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Affinity Research Group Model

APPLYING THE AFFINITY RESEARCH GROUP MODEL TO COMPUTER SCIENCE RESEARCH PROJECTS

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Patricia J. Teller[1] and Ann Q. Gates[2]

Abstract — *The Affinity Research Group model provides students with opportunities to learn, use, and integrate the knowledge and skills required for research with the knowledge and skills required for cooperative work. Although a conceptually attractive vehicle with which to involve undergraduates in research, retain them, and foster their interest in higher education, an often posed question relates to the feasibility of applying the model in a field like computer science, in which it is often the case that a solid academic foundation is required in order for a student to be involved in research. This paper addresses this question by describing how the model has been applied to computer science research projects that involve students with different skill levels and experience. In particular, it presents example structured tasks and related activities that illustrate how 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.*

Index Terms — *undergraduate research, cooperative learning, research group model, affinity research group.*

INTRODUCTION

Research in academe can have many goals. In addition to advancing the state-of-the-art, an active research environment creates a fertile landscape that offers both students and faculty opportunities for growth. For undergraduate students, especially those that ordinarily may not have considered getting involved in research, these opportunities can significantly influence their life paths. For example, the student research experience can:

- increase the probability that students will perform well in science and engineering classes,
- retain, in college, students who may otherwise drop out,
- strengthen student decisions with respect to their declared majors,
- improve students' confidence,
- cause students to consider graduate school, and
- improve students' technical, research, communication, and group skills, making them more attractive to employers.

Although a laudable goal, involving undergraduate students in research in technical areas presents many challenges. This is especially true in areas like computer science where involving these students in research presents challenges that stem from their lack of specific knowledge, skills, and attitudes that are essential to success in research. While involved in research, ill-prepared students can experience a sense of inadequacy, frustration, or a loss of confidence, which can lead them to forego the research experience. These problems arise if they do not possess the necessary technical, analytical, or domain expertise needed to address a research task, or are unable to accomplish an assigned task because they cannot set clear goals and manage their time appropriately. In addition, students may have underdeveloped written and oral communication skills that prevent them from asking appropriate questions, articulating their frustrations, explaining problems that they encounter, or reporting their findings. Accordingly, to involve a larger number of undergraduate students in research requires the development of knowledge, skills, and attitudes necessary to address the aforementioned problems. This is not feasible without an infrastructure.

The Affinity Research Group model, funded by the National Science Foundation, provides a socialization and infrastructure mechanism to engage students with different skills, experiences, talents, and interests in research and projects. Development of the model has been underway for over four years in the Departments of Computer Science and Electrical and Computer Engineering at The University of Texas at El Paso (UTEP). The original goals of the model are the retention of undergraduate students, especially those from underrepresented groups, and advancement of undergraduate students to graduate school [1]. As the model has matured, an unexpected outcome has emerged. It can be used to facilitate an increase of the number of students who have the opportunity to participate in research [2]. This is made possible by the non-hierarchical nature of the model, its adoption of the cooperative learning paradigm [3] to organize groups and promote team building, and the use of structured activities that develop the process and skills necessary for undergraduate students to be successful in research [4]-[5].

As discussed in [2], the Affinity Research Group model is comprised of six major components, which provide students with opportunities to learn, use, and integrate the knowledge and skills required for research with the

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knowledge and skills required for cooperative work. These components are: an annual orientation, a research project framework, defined deliverables, research-oriented weekly meetings, skill-oriented monthly meetings, and outreach activities. The *annual orientation* is targeted mainly at integrating new students into the research group and reinvigorating student participation [2]. Orientation activities focus on the affinity group philosophy and goals, available resources, the basics of cooperative groups, the research process, and group expectations. The *research project framework* provides mechanisms that link the mission and goals of a project to tasks assigned to students, and the tasks assigned to students to student-defined lists of related activities and associated timelines. This framework permits students to realize the relevance of their assigned tasks, the significance of their work towards completion of the project, and the importance of defining clear goals and balancing their time between research tasks and coursework. *Defined deliverables* are associated with all tasks; this is necessary in order to ensure individual accountability and progress towards research goals. *Weekly meetings* of the members of each reserach group afford student researchers opportunities to report progress, promote the refinement of research activities and possibly goals, solve problems, discuss research, present papers, and organize, facilitate, and document meetings. *Monthly meetings*, which bring together the research groups, center on fostering cooperation and the transference of expertise among these groups, in addition to further developing communication and higher-level group skills such as critical thinking, comparative evaluation, and justification. Finally, *outreach* activities target personal development. These activities are meant to foster a desire to contribute to the community.

The Affinity Research Group model allows 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. The infrastructure provides activities and projects that are appropriate for varying levels of students' knowledge and skills.

