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Affinity Research Group Model

**Meeting the Challenge of Expanding Participation
in the Undergraduate Research Experience**

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Abstract

The benefits of working in a research group are clear: students develop domain expertise, gain an understanding and appreciation of the research process and its practice, and acquire team, communication, problem-solving, and higher-level thinking skills. Students with this experience are better equipped to make informed judgements about technical matters and to communicate and work in teams to solve complex problems. Clearly, this type of research experience must be made available to a broader population. This paper discusses how the Systems and Software Engineering Affinity Research Group model provides a socialization and infrastructure mechanism that supports the development and management of large research groups that engage undergraduate and graduate students with a wide range of skill levels and experiences in research and projects. This non-hierarchical model integrates students into both a small research group and the encompassing large research group, and uses structured activities to develop their technical, communication, group, and research skills.

Introduction

There is a strong movement to include **all undergraduate students** in research. According to an advisory committee to the National Science Foundation, the objectives of this are to assist students in attaining a higher level of competence in the science, mathematics, engineering, and technology areas; understanding the methods and process of research; making informed judgements about technical matters; and communicating and working in teams to solve complex problems [1]. The undergraduate research experience meets these objectives and, in the process, promotes interaction among students and among students and professors. Professor-student interaction increases the persistence of students [8,9,10] especially if students begin their research work early in their career.

In order to make the research experience available to a large number of students and to ensure that each student

reaps the benefits of the research experience, the structure of research groups must change.

Typically, the students who professors involve represent a small subset of the student population. The challenges in increasing the number who participate in research has two perspectives, that of the mentor and that of the student. From the mentor's point of view, undergraduate students lack depth and breadth of knowledge to contribute to the research effort and, as a result, the mentor must invest time for student development. Because an undergraduate degree does not require the completion of a research project or thesis, many students are not committed to research tasks and may even drop out of the research program before graduation. As a result, the time a professor invests in a student may be lost, at least from the professor's point of view. Time issues are a concern for students with respect to balancing coursework and research tasks. In addition, many students are reticent to join a research group because of their lack of knowledge of the benefits of research and/or fears of not being able to contribute.

This paper discusses how the Systems and Software Engineering Affinity Research Group/Laboratory (SSEAL) model provides a socialization and infrastructure mechanism to engage students with a wide range of experiences, talents, interests, and skill levels in research and projects. The SSEAL model, funded by the National Science Foundation [2], has been under development for three years in the Computer Science Department at The University of Texas at El Paso. This non-hierarchical model integrates a student into both a small research group and the encompassing large research group using structured activities to develop his/her research, technical, communication, and group skills.

The remainder of the paper is organized as follows. The next section discusses how the SSEAL model facilitates the undergraduate research experience. In the third section, a methodology for involving a wider range of students is presented. The fourth section describes the results of a preliminary evaluation study that documents and assesses the development of the students in SSEAL and discusses the model's effectiveness in increasing the number of students who participate in and benefit from a long-term research experience. The study includes summaries of individual

student case histories that assess student competence and confidence. The paper concludes with a summary.

Facilitating the Benefits of Research Experience

The SSEAL model meets all the objectives of the undergraduate research experience, *i.e.*, the students attain a higher level of competence in a technical area, understand the methods and process of research, make informed judgements about technical matters, communicate and work in teams to solve complex problems, and persist through graduation. The sections that follow discuss the challenges of involving undergraduate and graduate students in research, and how this model addresses the challenges.

The Challenges

The many challenges in involving undergraduate students in research in a technical area are exemplified by the on-going evaluation of the project (see Evaluation and Results). Our experiences over the past three years have revealed that students who lack confidence typically are not included in the research experience. This lack of confidence manifests itself in many ways and may be attributable to the mystique surrounding research. Other obstacles are the students' lack of technical or domain expertise, their difficulty in setting clear goals and balancing coursework with research tasks, and their underdeveloped written and oral communication skills. The development of these skills as well as critical analysis and comparative evaluation skills, which are essential to success in research, is not feasible without an infrastructure. A naïve understanding of research can lead to loss of one's confidence when roadblocks are encountered and may result in the student dropping out of the research project and even the degree program. It is easier to involve students who already have the skills necessary to work independently and who can make research contributions in a timely manner. A student who fits this profile minimizes the time that is required for personal development, training, and supervision. Recruiting only these students, however, does not address the issue of expanding the pool of students involved in research, increasing the retention of students in technical areas, and facilitating the advancement of students into graduate school. The SSEAL model is addressing these issues by creating an infrastructure that develops the research and technical skills of undergraduate students.

