Teaching Undergraduates IT Research in a NSF/DOE Sponsored Program

Hsui-lin Winkler and Dennis Anderson
School of Computer Science and Information Systems
Pace University
1 Pace Plaza, NYC, NY 10038, USA

Abstract

We conducted a faculty-student team (FaST) research project in a joint National Science Foundation (NSF) and Department of Energy (DOE) sponsored program in the summer of 2003. With three students working in a designated research group at the Argonne National Laboratory (ANL), we designed a research project and managed the process for the purpose of teaching undergraduates the skills needed in a professional research environment. Through the process, we identified research skills that can be learned in a short but intense program vs. those that may require continuing efforts and motivation. The project management we applied in structuring and organizing the research program proved to be worthwhile in reaching our pre-defined objectives. This paper describes the research project, the team, the research environment and our assessment of the results.

Keywords: undergraduate research, faculty-student team, research environment, research skills and project management

1. INTRODUCTION

Each year the National Science Foundation (NSF) sponsors various types of undergraduate research education programs to provide students with real-life experience doing hands-on research work. The specific program we participated in is conducted inside the Argonne National Laboratory (ANL) operated by the Department of Energy and has a well-established research environment for professionals to conduct advanced research projects (NSF/FaST, 2003). Students form a team with faculty members from the university and an on-site supervisor to design a research project and carry it out. Often the national laboratory proposes the project or the subject area and there is an educational staff available to supervise all other student activities outside the research project.

As stated by the NSF funding agency (NSF/FaST, 2003), "the program is designed primarily to provide:

- An opportunity to contribute to and be on the ground floor of new ideas and exciting projects leading to publications for faculty and graduate careers for students;
- A highly interactive and stimulating immersion experience in the research environment;
- Sustainable professional relationships between faculty and National Laboratory investigators;
- A supportive approach that reinforces learning through research participation;
- Workshops and training to minimize the "culture shock" of entering and working in a National Laboratory setting;
- Opportunities to reform undergraduate education;
- Internet-based technologies to support distance education and research collaboration;
- An opportunity to add to the diversity of the science and engineering workforce at the DOE Laboratories; and
- An opportunity for Laboratory investigators to have a dedicated team supported and working to advance their research and development objectives."

As participating faculty, our main objectives were to provide students with an opportunity to experience research in a formal setting, to learn research skills, to build a role model for the classroom, and to encourage some of them to pursue research careers in the future.

The program was also designed such that faculty from primarily teaching colleges can supervise students conducting research in a small group. To participate, an academic institution also needs to have an active NSF grant (CESMS, TCUP, CREST, ATE Centers, Louis Stokes- AMP, HBCU) through which a request for supplementary funding can be written to support the costs of the faculty and student stipends and travel allowances. In our case, NSF/CESMS is the grant through which we submitted our research proposal and received funding for the research project.

This paper describes the education and research experience learned from our faculty-student team that participated in such a program during the summer of 2003. We intend to describe the project design and our experience without going into the details of the case specifics. In the following, we describe the research design in the preparation and planning phase, in the day-to-day progress phase and in the final research conclusion phase. The focus here is on the faculty's viewpoint in structuring, mentoring and supervising student research and excludes aspects of student life and activities that were monitored by the on-site education staff.

2. PREPARATION AND PLANNING

All NSF funded programs require a formal and dual approval process: NSF for funding approval and DOE for access to the laboratory and for on-site support. Students were selected from a pool already enlisted in our NSF/CESMS Grant program and majored either in Computer Science or Information Systems. It took about three months to obtain the final go ahead before the planning phase began. In our case, we had one information systems major and two computer science majors.

There was no set format on how to go about the process. Since the on-site research supervisor decided on the research interest, it was easy to request the general reference material directly from the host institute. However, due to the approval process and the lack of specifics in the research agreement, most research design and scheduling began when the team arrived at the national lab at the beginning of the program. Table 1 describes the research project proposal distributed to students during the preparation phase.

