FOSTERING AN ACTIVE LEARNING ENVIRONMENT FOR UNDERGRADUATES:
Peer-to-Peer Interactions In a Research Group

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Educators have previously established the benefits of introducing active learning into the passive environment of a traditional lecture setting.[1-4] But what, exactly, are the characteristics of this learning model? Silberman[2] provides an illustrative model description by saying:

> *When learning is active, students do most of the work. They use their brains . . . studying ideas, solving problems, and applying what they learn. Active learning is fast-paced, fun, supportive, and personally engaging . . . To learn something well, it helps to hear it, see it, ask questions about it, and discuss it with others. Above all, students need to "do it"—figure things out by themselves, come up with examples, try out skills, and do assignments that depend on the knowledge they already have or must acquire.*

This description applies both in and out of the classroom. Although some would argue active learning could take place individually, a key component of many active learning environments is interaction among participants. While most investigations of active learning have dealt with traditional classroom/lecture situations, undergraduate research and independent study are becoming increasingly more important in the undergraduate experience. Undergraduates may now do research at their own institutions during a typical semester, and summer research experiences (the Research Experience

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for Undergraduates or REU) are becoming well-recognized. Independent study, in connection with a research group, would seem an ideal opportunity for fostering active learning. Little attention, however, has been given in engineering education to fostering active learning or measuring the outcomes.

The objective of this paper is to quantify the level of active learning exchange in a research group composed of undergraduate and graduate students, using analysis of the number and types of verbal exchanges taking place. With funding from the National Science Foundation, we have developed a model called the Research Communications Studio (RCS), which has served as the testbed for research on learning. While data have been collected in the RCS environment, the means of promoting active learning and the lessons learned should be within reach of faculty and their own research groups. A number of practices that make the studio approach a successful model for facilitating active learning are recommended to educators.

This paper details a number of principles that can be used by engineering educators to facilitate active participation among undergraduates in a research-learning environment. The RCS, which is a refinement of the typical research group containing undergraduate and graduate students, is presented as a test-bed for the approach. A quantitative study of activity levels is pursued and the subsequent analysis is presented.

GUIDELINES FOR ENGINEERING EDUCATORS/RESEARCH GROUP LEADERS

While classroom teaching is usually governed by well-organized textbooks and syllabi, the research group is typically more of an apprenticeship situation in which aspiring researchers learn by doing. In our experience, a typical research group may or may not employ structured learning approaches, depending on the faculty director's preferences. Research group leaders, whether faculty or senior graduate students, may improve the intensity of learning in their undergraduates by explicit consideration of some guiding principles, as well as educational theory. We recommend the following four guiding principles be incorporated into a research learning situation, and these should be made explicit to student researchers:

- *Instill personal ownership of the project*
- *Focus on communications products (papers, poster, etc.), with appropriate instruction*
- *Promote awareness of distributed cognition*
- *Facilitate peer-level interaction*

These principles are further described below.

Instilling Project Ownership

When undergraduate students are in a position of ownership of their projects, they are more likely to exhibit a genuine interest in their own creative work and learning processes. It becomes even more clearly the students' responsibility to make progress in research and to take the initiative to learn. We have found that a strong sense of personal ownership drives undergraduates to stimulate conversation on their project. In a research setting, students perform original work (as opposed to well-defined homework or laboratory exercises with predetermined solutions and presentation formats). This is, in fact, inherent in the nature of all research groups. The research group leader must put forth effort in order to promote student ownership of their projects. As soon as is feasible, students should clearly articulate their own objectives and deliverables.

