program, an orientation session introduces REU students to each other, the campus, and each research lab. Formal community building activities include cookouts at faculty homes, a ropes course for team building, and several events with students in summer international programs. Students arranged additional events, including go-kart racing, dance and dining outings, game nights, and potluck dinners.

Table 1: Seminar series topics for REU year 2

Seminar 1	**Scientific research and technical writing tips**
Seminar 2	**Faculty research presentations**
Seminar 3	**Time management workshop**
Seminar 4	**Computing graduate & career opportunities**: diversity & innovation, funding graduate school
Seminar 5	**Cross-cultural discussion** with visiting Korean students on attitudes toward outreach & service
Seminar 6	**Diversity training**
Seminar 7	**Faculty research presentations**
Seminar 8	**Personality and teamwork workshop**

As a cohort, the REU students are provided a number of developmental activities. Students attend a GRE preparation course twice a week to help students pass the Graduate Record Examination required for admission to US graduate programs. In our second year, we developed a weekly seminar series, described in Table 1, to prepare students for success in computing research and doctoral programs. Faculty research seminars engaged seven local professors to discuss their research, and served to broaden REU students' knowledge of computing research. In 2007, half of the participants completed seminar evaluations and a majority would recommend each of the seminars to future participants.

REU students are required to present their research through both writing and speaking. Throughout the summer, students each maintain a project website and blog (online journal). Each student presents their research in a final public forum. Awards are given to the top three researchers each year, and final presentations are available at our REU website.

2.3 Situated Learning in Research Labs

Situated learning is a sociocultural theory of learning, where learning occurs through a process much like apprenticeship, called "legitimate peripheral participation" [7]. In this process, the learner participates as a legitimate member of a community of practice. Initially, the learner participates peripherally, but this scope expands gradually until she becomes a full-fledged community member. Most importantly, learning takes place in a community and context where the knowledge is used. This theory reflects the structure of the computing research community, and informs the structure of our REU program.

Students are assigned into one of four REU teams based on preferences stated on their applications. Each REU team consists of faculty and graduate mentors and the REU students. Students' research training takes place through immersion into the culture of their assigned lab. Students work closely with their REU team towards a team research goal. Initially, REU students perform a supporting role to other researchers on their team as a means to become familiar with the lab environment and the overall research objective. When they are ready, individual REU students are guided to perform a literature review to motivate a unique line of inquiry. Advanced students, or those returning for a second year, move towards becoming independent contributors and ultimately take the lead in generating and publishing results.

Students fully participate in weekly lab meetings wherein faculty, graduate, and REU students discuss their research progress and challenges, and practice their conference and dissertation defense presentations. At these meetings, constructive feedback helps each team member improve their projects and presentations. Students also participate in the social activities of their research labs. Our intent is to fully immerse the student into the "life" of the lab and provide formal and informal access to peer and faculty mentors.

2.4 Sustaining the impact of the experience

Students are encouraged to continue their participation in research during the academic year through the STARS Leadership Corps, a synergistic program that engages students in research, outreach, and service during the academic year [8]. REU students participate in the Corps by developing presentations and demonstrations intended to inform and excite pre-college students about computing research. The REU student may continue their research through a credit-bearing course, such as a senior project. However, engaging in outreach to share their research provides a mechanism to keep the REU student engaged in the research without requiring their presence on our campus or a large time commitment. This provides a bridge to the next summer session or to the student's ultimate entry into graduate school.

2.5 Project examples

The research labs involved in the project are:

- Visualization: Researching visualization to analyze problems in scientific and geospatial contexts.
- Future Computing: Researching virtual humans for training.
- Games + Learning: Researching learning computing, math, and culture through interactive games and media.
- Mobile robotics and networking: Researching mobile robotics applications that use sensor networks.

We showcase two projects that demonstrate the depth and breadth of our computing REU program.

2.5.1 Game2Learn

Game2Learn is a project in the Games + Learning Lab at UNC Charlotte, which seeks to build games for teaching introductory computing concepts. This project provides advantages for both Game2Learn developers and players. Developers learn important concepts in design, computing, and research while they create games for use in introductory computer science classes. Finished projects are then tested in our intro-level computing classes. One such game, created in 2006, was Saving Sera.

Saving Sera is a two-dimensional exploratory game where the player learns of the kidnapping of the princess Sera and decides to rescue her. In the game, players with sufficient knowledge can create "machina" (which are really programs) to solve problems. In Saving Sera, the player fixes machina by unscrambling a while loop to track a fisherman's catch; debugging a nested for loop placing eggs in crates; and visually piecing together a flowchart for quicksort. When players make mistakes, they must fight "script bugs" by answering various computer science questions.