Although a conceptually attractive vehicle with which to involve undergraduates in research, retain them, and foster their interest in higher education, an often posed question relates to the feasibility of applying the model in a field like computer science, in which it is often the case that a solid academic foundation is required to become involved in a research project. This paper addresses this question by describing how the model has been applied to research projects in the Department of Computer Science at UTEP to involve both undergraduate and graduate students with different skill levels and experience. In particular, it presents example structured tasks and related activities for students with different skill levels and experience, and it illustrates how, through these tasks and activities, 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. In terms of the six major components of the model, the paper focuses on research project framework, defined deliverables, and weekly and monthly meetings in the context of computer science research projects.

The remainder of the paper is organized as follows. The next section introduces two of the research projects in the Department of Computer Science at UTEP that have utilized the model and characterizes the students that have participated or are participating in the projects. The next four sections focus on example tasks and related activities that have been assigned to students involved in these two projects. The rationale behind each of these assignments is presented. The paper concludes with a discussion of the pros and cons of using the Affinity Research Group model to manage a research group.

THE SYSTEMS AND SOFTWARE ENGINEERING AFFINITY RESEARCH GROUP

The Affinity Research Group model has been applied to several different research groups in the Departments of Computer Science and Electrical and Computer Engineering at UTEP. In all cases, the groups are comprised of both undergraduate and graduate students with different knowledge, skills, experience, and interests. Both departments have a growing undergraduate population, a master's program, and a new Ph.D. program. The remainder of this paper focuses on the activities of the Systems and Software Engineering Affinity Research Laboratory (SSEAL).

Through the SSEAL infrastructure, the SSEAL faculty mentors oversee four research projects and simultaneously facilitate the development of students. This paper focuses on how the Affinity Research Group model has been used to develop the process and skills necessary for undergraduate students to be successful in two of these research projects: the DynaMICs and POEMS research projects, which are described in more detail below.

DynaMICs is the acronym for Dynamic Monitoring of Integrity Constraints [6]. The project involves the design and development of a comprehensive system that monitors program correctness at runtime. The system is intended to be used as an adjunct to other verification and validation tools. To realize the system design and development, efforts in the following areas are ongoing: elicitation and specification of integrity constraints, i.e., assertions that define correct program behavior; automatic generation of monitoring code; automatic instrumentation of application code; performance-friendly monitoring mechanisms; and tracing tools that can be used to reconcile violations of constraints. This research is funded by NASA and Sandia National Laboratories.

Since its inception in 1995, the DynaMICs research project has involved many undergraduate and graduate students. Currently, one graduate student is working in automatic code generation, three graduate students in automatic instrumentation, two graduate students in monitoring mechanisms, two graduate students in tracing, one undergraduate in tool building, and two undergraduate students in a study of the effectiveness of integrity constraints. Note that five of the eight graduate students joined the project as undergraduates.

POEMS is the acronym for Performance-Oriented End-to-end Modeling System [7]. The overall project represents a collaborative effort with five other universities to design and develop a highly flexible platform capable of modeling and analyzing the end-to-end performance of complex applications on large-scale parallel computers. UTEP's involvement in this project focuses on the use of, development of, and interface between component models of processors and the memory hierarchy. Related research includes: evaluation of state-of-the-art simulators, evaluation of on-chip processor performance counters, enhancement of processor/memory simulators, simulation-model-based performance evaluation of applications/architectures, collaborative performance evaluation using hybrid performance models, design of a specification language, and design of a performance database. This research is funded by DARPA and NSF.

Since its inception in October 1997, the POEMS research project has involved six graduate students and three undergraduate students in research. Currently, the project involves one staff member, one graduate student, and three undergraduate students, one of which has applied for graduate school. When joining the group, two of the undergraduates had not yet taken any upper-level courses.

In both projects, lower- and upper-level undergraduate students have been involved in research. The methodology and infrastructure provided by the model certainly facilitates the integration of these types of students into a research group and their involvement in the research project; nevertheless, care must be taken in selecting the tasks and activities that are assigned to the students in order to make the research experience a positive one. In addition, deliberate activities must be structured into group meetings, and one-on-one interactions are necessary.

The next four sections present examples of tasks and related activities that are associated with the aforementioned research projects. These examples fall into four categories: create an expert, work in tandem, apprentice, and explore. Each section, which corresponds to one of these categories, begins with a descripton of the corresponding category and ends with one or more example tasks and related activities. The category is described in terms of the goals, method, and challenges associated with the method. Each example describes a task and is presented in terms of the profile of a student for which the task would be appropriate, a description of the task itself, a definition of the deliverables associated with the task, and a discussion of the results of assigning the task to the profiled student or students.

CREATE AN EXPERT

Goals: Integrate a student into a research group. Convince the student that s/he can succeed at research.