Focusing Students Toward Communications

"The job isn't over until the paperwork is done." Experienced research mentors know that "paperwork" today may mean a journal article, contribution to a technical report, poster presentation, oral/electronic presentation, research notebook, or other form of research communication. It is essential to orient the student early on to communication skills. By "focusing," we mean that the research group leader explains the importance of communication in research, and specifically identifies one or more forms of "paperwork" that are the required research product. Typically, the end of an academic or summer term is a good time to require final communication products, as setting deadlines also defines rigorous due dates for papers, posters, and presentations. Students should be required to regularly update their communication products and submit them for review and comment by the advisor and senior research associates. This requirement provides a common ground for undergraduates in initiating discussions with more experienced members of the research group. With this orientation, students focus on how to best explain their work to their peers as well as begin to perceive how their communication products come across to others. Interactive peer critiques of research deliverables aid the student on the given product but also provide others with experiential learning from the activity.

Promoting Awareness of Distributed Cognition

Distributed cognition, simply defined, is the process of learning through the combined knowledge and experiences of diverse individuals. There are certainly times when the researcher must forge ahead with individual effort, but much research today is conducted in an interdisciplinary team environment. Thus, undergraduate students should be taught to actualize John Donne's words: "No man is an island, entire of itself; every man is a piece of the continent, a part of the main." Undergraduate researchers should be taught the concept of distributed cognition and encouraged to use it.[5] The learning that occurs through the group's distributed cognition doubles back into new learning for the individual students.[5] Practice helps them become more confident and aware of their role in an active learning environment. Students who are aware of how they learn will look for opportunities both to give information out to and receive it back from their

***Figure 1.** A typical RCS session in which the undergraduate researchers, mentors, and faculty meet to discuss all aspects of research.*

***Figure 2.** A participant presenting or explaining her research to the RCS group during a meeting.*

peers. They look for others to contribute knowledge to solving their particular problem and reciprocate by sharing what they know to help others.

Facilitating Peer-Level Interactions

Undergraduate researchers may expect that the senior investigator will tell them everything, and they may have no appreciation for the importance of active communication among group participants at all levels. An integral piece of the aforementioned distributed cognition, however, is the interaction at peer level. An obvious way to facilitate peer-level participant interaction is to train a graduate student or post-doctoral scientist to moderate (not dominate) the research group environment and actively elicit the participation of the undergraduates. The research group leader (principal investigator; senior faculty member) can then focus on stimulating scholarly discussion, analyzing results, and creating openings or opportunities for others to contribute.

THE RESEARCH COMMUNICATIONS STUDIO AS A TESTBED

The RCS is an innovative structure, funded by NSF, designed to conduct cognitive research using the guidelines and pedagogical theory described above.[13, 14] The RCS is an ongoing effort to improve undergraduate education by creating an environment, similar to the typical research group, in which students are actively learning to better perform their own research using a communications-based approach. Studio leaders actively elicit participant interaction. At our university, the RCS activities are formally scheduled through a one-credit-hour independent study course (for three semesters) for which students receive academic credit in their majors. This academic structure was purposely chosen, as independent study courses are fairly common in undergraduate engineering curricula. Small interdisciplinary groups of undergraduate researchers with authentic projects meet weekly under the mentorship of a senior (Ph.D.-level) engineering student. The senior engineering graduate student is chosen based on experience in the conduct of research, including publishing and participating in conferences. The experiences of this senior student become part of the knowledge base of the distributed cognition system.