3. RESEARCH PROGRESS

Research Environment While on-site, students reported to the local education department as well as to the specific research group with which they spent the summer. They were formally integrated into the local 'employee' status immediately after arrival. Figure 1 illustrates the immersive research environment, with formal reporting to both the local education department and the research department as indicated by arrows.

For out-of-town students like our group, all students were provided with on-site housing shared with other program students. There were a series of daily research seminars on a wide variety of subjects for students to attend and many more weekend activities. The ultimate goal for the faculty-student team was to immerse students in a formal research setting for the two-month period to experience the research environment and to cultivate their skills to do research independently.

We agreed with our local supervisor that working on a research project with definite requirements can help students move from learning by doing assignments as in most classroom settings to problem solving and eventually to exploring research independently.

Research Goal: To develop a visualization tool that allows a user to view both laboratory shake table experiments and animations on a remote workstation.

Deliverables:

- Create a visualization tool kit which can be used to construct architectural models and subject them to ground shaking.
- Demonstrate a prototype that can be used to visualize laboratory scale shaking experiments for the NeesGrid project.
- Write a report about the tool kit and the applications of the tool.

Suggested Approaches:

- Use Java3D/Open GL and open source IDE.
- Use CVS to organize codes.
- Quick prototyping for implementation.
- The project is divided into three modules: an architectural model, a data model and a viewer. The group will work together on the overall design, but each student will be responsible for the detailed design of his/her module.

Readings:

- NeesGrid project - http://www.neesgrid.org/
- Visualization tool - http://www.j3d.org/tutorials/raw_j3d/index.html

Table 1. Research project proposal description distributed to students during the preparation phase.

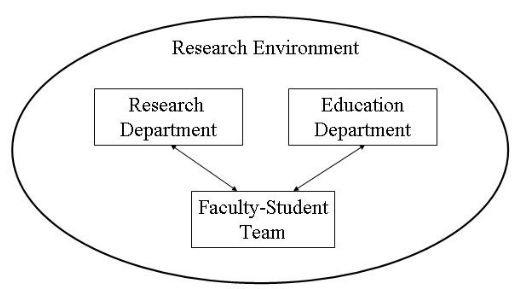

Figure 1. The research environment for the faculty-student team.

Research Tasks In our 10-week research project, we applied project management discipline to carry out the process. Since our students had little project management training, we drafted a simple project management guideline (Pressman, R.S., 1997) and set up the following task timelines for them as described in Table 2. The plan is to finish a prototype in two increments - build a simple working 3D model to demonstrate the feasibility in the first iteration, then add functionality to the working model in the second iteration. The project management applied to this research project ensured that we could achieve our objective on time. It also served as a teaching tool with which we could demonstrate to students exactly how the research was progressing using a simple model.

Week	Description
1	-Project orientation -Define project scope -Understand project environment
2	-Finalize project scope -Install research tool -Hold weekly group meeting Each student will submit a weekly review during the group meeting, so we can evaluate and adjust the schedule accordingly.
3	-Overall Design – Group -Individual Task: Design simple Java 3D objects, Design basic interface to lab data, and Design User Interface(Viewer).
4	-Detailed Design – Group -Individual Task: Complete design on building model, Complete design on data representation, and Complete design on viewer.
5	-Prototype the simple model: Build basic model properties, Build elemental data model, and Complete basic viewer.
6	Integrate the three modules for the simple model.
7	-Update modules to add complexity. Complete the building blocks, Complete the data model, and Complete the viewer.
8	Final Integration
9	Testing
10	Presentation/Documentation

Table 2. Weekly tasks for the research project.

With three students, two faculty advisors (one onsite and the other at the University) and one project supervisor, the teaching format is more mentoring and tutoring rather than lecturing. We also conducted occasional teleconferences with the university research group to update the progress.

It is debatable whether imposing a strict time frame is a proper approach for doing creative research. Researchers in a formal research laboratory tend to work in a free flow style because most professional research tends to focus on new ideas and less on development. However, for students with little or no research experience, a project management structure gives a good direction for them to start. It proved to be the case that the hurdle we encountered near the seventh and eighth weeks was much greater than expected. With a simple model in hand we were able to iterate and add different functionality. Had we not fixed on the simple model to begin with, we may very well have hit the obstacle in the beginning and wandered off in all directions.