Method: Assign a task that develops the student into an expert with respect to knowledge, a tool, or a skill that other students in the research group will need to learn.

Challenges: In some cases, foundational skills must be developed in order for the student to be able to attempt the task.

Example

Student Profile: An undergraduate student who has completed CS3.

Task: Understand the function of and learn how to use a set of the SGI Origin 2000 native primitives in order to design and implement a simple shared-memory parallel program. Using *rusage*, a system call that can be used to measure execution time, execute the program to demonstrate that the program did indeed run in parallel. Repeat this process using progressively more complex programs that require a larger set of primitives. Report progress each week at the weekly meetings.

Deliverables: Write a user's manual that facilitates writing and executing a parallel program using native primitives. Teach research group members how to write a shared-memory parallel program that executes on the Origin 2000.

Benefits: For the student--familiarization and interaction with other group members, development of written and oral communication and technical skills, application of inquiry, appreciation of the value of documentation, and practice with goal setting and time management; potential of an increase in confidence and a desire to learn more about the subject topic. For the research group--availability of a written resource and an expert that can teach others a technical skill.

Discussion: This task was assigned to an undergraduate apprentice system administrator and research assistant in the POEMS research group. Although he had no knowledge of parallel programming, at each weekly meeting the faculty mentor taught him and the other members of the research group fundamental skills. On his own, the student was required to use manuals and on-line documentation. Through observations of his teaching, it is clear that his understanding of parallelism and the tools that support parallelism has matured and his ability to further explore the topic on his own has increased. Note that a faculty mentor should be present at the teaching sessions to ensure that probing questions are asked and that students gain the necessary information from the session.

WORK IN TANDEM

Goals: Provide quality control, continuity, and risk management through collaboration.

Method: Assign a task to two students. Have the students divide between them the activities that are needed to accomplish the task, indicating the deliverables and timeline associated with each activity. Specify that the responsibilities of each student include collaboration, review, and critical analysis of each other's work. Assign a lead to collaborative efforts.

Challenges: Defining realistic timelines, managing time, and applying collaborative skills outside of meetings with faculty mentors.

Two examples are given. The first example illustrates how faculty mentors can manage risk within a project as well as provide quality control. The second example demonstrates how the work-in-tandem approach can be used to prepare a student who will be assuming the tasks of a student leaving the group.

Example 1

Student Profile: Two upper-division undergraduate or graduate students.

Task: Using software engineering principles, design, develop, and implement a parallel-discrete-event simulator of the DynaMICs snoopy coprocessor monitoring system [8]. The simulator is to be implemented in such a way that it is capable of executing on the SGI Origin 2000. The student who has become an expert in implementing programs for this platform (see "Create an Expert") facilitates the training needed to complete this task.

Deliverables: Create a design document using IEEE standards. Implement with respect to the design, document test plan, and test.

Benefits: For the students--development of technical, research, collaborative, critical analysis, and technical writing skills, and practice with goal setting and time management. For the research group--availability of a parallel-discrete-event simulator that can be used as a test bed for further system development and risk management, i.e., if one student leaves the group there is another who understands and can extend the work.

Discussion: This task was assigned to two graduate students, both of whom have a working knowledge of the DynaMICs project. One student was involved in the initial design of the DynaMICs snoopy coprocessor monitoring system [8], while the other student had to depend on published papers, presentations, and discussion to develop an appropriate foundation. Both students had taken software engineering and computer architecture courses at the undergraduate level at the time of the assignment. In spite of exposure to technical writing in software engineering, the students had difficulty in writing the design document. As a result, an apprentice approach was adopted to address this problem. (See "Apprentice".)

Example 2

Student Profile: An advanced undergraduate student.

Task: Read and critically review the master's project report of a graduate student. In this example, the project analyzed the accuracy of R10000 performance counters. Compare and analyze differences among experimental data collected on different computer systems that utilize the same processor. Extend the work to increase the number of countable events that are studied and to analyze the accuracy of R12000 performance counters.

Deliverables: Write a report and give a presentation with respect to the comparative analysis. Write a design document and give a presentation that describes the experimental method to be used in extending the work. After refinement of the design document and implementation of the experiment, write a paper that presents and analyzes the results.

Benefits: For the student--development of technical, research, collaborative, critical analysis, and written and oral communication skills, appreciation of the value of documentation, increased confidence, improved performance in related courses, and practice with goal setting and time management. For the research group--publishable research results and a more experienced research group member.

Discussion: Prior to acquiring the necessry knowledge to address the research, the student worked on tasks that supported the POEMS research and her faculty mentor. These tasks developed her sense of responsibility, timeliness, and resourcefulness, as well as her technical, research, and leadership skills. The tasks included web page development, literature searches, and tool development. Also, during the time that she performed support tasks, she took a course in computer architecture and had opportunities to discuss the task and related activities with the graduate student who completed the related master's project. The graduate student has since left the project and the undergraduate student is extending the work.