The Systems and Software Engineering Affinity Research Group

Using the cooperative learning paradigm [3] as a basis for structuring the groups, the SSEAL model defines activities that develop the process and skills necessary for undergraduate students to be successful in research [4,5]. The cooperative learning paradigm focuses on five essential

elements for building effective groups: positive interdependence, face-to-face promotive interaction, individual accountability, group and social skills, and group processing. These elements are built into each of the major components that comprise the model. For each major component briefly described below, we specify its purpose and how it facilitates student development.

Orientation

Purpose: To facilitate the assimilation of new students into the research group and to increase student ownership of the research model.

Description: The 6-hour orientation [6] is held once a year before the beginning of the fall semester. The orientation is comprised of four major sections: the SSEAL philosophy and goals, cooperative group skills, research activities and skills, and student/faculty concerns. Through well-defined activities specified by the faculty mentors, the participants learn the goals of the group, become familiar with available resources, learn the basics of cooperative groups, discuss the research process, and become aware of the expectations of the group.

Benefits: The orientation is key to the members' understanding of basic group and research skills, and in building positive interdependence between old and new group members. In addition to reinvigorating students and faculty mentors, the orientation provides a venue, through group processing, to reevaluate the model, to assess the success of the model, and to identify adjustments that are needed due to changes in the group's composition and attitude.

Research Project Framework

Purpose: To provide a framework in which students can realize the relevance of their assignments.

Description: Based on the feedback we received from the evaluation of the model, we recognized the importance of demonstrating the significance of assigned tasks by tying tasks to the mission and goals of the research project. The faculty mentors clearly define the mission statement, the goals, the tasks that are needed to complete these goals, and the dependencies between tasks. The student is required to define the activities that are needed to complete an assigned task and to construct a timeline.

Benefits: The students learn to manage the research project and understand the importance of their work toward completion of the project. By showing dependencies between assigned tasks, it is possible to build positive interdependence among research group members. Having students define activities assures the faculty mentor that the student understands the steps needed to complete a task. The timeline helps the student define clear goals and balance his/her time between research tasks and coursework. The

framework also helps the faculty mentors evaluate the workload of the student when the student is assigned to more than one task.

Defined Deliverables

Purpose: To define milestones in the project.

Description: The faculty mentor associates a deliverable with each task that a student is assigned. The deliverable may be defined in terms of a product, documentation, presentation, summary, critical review, literature review, or publishable paper.

Benefits: The deliverable provides the student with an opportunity to develop domain expertise and to hone his/her technical writing skills through critiques by students and faculty mentors. The deliverable gives the student an opportunity to tangibly contribute to the research. In addition to holding the student individually accountable for his/her task, the deliverable allows the faculty mentor to track the progress of the research.

Weekly Meetings

Purpose: To report progress, to promote the refinement of weekly goals, to solve problems, and to discuss research.

Description: The structured weekly meetings, under the supervision of a faculty mentors, require the students to discuss the status of their assigned tasks and problems encountered. The progress or results of members, unforeseen events, and fruitless pursuits may cause a change in the direction of the research. Group discussion helps relieve some of the frustration that a student feels when a task changes. Another important component of the weekly meetings is brainstorming to solve the problems articulated by the student researchers. Students may be required to “teach” new concepts, present technical paper summaries, present significant research contributions that have been identified as milestones, and explain technical issues relevant to completing their tasks. Constructive criticism is emphasized at the meetings. Documentation of each meeting is achieved through a written research summary, *i.e.*, a report of the research progress as discussed in the meeting. Students alternate the role of compiling these reports.

Benefits: Byproducts of these meetings include building positive interdependence, practicing face-to-face promotive interaction, structuring individual accountability, practicing group, oral and written communication skills, and developing domain expertise. The format aids in the revision of research goals, tasks, and methodology.

Monthly Meetings

Purpose: To integrate research results, to bring together students who are working on different research projects, to

practice and critique presentations, and to develop higher-level group skills such as critical thinking, comparative evaluation, and justification.

Description: At the beginning of this meeting, faculty mentors recognize students who have published or presented papers, participated in outreach projects, and received awards. Next, a member who represents each research project summarizes his/her group’s progress and achievements toward short-term goals. After the students complete their presentations, a higher-level skill is taught and practiced. This is accomplished through an activity that is given to small groups comprised of 3-4 students. Care is given to create groups that include students who do not regularly work with each other. Group processing occurs at the end of the activity.