The look and feel of Saving Sera is classic, with a simple, colorful map and cheerful music. The game was created in RPGMaker XP, a program designed to aide users in creating their own role-playing games. To develop games in RPGMaker, students use a drag-and-drop interface to create a tile-based map and dialog trees for characters. Since RPGMaker supports only arrow key and space bar interaction, REU students used Ruby to modify the games with full keyboard and mouse controls. These modifications required students to: become familiar with a new scripting language, learn how the existing RPGMaker system worked, design new interaction techniques, and implement them.

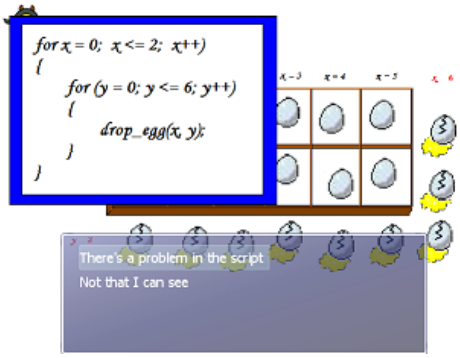

Figure 1: Egg Drop Quest in Saving Sera

The most favoured mini-game by play-testers in Saving Sera was the Egg Drop Quest, shown in Figure 1. In this quest, the player must fix the machina that drops eggs into crates. The player answers multiple choice questions to debug the nested for loops, determining that the loops count too high. After interactively correcting the loops and watching the results run, the player's character explains to the owner why for loops seem to count one lower than the number needed: because the counting starts at zero.

Game2Learn REU students employ a highly iterative rapid prototyping development model and use existing game engine technologies to provide content including art, models, and sounds. (In Summer 2007 students built games using Microsoft's XNA GameStudio Express). These design choices allow REU students to focus on developing and evaluating the impact of their learning games. This structure allows students, from 2nd year sophomores to graduating students, to participate much more equally and produce working games in a short amount of time [5].

2.5.2 AVARI

Avari is a project in the Future Computing Lab, which seeks to build a persistent, interactive agent who interacts with visitors to the department of Computer Science at UNC Charlotte.

Many applications have been built to investigate various aspects of how people interact with virtual agents in social, informational, and learning settings. However, most virtual agents never see the outside of a lab, interacting only with the computer-literate developers and other members of their lab. At best, some virtual agents interact with participants of an experiment, but only for a short amount of time under restricted conditions. With such a limited audience, it is hard to get an accurate idea of what interaction between a virtual agent and members of the population in general would be like. This summer, five students developed a virtual agent that could be deployed in a public setting. This will allow us to collect data about interaction between an agent and a broader sample of the population. The end result of this work is a virtual character named Avari (Animated Virtual Agent Retrieving Information).

Figure 2: Avari: Computer Science Virtual Receptionist

Avari uses text-to-speech and voice recognition to converse with users who approach her. She talks about members of the computer science faculty at UNC Charlotte, guiding the user to choose a professor, then answering the user's questions about that professor. Avari keeps a record of all user interactions. She was designed to be placed in a building hallway where typical students can interact with her.

Avari runs on a computer enclosed inside a desk that REU students and mentors built together. To make it look like Avari is a person standing behind a desk (see Figure 2), a stuffed shirt was placed on a model of a person's shoulders; Avari's face is a monitor mounted on top of this,). Another monitor used for keyword and picture display is mounted beside Avari on the desk. Speakers, a microphone, and a camera are also attached to the desk.

Avari's underlying framework is mostly web-based. Her appearance, behavior, and speech are implemented using Haptek. She uses MySQL to store her knowledge database, and PHP to match user questions to stored questions in the database, and to retrieve and update the database. SALT (Speech Applicaiton Language Tags) is used for speech recognition, and vision processing is done using Matlab. Javascript allows all these components to communicate with each other, and defines Avari's conversational structure. Each member of the REU team was responsible for the design and implementation of one or more of these components.

3. RESULTS

During the 2006 and 2007 programs there were a total of 34 participants. In 2006 there were 13 applicants, all of whom were accepted into the program, but one student did not attend, while three additional students were added to the cohort through the Computing Research Association – Distributed Mentor Program (CRA-DMP), for a total of 15 students. In 2007 there were 48 applicants, of whom 17 were accepted. Three declined the invitation and an additional three students were accepted, and 1 student applied late to be an unpaid intern, and Dr. Barnes added one CRA-DMP student to the program, for a total of 19 students.