APPRENTICE

Goals: Advance students to a higher level in terms of their research and technical skills.

Method: Schedule sessions in which one or more students work with an expert to learn about the task and how to accomplish it.

Challenges: Evaluating the apprentice's foundational knowledge to decide if s/he will benefit from apprentice sessions and determining when the student is ready to proceed alone.

Example

Student Profile: An advanced student with prior knowledge of the research project.

Task: Using a laptop computer and projector, walk through the design document for the DynaMICs snoopy coprocessor monitoring system with faculty mentors and other research group members, note corrections or changes as errors are discovered, and seek understanding for the changes.

Deliverables: Revised document in which changes (based on what has been learned) have been applied to areas not covered in the review.

Benefits: For the student--development of technical, research, collaborative, critical analysis, and written and oral communication skills. For the research group--advancement of research and development of student researchers.

Discussion: Making written corrections to a document is time consuming and, in the case of major modifications, requires another meeting to explain the changes. This approach permits everyone to enter the discussion. By explaining the reasoning behind the change, everyone in the group benefits. After a session, the student should be able to make other changes to the document, using the newly gained knowledge.

EXPLORE

Goals: Develop student's ability to explore, experiment, or analyze data during the research process.

Method: Student reads and critically reviews papers related to the research. An alternative is that the student is given a research task that focuses on an experimental design. In this scenario, the student writes a report and gives an oral presentation that defends the design and/or results.

Challenges: Ensuring that the student understands the goals of the research, does not take short cuts, and documents the process.

Example 1

Student Profile: An undergraduate or graduate student.

Task: Read and critically review seminal and related research papers with the goal of advancing the DynaMICs or POEMS research. At a weekly meeting, lead a discussion of an assigned paper, which has been read by others in the group, and field questions.

Deliverables: For each paper, a written summary that includes an extended abstract, critique, support for current research, and future research questions.

Benefits: For the student--development of technical, research, collaborative, critical analysis, and written and oral communication skills. For the research group--advancement of the research and development of a student who can conduct a peer review.

Discussion: Care must be taken to match the level of the student to the level of the assigned papers. Student summaries must be reviewed and edited by faculty mentors until the resultant summaries are of acceptable quality. Critiques of student presentations can aid in developing oral communication skills. In the DynaMICs research group, this task was assigned to several students at different academic levels during one summer. In the POEMS research group, this task has been assigned to students at different academic levels periodically during the academic year. It has been successful in moving research forward.

Example 2

Student Profile: An undergraduate or graduate student.

Task: Read and report on papers that might be relevant to the design of the snoopy coprocessor monitoring system. Working with faculty mentors, design such a system.

Deliverables: Write a paper that describes the design, and present the paper at a weekly or monthly research group meeting. After refinement, submit the paper to a relevant conference.

Benefits: For the student--development of technical, research, collaborative, critical analysis, and written and oral communication skills. For the research group--advancement of research and development of a peer researcher.

Discussion: The student had taken a course in computer architecture and was highly motivated. Regularly scheduled meetings for brainstorming and refinement of ideas were necessary. The student made significant contributions to the research and jointly published a paper with his faculty mentors. He presented the paper at an international conference.

SUMMARY

The Affinity Research Group model provides an 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 organized and effective infrastructure for applying best practices in the mentoring of students as they pursue research activities. The infrastructure supports the development and management of large research groups, which include both undergraduate and graduate students. Some of the challenges in involving undergraduate students includes their lack of domain expertise, the time commitment required of the faculty mentor to develop the students, and the risk of losing domain expertise when students leave the research group upon graduation. This paper presents four different categories of tasks and related activities that have been effective for addressing these problems in SSEAL: create an expert, work in tandem, apprentice, and explore. The central theme among these different types of tasks is that each focuses on the skills necessary for the student to succeed in research. Tasks are structured in such a way that the time required to develop students is optimized from the mentor's point of view, i.e., the mentoring scales up because the instructor is working with more than one student, students are becoming experts, more than one student is working on a project, and students learn from other students.

For an affinity research group to be successful, it is imperative that the faculty mentors recognize the value of involving undergraduate students in research and understand that the research process and the rate at which publications will be produced may slow down because of the need for student development. This can be alleviated in a department where the curriculum supports development of some of these skills. Often it is the case that graduate students also may require development, especially when they enter the program without a sufficient background in computer science. These same tasks and activities can be used for the development of graduate students as well. In departments with no Ph.D. program or a small Ph.D. program, starting at the undergraduate level can reap additional benefits. Some students will participate in a research project during their undergraduate tenure as well as their graduate tenure, providing continuity for the research project.

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