Research Results This section briefly describes the research results by showing the simple model implemented by the fifth week and the final model completed at the end of the project. A complete description can be found in Chan et. al. (2003).

The architectural structure consists of layers of scene features and a set of architectural objects to represent the virtual building and sensors. The Java3D API is used for the viewer and the visualization implementation. A set of behavior functions, which allow direct data control or user interaction, are used to simulate the building motions in time. The viewer, which integrates both data streaming and visualization, contains the functionality of 3D object manipulation, data loading, and control of the behavior functions.

We explored two types of behavior functions, which can vividly reflect the building vibrations due to shaking. One is to construct all geometrical objects and use the sensor data to drive the object motions. The advantage of this approach is that the sensor data can be applied in real-time in exactly the same way that an earthquake affects a building. However, with limited sensor data in each experiment, an extensive extrapolation of the behavior function will be needed to reflect all motions. We assumed that each floor has the same behavior function to reduce the number of behavior controls. Figure 2 shows the results of this type of motion generator, in which a two-floor building with columns and beams (cylindrical bar) clamped together by joints (sphere), was subjected to forced motion. Displacement sensors (cone) placed on the building can receive motions from the server and drive the vibration simulation of the building as indicated in the four side panels.

The other approach is to construct a vertices-based structure, with each forming a motion frame. As shown in Figure 3, there are five snapshots of a two-floor building. By manipulating movements on only a few vertices, we can easily achieve the motion behavior. The deformation of the building can be vividly simulated in this approach. However, the frame forming approach requires buffering of certain time steps. In both approaches, we can apply interpolation function to smooth the time behavior of the motions.

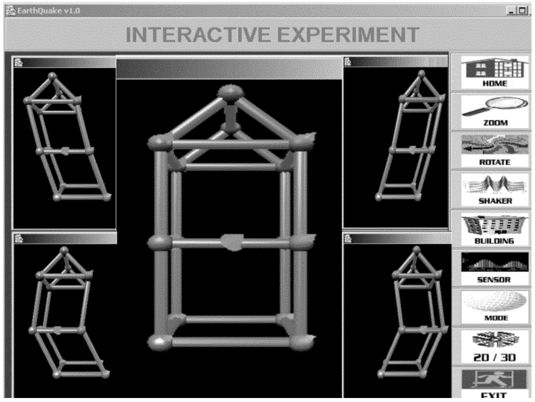

Figure 2. The viewer displaying 5 snapshots of the shape node based building vibration driven by displacement sensor data.

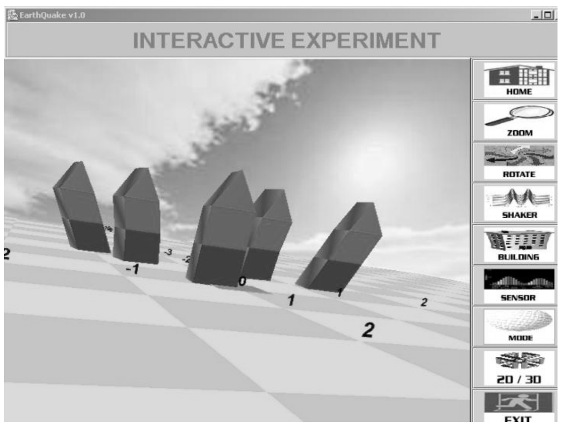

Figure 3. The viewer showing the captured vibrations of five vertices constructed frames. Displacement sensor data is used to drive the building motions.

By building the simple shape node based building model, we were able to demonstrate how a viewer can integrate streaming data from a remote laboratory experiment with visualization objects. The more elaborate model using vertices was built by adding the extra functionality in the second half of the project.