- In 2006, there were 6 men and 9 women, with 4 African American students; in 2007, 10 men and 9 women, with 4 African American students and 1 Hispanic student.
- The age range for the students was from 18-33 years old.
- In 2007, four REU students were 2006 REU participants.
- In 2006, 40% of students came from UNC Charlotte, while 53% came from other schools in NC, SC, and VA, and 7% outside of these states. In 2007, 42% of participants were from UNC Charlotte, while 42% were from other NC, SC, or VA schools, and 16% outside of these states, reflecting the larger applicant pool.
- During 2006, 53% of students resided on campus, while 84% stayed on campus in 2007.
- Students were younger in 2006, with 4 rising sophomores (2nd yr.), 7 juniors (3rd yr.), and 4 seniors (4th yr), while in 2007 there were 2 rising sophomores, 2 juniors, and 15 seniors.
- Seventy-eight percent of the 2006 participants had family members in research, while 27% of 2007 participants had researchers in their families.

3.1 Student Survey Results

To measure the students' experience and attitudes toward computing research, a post-survey was administered at the end of the 2006 program, and pre- and post-surveys were administered in 2007. A six-point Likert scale was used: Strongly Agree (1), Moderately Agree (2), Slightly Agree (3), Slightly Disagree (4), Moderately Disagree (5), Strongly Disagree (6). All students completed the pre-survey in 2007, while our post-survey return rates were 80% and 63% in 2006 and 2007, respectively. The surveys measured students' exposure to research, computing self-efficacy, help-seeking behavior, and academic and career plans. The post-surveys additionally asked about the students' satisfaction with the REU program, the interaction levels they had with mentors, and what types of activities they undertook.

Students felt that the most valuable elements of the REU experience were:

- obtaining constructive feedback,
- working directly with faculty, and
- building confidence by completing their projects
- experiencing research as a way to achieve academic gains, and make career choices.

Students reported that encouragement from teachers, friends, and relatives was not as important in their decisions to pursue computing interests as was that computing/IT is enjoyable and interesting, and that it affords career opportunities. In the open-ended question about what sparked their initial interest, themes of *play*, *being good at something*, and *tinkering* and *fixing* emerged. Problem solving and creativity appear to have motivated students towards computing research. The top expectations for their summer experience were indicated as "Explore whether research and graduate school may be the right path for me," and "Gain exposure to research literature in my field." One student commented that "I had not seriously thought about graduate school until this project."

In looking at prior exposure to computing, a notable difference was found between the first and second cohort. In 2006, 78% of students reported having an immediate family member involved in research, whereas only 27% reported having a family member in research in 2007. This indicates that we have been successful in recruiting students with less prior exposure to research.

Table 2: 2006-2007 REU participant academic self-efficacy

Academic Self-Efficacy	2007 Pre	2007 Post	2006 Post
I am confident in my ability to discuss computing research.	73%	90%	99%
I am confident in my ability to design a computing research study.	13%	60%	99%
I find research to be challenging and exciting.	66%	80%	99%
I am confident in my knowledge of computing research methods.	26%	60%	99%
I am easily frustrated when doing research.	7%	20%	33%
I am confident in my ability to present research findings.	66%	60%	N/A
I thought learning to do research was enjoyable	67%	87%	99%
I feel like I "fit" in the field of computing.	73%	80%	N/A
I would like to obtain a PhD in computing.	80%	90%	N/A
Research in computing is important for identifying problems and solutions of value to society.	94%	90%	100%

3.2 Faculty Results

Each year a survey was administered to gauge faculty mentor perspectives on the REU program. On average, faculty were neutral about how well-prepared 2006 REU students were for research, while faculty agreed that 2007 participants were prepared, reflecting the balance of more mature students in the 2007 REU program. On average they spent about 10 hours per week working to support their students and met with students 2-5 times each week. In 2006, some students worked individually, but in 2007, all faculty grouped REU students into teams. The labs varied according to how frequently graduate students met with REU students. All faculty noted that their REU students seemed more interested and informed about graduate school.

As one faculty noted, the most valuable component for the REU was, "Living together on campus and the frequent get-togethers helped develop a strong team spirit." Several mentors noted that the teamwork between students helped address uneven preparation for research and improve the quality of projects. Faculty also noted that the program has effects on undergraduate students NOT in the REU program: after learning about the program through friends or lab visits, many apply to the program or are considering graduate programs in computing.