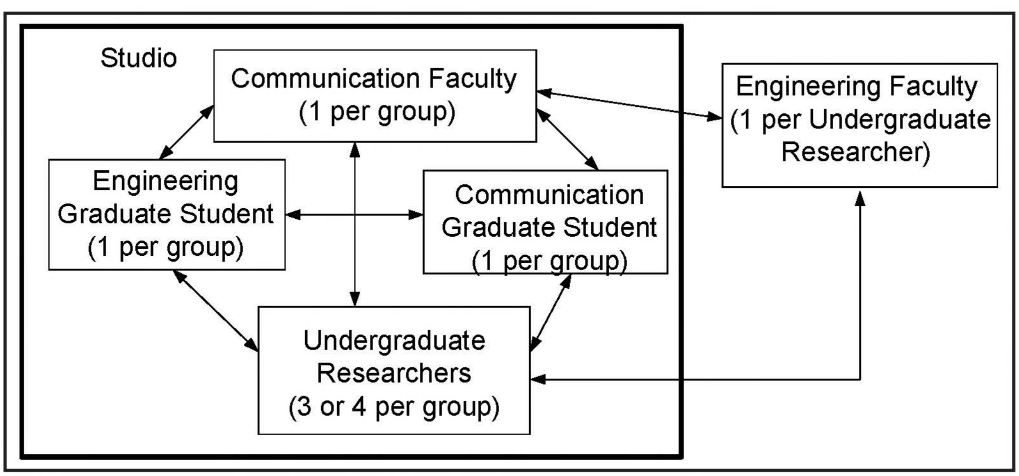

***Figure 3.** The studio is an environment of distributed cognition, in which thinking and learning processes are distributed across the network of participants.*

In the weekly studio meetings, students discuss, write about, reflect upon, and present their research as it progresses, and in doing so, they learn how to communicate more clearly (Figures 1 and 2). Through this approach, principles of research and communication are made explicit. RCS activities enhance learning outcomes through intensive practice of communication skills. Figure 3 shows the interactive relationship among the interdisciplinary staff and undergraduates, along with the connection of all participants to the engineering faculty members. The RCS is a student-centered approach in which all activities and the associated communications products are driven by students and their advisors. While each studio group has its own dynamics, the sessions have some elements in common. The staff, which includes an engineering and a communications graduate student, as well as a communications faculty member, encourages students to take control of the discussion as much as possible. Staff comments are most common in situations when the student seems to be unsure of what to do next or has questions about best practices, such as effective information arrangement and design for posters, slide show presentations, and technical papers.

Further details of the RCS research initiative as well as a detailed studio description can be found on the Web (<http://www.che.sc.edu/centers/rcs/rcsmain.htm>) and in the professional literature.[13-17]

QUANTIFYING INTERPERSONAL DYNAMICS: CONFIRMING ACTIVE PARTICIPATION

As communication is an integral part of active learning, particularly in a group setting, we have investigated communication activity to verify the level of active participation. We undertook an analysis of the linguistic interaction in studio sessions, using theoretical constructs and techniques from conversation discourse analysis. Among the most important constructs are those of the linguistic event ("turn") and the "floor." Here, a linguistic turn is considered an instance or period of participation in which one is expressing a thought or idea. This turn is the elemental building block of a conversation. Furthermore, the individual(s) communicating at a given point in time is said to have the floor.

Active participation can be confirmed through an investigation into the dynamics of the interactions taking place within a given environment. To date, most studies on the processes of learning and communication have been predominantly qualitative in nature, as these processes are notoriously difficult to quantify. A few quantitative attempts have been made, however. Among these is the development of an observation system intended to capture the effects of differences in instructional approaches in engineering classrooms, especially with regard to interaction levels and levels of student engagement.[8] Interactions between educators and students, and the resulting impact on education, have been quantified and characterized using coding systems.[9, 10] Clarke, et al. present a review of techniques for analyzing classroom discourse as well as a complex technique that overcomes the limitations of many previous methods.[11] These works, however, focus their attention solely on the classroom setting. This present study employs a new coding methodology, similar to that of Power[9] and Stiles, et al.,[10] to analyze the interpersonal dynamics in a learning environment other than the classroom. The activity levels in the RCS are verified by quantifying interaction frequencies and conversation alignments.

To analyze how engineering students contribute to and benefit from a distributed cognition environment, both audio and video records of sessions were kept. These records are the basis for this quantitative analysis to confirm active participation levels.

A coding approach is used to review a number of representative sessions and to create a chronological map of how information is exchanged between studio members during a session. The direction and duration of communication flow between participants on an event-by-event basis is tabulated. This includes noting the time at which a turn begins, who is controlling the floor, as well as whom they are addressing or communicating with. Note the analysis also captures key aspects of communication such as gesture, body language, or other nonverbal means of communication such as drawing, and writing. To make the coding process manageable, however, hard-to-identify events such as head nods, hand waves, and minimal verbal responses that do not significantly impact the flow of conversation are ignored. More easily identifiable nonverbal events such as reading and writing silently are recorded. Pauses in communication are also recorded as events when no communication occurs between members for a significant period of time.