4. RESEARCH REPORTING AND ASSESSMENT

The sponsoring education department requested two reports: a mid-term progress report and a final written paper. Separate formats were provided for faculty and students for submitting their written reports. Although we worked as a single faculty-student team, the education department gathered feedbacks separately from students and from faculty. An oral presentation was also required for students to summarize their findings in the research project.

Informally, the research supervisor and faculty members conducted their own assessment of student learning and research skill improvement in our weekly meetings. In the following, we focus on the informal assessments in an attempt to learn the effectiveness of the method and the process we used in teaching student research. We hope that the approach may be applied in regular classroom settings.

In the process, we identified the basic skills a student needed to have going into a research project and the research skills gained through the research experience. We evaluated each student for these skills in terms of whether they met our expectation, were above our expectation or were below our expectation. A simple score is used to provide our final assessment: 2 for meeting expectation, 3 for above and 1 for below. The averaged score for each skill is the simple average for the three students.

As listed in Table 3, the basic skills include how well the students understand the research project, utilize research tools and environment, possess basic technology and training, and collaborate within a research team. The selected students are on the Dean's NSF/CESMS Grant list and need to learn only a few new tools in the beginning weeks. We found students are in general above our expectations in these basic skills.

In terms of research skills such as exploring solutions, possessing presentation skills, pursuing research independently, and identifying the next research subject, we found that all students were well trained in oral presentation both in media preparation and speaking skills. Finalizing the content of the research project remained the most difficult issue for them when the final date approached. As in most of the project-ending phase, students tend to spend more time working on the project than shaping it or finding an exit. About one in three proved able to do research independently and to explore solutions while doing the project.

Basic skills	**Score**
Understand the research project	3
Utilize research tools and environment	2.7
Possess basic technology skills and training	2
Collaborate within a research team	2.3
Research skills	
Explore solutions	1.7
Possess presentation skills	2.7
Research independently	1.3
Identify the next research subject	1

Table 3. The basic and research skills included in our student research assessment.

One key factor that is not included in our observations is the 'continuity' of this type of training to enhance student research skills. In a longer time frame other factors may be equally important such as motivation and devotion to certain research interests.

5. SUMMARY

FaST is a well-supervised program in both educational and technical aspects to encourage undergraduate students to develop research skills and gain experience.

Our experience with applying project management for getting students through the process is quite positive. The small group enabled a close observation of each student's skills that may not be possible in a regular classroom. Similar project management is taught in a regular classroom course of System Implementation for mostly senior students without the instructor being directly involved in each group's implementation process. We recommend that this type of project management be applied in general to IT education projects to guide students through the process.

Judging from a project management perspective, we successfully carried out the research process. The overall support structure worked very well in facilitating the program objectives and completing what we set out to do.

From a research education perspective, we find that all our students have the basic skills to begin a research project. However, when we measure a student's ability to work independently, two months may be too short a time frame to change their overall learning attitude toward exploratory study.

6. ACKNOWLEDGEMENT

This project was funded by NSF (Grant **#DUE-0123052)** and U.S. Department of Energy's FaST program during the summer of 2003. We thank Dr. Gregor von Laszewski, our supervisor at MCS of Argonne National Laboratory for the everyday help in all the research questions and problems that we had, and Dr. Linda Washington, Director of DOE/NSF education programs, for their efforts in making this joint project a reality. We also would like to thank Dr. Paul Hubbard (2003), who introduced us to his NEESgrid laboratory and helped get the project off the ground. NSF CESMS Grant also supported all students who attended the program in order to be eligible for this project.

7. REFERENCES

Chan, S., O. Yunakov, S. Chowdry, H. Winkler and G. von Laszewski, "3D Visualization for Earthquake Engineering Experiments, 2003." ANL Summer Student Presentation Report.

Java 3D and Java Sun 1.4.1, http://java.sun.com

NeesGrid Prgogram, http://www.neesgrid.org/

NSF/FaST program, 2003, http://science-ed.pnl.gov/fast.stm

Pressman, R.S., 1997, Software Engineering, A Practitioner's Approach, 4th Edition, The McGraw-Hill Companies, Inc.