In 2006, mentors included 3 senior faculty, 3 junior faculty, and 3 graduate students. In 2007, mentors included 3 senior faculty, 5 junior faculty, and 4 graduate mentors. Our program practices tiered mentoring at multiple levels; in 2007 a number of new junior faculty members were added to the program. We feel this addition of supporting junior faculty will be beneficial in jump starting research for new faculty and provide REU students with more faculty contact time.

3.3 Where are they now?

Of the fifteen 2006 participants, 5 have entered the computing graduate program at UNC Charlotte, and 10 are continuing their undergraduate computing studies (with 4 of these returning to the 2007 REU and 1 obtaining a Google internship). All 15 participants were invited to join the STARS Leadership Corps, and 10 of them did so. Of these 10, 4 are continuing in the SLC for the 2007-2008 school year. One of our 2006 participants, Eve Powell, won the 2006-7 Essam El-kwae Student-Faculty Research Award award with her faculty mentor, and received a summer 2007 Computing Research Association – Distributed Mentor Program award to do research at Georgia Tech.

Of the nineteen 2007 participants, 9 were eligible to join the STARS Leadership Corps and 7 of these have joined for 2007-2008. Three of these students applied for scholarships to attend the 2007 Grace Hopper and Tapia conferences. One of these students, Michael Eagle, will be funded to present a poster at Tapia, and plans to pursue a PhD. at UNC Charlotte.

4. CONCLUSIONS

Undergraduate research can be an excellent means to recruit and retain computing undergraduates, allowing curious students a way to discover if research is for them. Our REU site has strengthened our students' feeling of "fit" in computing, while also increasing their self-efficacy and commitment to computing graduate programs. We believe that the situated learning experience and community building are the major contributing factors to our program's success. Community building is an essential component in recruitment and retention, especially among underrepresented student populations. Through our efforts to situate learning in a community of computing research practice, the REU students were able to see themselves as part of the computing culture within their departments and the field at large.

Through the STARS Alliance and the opportunity to repeat the program, REU students have ways to continue engaging with our research labs, making students' connection to computing culture authentic. This has been an important factor in bringing our REU students into UNC Charlotte graduate programs. In future years we plan to expand our recruiting efforts to reach more students earlier in their undergraduate studies. We plan to continue our efforts to find ways to engage more students and faculty, while reducing the external funding to run the program. We believe that the structure and content of our REU Site minimizes faculty workload, engaging faculty in extending their existing research, while effectively supporting the retention and recruitment of undergraduates into our graduate programs.

5. ACKNOWLEDGMENTS

This work was partially supported by the National Science Foundation Grants No. 0552631 and 0540523, the UNC Charlotte Diversity in Information Technology Institute, and the Computing Research Association Distributed Mentor Project in 2006-2007.

6. REFERENCES

[1] Zweben, S. *Computing Research Association Taulbee Survey*, May 2007.

[2] Aspray, W., & Bernat, A. *Recruitment and retention of underrepresented minority graduate students in computer science: Report of a workshop*, March 4-5, 2000. Washington, DC: Computing Research Association.

[3] Peckham, J., Stephenson, P., Hervé, J., Hutt, R., and Encarnação, M. 2007. Increasing student retention in computer science through research programs for undergraduates. *SIGCSE 2007:* 124-128.

[4] Walker, E.L. and Slotterbeck, O.A. 2006. Integrated Research Components: A practical and effective alternative to senior projects. *Journal of Computing Science in Colleges*. 22, 1 (Oct.2006), 72-83.

[5] Barnes, T., H. Richter, E. Powell, A. Chaffin, A. Godwin. Game2Learn: Building CS1 learning games for retention. *ITiCSE2007*: 121-125.

[6] Granger, M., G. Amoussou, M. Labrador, S. Perry, & K. Van Busum. Research Experience for Undergraduates: Successes and Challenges, *SIGCSE Bull. 38*, 1 (Mar. 2006), 558-9.

[7] Ben-Ari, M. Situated learning in computer science education. *Computer Science Ed. 14,* 2 (2004), 85-100.

[8] Dahlberg, T., T. Barnes, A. Rorrer. The STARS leadership model for broadening participation in computing. *Proc. IEEE Frontiers in Education Conference*, WI, US, Oct. 2007.

[9] Polack-Wahl, J. and Anewalt, K. Undergraduate research: Learning strategies and undergraduate research. *SIGCSE 2006:* 209 – 213.