A typical event (turn) has one active speaker, a set of recipients (the audience) being addressed by the speaker, and a set of bystanders who are not directly involved in the communication exchange. In fact, the principle that one speaker talks at a time (*i.e.*, in a one-speaker floor) has formed the basis for much linguistic research. Edelsky,[20] however, shows that this is not always the case. In many communicative situations, a distinction can be made between interaction in which one identifiable speaker has the floor at any given time and interactions in which the floor is shared, as in a collaborative floor or during schisming (when one conversation among all participants present splits into two or more distinct conversations). In the present analysis, speakers frequently share a collaborative floor and have schisming conversations.

The present study focuses on the analysis of representative RCS sessions taken from each of three consecutive semesters. The dates of the sessions were March 3 and Sept. 22, 2003, and Feb. 2, 2004. It should be noted that the groups do not necessarily involve the same undergraduates, mentors, and faculty, as the groupings change on a semester-to-semester basis, though all sessions do follow the typical RCS approach.

RESULTS AND DISCUSSION

From the coding scheme, a wide variety of quantitative information can be obtained that describes the dynamics of the interactions in the distributed cognition environment. The lowest level of information obtained is a simple average frequency of turns in a given session. It was found that the average turn frequency in the sessions considered ranged from 5.7 to 7.3 turns per minute (Table 1). That is to say, the floor changed hands roughly every 10 seconds throughout the meeting. This is significantly more frequently than the change of floor in the more passive learning model of the traditional lecture environment. This, in itself, is an indicator of active participation.

By noting the speaker in the coding process, the role of the individual controlling the floor can be analyzed. It was found that at any given time, a single person almost exclusively controls the floor, *i.e.*, through the "one-speaker floor." Only in rare instances of a collaborative floor or schisming is the floor shared. In general, the undergraduates control the floor the majority of the time (32.6% to 46 %), followed by the mentors (32.7% to 33.4 %), and then the faculty (20.7% to 20.9 %). This is to be expected, as the groups consist of more undergraduates than mentors, and more mentors than faculty. On a per person basis, however, the faculty member actually takes the most turns, at roughly 20% (Table 1). This is still a significantly reduced role as compared to the classroom environment, in which the faculty member is expected to dominate the floor. In another study on the RCS, Donath, et al. found that the faculty member's contributions are mainly "elicitation of critique" and "negotiation."[14] This reduced role of a faculty member exemplifies the RCS distributed cognition strategy in which the participants drive the discussions and learn from each other, in addition to learning from the mentors and the faculty.

The speaker and audience (or intended recipient) can be further analyzed to indicate the difference that role (*e.g.*, student, linguistics mentor, etc.) makes in the verbal interactions. In this way, we have examined the prevalence and specific instances of peer-level interactions. It was found that the sessions were dominated by multilevel interactions in which a single person is addressing the whole group. In these cases, interactions of all levels are taking place. That is to say, the

TABLE 1
Summary of Quantitative Data of Studio Group Dynamics.
(*Multilevel interaction types account for interactions that include everyone and thus every interaction level.)