Benefits: This meeting is useful in fostering cooperation among the standing research groups by highlighting areas of expertise that are transferable [7]. Students develop domain expertise, practice oral communication skills, and refine their group skills.

Outreach Involvement

Purpose: To educate the community about the opportunities in the computing areas and to recruit pre-college students.

Description: Throughout the year, students design and document reusable components that are adaptable to various outreach programs organized at the university- and college-levels. Example computer science modules include web page development, the Internet, computer animation via software tools, robotics, and graphics using a high-level programming language. In addition, SSEAL students relay to pre-college students their personal experiences and give them information surrounding scholarships, internships, co-ops, and job and graduate school opportunities.

Benefits: Outreach involvement provides opportunities for SSEAL students to develop organizational and communication skills, to instill an awareness of issues concerning retention in the computing areas, and to foster a desire and fulfill a need to contribute to the community.

An electronic framework is in the process of being developed to assist in the management of projects and development of students in SSEAL. It includes tools that support literature searches and that maintain a knowledge base of extended abstracts, support for current research, and new research questions through a bibliographic-entry system. The project management tool identifies students assigned to a project, relates the mission and goals of a research project to tasks and activities, presents a dependency graph of tasks, maintains a change history, warns members of upcoming deadlines, and tracks students’ progress on tasks.

Through the SSEAL infrastructure, the faculty mentors oversee several research projects and simultaneously facilitate the development of students. Current research projects that involve students in SSEAL include:

- investigation of a software-fault detection approach and the development of supportive monitoring and traceability tools, funded through NASA,
- research in data mining and decision-support systems, funded by the NASA Pan American Center for Earth and Environmental Studies (PACES),
- development of a highly flexible platform capable of modeling and analyzing the performance of complex applications on parallel computer systems, a collaborative effort with several universities funded through DARPA, and
- development of project management and research support tools, funded through DOE.

Expanding Participation through Affinity Research Groups

The challenges presented in broadening the population of students who can gain research experience are centered on the selection of those who typically are not involved outside the classroom. Because extending the research experience involves working with students with diverse backgrounds, it is critical to create an environment that develops, nurtures, and supports their practice of research. Expanding the pool requires recruiting students who do not aggressively seek research opportunities, who are unaware of the benefits of the research experience, who believe that their lack of expertise precludes their involvement in a research group, and/or who lack confidence in their abilities. Professors also have to target students whose grade-point average does not reflect their potential. In order to accomplish this, professors must 1) actively recruit students based on their classroom participation and performance, 2) educate the student population about research opportunities in their departments and the benefits of research experience, 3) be aware that students may be intimidated by the prospect of involvement, and 4) provide an infrastructure, similar to the one described in the previous section, that supports and manages this diverse population.

This framework allows the faculty mentors to manage a larger group of students and a more diverse population, getting away from one-on-one mentoring which does not scale. Because skills are developed, it is possible to bring in freshmen and sophomore students, including those who are competent but not confident, by giving them tasks such as information retrieval and tool development. The infrastructure provides activities and projects that are appropriate for varying levels of students' knowledge.

Evaluation and Results

The evaluation effort is multi-method. Surveys, interviews, and participant observation provide documentation and assessment of the SSEAL project. Evaluation activities and results are designed to help project developers improve their program, articulate their model, and assess the impact and effectiveness of the program. Based on the nature and context of the project, the evaluation focuses on the impact of the program on individual students and on the students as a whole. This section reports results of preliminary data analysis of the evaluation effort to this point in time.

Examining Survey Results

In spring 1997, there were 17 members; five females and three males had been members of SSEAL for two or less semesters. Three females and six males had been in the program for three or more semesters. 77% of the students were Hispanic, 6% of the students were Mexican Nationals, 18% were Anglo/white. In fall 1997, there were 19 members; five females and three males had participated in SSEAL for two or less semesters. Two females and 6 males had participated in SSEAL for three or more semesters. A majority of the students were Hispanic. For both spring and fall, students were asked to complete questionnaires that are designed to assess student self-ratings of their ability to work in research-based teams.

In general, students reported that they were satisfied with their current teamwork, communication and social skills. When asked if they can contribute to team discussions, 88% of the students reported that they were satisfied with their skills. When asked if they can cooperate with other group members, 94% of the students reported that they were satisfied with their skills. They were less satisfied with their current research and technical skills. When asked if they can conduct research without much supervision, 59% of the students reported that were satisfied with their current skills. 36% reported that they could design a research project with minimal help from a faculty member. These figures are not surprising. Students come to a research project with the expectation of learning how to do research. In examining student essays describing a time when working with others on a research project went well, it was found that the SSEAL model helped the students to develop teamwork skills that in turn facilitated their research. As one student wrote, "I have learned how to better organize my approach to big problems which cannot be accomplished individually in an effective amount of time. Organization is the first step to success when tackling a problem with many tasks. I have learned a lot from the research process by involving myself with the research groups. Also, by communicating with professors and graduates students, I am learning about what courses to choose and how to choose them to better my learning process." Fall results look similar.

Evaluation surveys over the past two years have shown that the SSEAL model contributes to expanding students' knowledge about groups, research, and graduate school opportunities. Students reported that they became involved with SSEAL in order to interact with professors and other students in the same area, gain exposure to research topics, learn more about subjects in their major, improve their skills, and for other personal reasons. Students felt that collaborating with individuals in the same discipline would provide them with a support network and help them attain their personal goals. Most students communicated the desire to expand their knowledge of computer science beyond the course level. In addition, students recognized that engaging in research provided them with opportunities for advancement beyond the bachelor's level. A majority of students recognized that learning research, technical, group, and communication skills would help them be more successful in the future. Personal issues that students cited as encouraging them to participate in SSEAL included a professor's invitation, financial assistantship, and better job opportunities in the future.

Students' impressions of graduate school ranged from acknowledging that graduate school is demanding and rigorous to realizing the freedom that graduate school provides individuals to pursue their own interests. A majority of students recognized the fact that graduate school would expand their knowledge and understanding in their chosen field. A few students were unsure of the benefits of attaining a master's degree if they planned to work in industry, yet others felt it would provide them with better job security and marketability. Results from past evaluations indicate that 55% of undergraduates were very sure that they would attend graduate school, 30% were moderately sure, 5% were unsure, and 10% were sure that they would not attend graduate school.

In essays written in the spring 1997 semester, students observed that the SSEAL structure has provided them with a methodology for working with others. They felt that learning how to resolve conflict, give constructive criticism, brainstorm problem solutions, ask questions, and communicate with team members helped them transfer these techniques to group situations outside of SSEAL. Students wrote that they feel more comfortable working in groups, they realize the necessary elements that should be in place for a group to function well, and they trust and depend on their team members more than they did before their SSEAL experience.

For most students, the SSEAL experience was the first time that they had participated in research and they had preconceived notions of the research process. Students were generally surprised to find that research can be a difficult, slow, changeable, time consuming, and at times, a frustrating process. They recognize that research takes great patience and determination and that clearly defined goals, time management, team management, background research

and feedback from individuals in the research area are important in order to accomplish any significant results.

For the majority of students, the SSEAL experience helped them improve their research, technical, group, communication, and leadership skills that they may have lacked prior to becoming involved. They felt more connected to the university, more aware of the needs of other individuals, and more confident of their own abilities to function as a member of a research group.

Using Individual Case Histories of Students

Preliminary data analysis of student case history data suggest that the nature of critical events influences a student's decision to go into computer science or go on to graduate school. Students report that a class or opportunity to explore computer science influenced their decision to go into computer science, but it was interaction with a faculty member during their research experience or working on the research project itself that influenced their decision to go on to graduate school. As two students reported, it was a faculty member's invitation to join SSEAL and encouragement to pursue careers in computer science that led to their decisions to go on to graduate school and pursue the research they started as undergraduates. It was not until students found success in the research experience that they perceived themselves as someone who could be involved in research and become a graduate student. Once engaged in the research process, students saw themselves as becoming an expert in an area of specialization. One student, who felt that classroom discussion revealed weaknesses in his/her knowledge, said that working in SSEAL provided him/her with "more knowledge" and, in the process, made him/her "less intimidated" by others in his/her classes.

An unanticipated consequence of the SSEAL model is the fostering of a commitment of SSEAL members to help other students succeed in computer science and research. As one student reported when asked to give advice to an incoming computer science student, "My advice is to find a faculty member, [upper-division student] or graduate student who will tell them what to do, who is interested in them, and will get them motivated to pursue research. I am a person who wants to do that."

Summary

The SSEAL model provides a methodology and infrastructure for expanding the number of students who benefit from the undergraduate research experience including those who have potential but lack a chance to excel. This model provides an infrastructure that supports the development and management of large research groups. In addition, it facilitates the development of the skills that are necessary to successfully contribute to a research project. The evaluation plan and assessment results, which are used on a continuous basis to refine the model, show that the

model is effective in meeting the objectives of the undergraduate research experience that are outlined in the paper.

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