	Session 1 (March 3, 2003)		Session 2 (Sept. 22, 2003)		Session 3 (Feb. 2, 2004)	
Group Make-up			-----		-----	
Number of Participants	3		4		4	
Number of Mentors	2		2		2	
Number of Faculty	1		1		1	
Group Activity	-----		-----		-----	
Total No. of Turns	542		411		455	
Session Duration (min)	74.1		61.6		80	
Turn Frequency (turn/min)	7.3		6.7		5.7	
Who has the floor?	% Turns	% Time	% Turns	% Time	% Turns	% Time
Undergraduates	33.9	32.6	48.1	43.8	38.5	46
Mentors	32.8	32.7	28.2	33.4	30.3	32.7
Faculty	20.3	20.7	21.4	20.9	30.1	20.7
Shared	12.9	14	2.4	1.8	1.1	0.6
Group Interactions	% Turns	% Time	% Turns	% Time	% Turns	% Time
Peer	4.6	3.5	12.9	8.8	2	1
Undergraduate-Mentor (Near-Peer)	25.1	33.2	19.2	16.7	26.4	25.4
Faculty-Undergraduate	21.4	18.2	22.1	14.6	35.4	27.7
Mentor-Mentor	5.2	3.5	3.2	3.6	0.7	0.2
Mentor-Faculty	3.9	2.9	2.4	1.9	3.5	1.6
Multi-level*	39.9	38.7	40.3	54.4	32.1	44.1

interactions include communication on the peer level, as well as those between undergraduates and mentors, and between undergraduates and faculty. This is expected, as the groups are small and one could address everyone with relative ease. These multilevel interactions accounted for 32.1% to 40.3% of the total interactions on a turn basis (38.7% to 54.4% of the interactions on a time basis). The pure peer-level interactions accounted for 2% to 12.9% of the interactions on a turn basis, and 1% to 8.8% of the interactions on a per-time basis (Table 1). Again, this peer-level interaction is one indication of active participation not necessarily encouraged in the lecture setting. It is, however, a kind of interaction that the studio staff strives toward.

Studies on the group as a whole provide useful information with regard to how the studio provides a forum for undergraduates to work with each other in the distributed cognition environment. Although beyond the scope of this paper, it is conceivable that exhaustive analysis of data on a single participant, paired with long-term assessment, could prove useful in showing the effect of active participation on the individual's progress in the transition from novice to more mature researcher. Nevertheless, the analysis of the three sessions clearly indicates the consistency in the sustained activity levels stimulated by the distributed cognition environment.

Herbert Simon[18] points out that the basic principle of the enterprise of cognitive studies is that "learning takes place inside the learner and only inside the learner." Simon also recognizes that "whether from books or people, at least 90% of what we have in our heads . . . is acquired by social processes, including watching others, listening to them, and reading their writings."[18] The research group must take into account this socially distributed nature of learning by building an optimal environment for research learning to occur. The RCS learners' knowledge construction process is aided by an environment of distributed cognition in which participants at all levels—experts, mentors, accomplished novices, and novices—learn from and teach each other.[7] The explicit attention to distributed cognition, accomplished in the RCS through a focus on communication, addresses both the learners' cognitive development and the development of communication abilities within a system of distributed cognition.

Small groups provide an optimal environment for peers, near-peer mentors, and communications faculty to interact through various modes of communicating. The acts of speaking, writing, drawing, gesturing, using computer programs, etc., mediate individuals' construction of knowledge. At the same time, these media represent knowledge externally for others, who can both provide feedback and use it in their own knowledge constructions. The process of constructing knowledge is enhanced by expert guidance and feedback as the learners work on increasingly challenging aspects of the research projects they are involved in with their research advisors. What learners can do initially with experienced guidance they can do later by themselves. The distance between what learners can do independently and their abilities to solve problems with guidance was conceptualized by Vygotsky[19] as the zone of proximal development. Research groups comprising graduate students and undergraduate students, as well as faculty and research staff, provide a zone in which undergraduate engineering students from different engineering disciplines, graduate student mentors also from different engineering disciplines, graduate students from linguistics and English, and communications faculty all interact with and learn from one another. This interaction occurs in a rich environment of advanced computer tools and all the possibilities of intellectual stimulation provided by a college of engineering.

From the discourse analysis of representative groups, it is seen that the verbal and nonverbal communication activity levels in the RCS (and, by extension, it is presumed in a structured research group setting) can be elevated, particularly in comparison to that expected in the traditional classroom. The results are characteristic of the definition of an active learning model.

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