The Research Communications Studio as a Tool for Developing Undergraduate Researchers in Engineering

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Abstract

The NSF-funded Research Communications Studio (RCS) project at the University of South Carolina, responding to groundbreaking theories in *How People Learn,* is among the first attempts to measure students' responses to research-based learning in a distributed cognition environment. As an alternative to the unguided research scenario often encountered by part-time undergraduate researchers, the project provides a more structured environment in which contemporary constructivist learning theories are used to develop the research and communication skills of novice researchers.

The undergraduate researchers meet weekly in small interdisciplinary studio groups to strengthen their research and communication skills. Their needs drive discussions that typically revolve around some form of a deliverable (i.e., poster, journal article, presentation) regarding the research in which they are involved. Fellow undergraduates assist each other with problems as part of a peer relationship, while graduate mentors from both engineering and English provide near-peer support. Communications specialists and the undergraduates' research advisors confer regularly and provide faculty perspectives. The dynamics of the meetings reflect a team-centered approach, offering solutions that stem from a network of distributed cognition.

The RCS is presented as an educational model that augments undergraduate research while supplementing classroom instruction. The research team has developed a multi-dimensional rubric and a coding system to quantify extensive qualitative data: student deliverables and videotapes of small group sessions. This paper focuses on the method for quantifying traditionally qualitative data, and, based on analyses of those data, reports progress undergraduates have made in their research learning through the distributed cognition environment of the RCS.

The Research Communications Studio Approach

The Research Communications Studio (RCS) is an innovative structure that integrates communications into the undergraduate research experience (http://www.che.sc.edu/centers/rcs/rcsmain.htm). In the RCS, small groups of undergraduates who are working on research with engineering faculty, meet weekly under the mentorship of communications faculty and engineering and English graduate students. In the studio, students discuss, write about, and present their research as it progresses. The studio approach provides an environment for constructivist learning practices. Through an inquiry-based learning approach, principles of research and communications are made explicit, and students are engaged in reflecting on their own learning. As the students discuss, write about, reflect upon, and present their research, they learn how to communicate clearly. RCS activities enhance learning outcomes through intensive practice of communications. *Figure 1* shows the interactive relationship among the interdisciplinary staff and undergraduates along with the connection of all participants to the engineering faculty members.

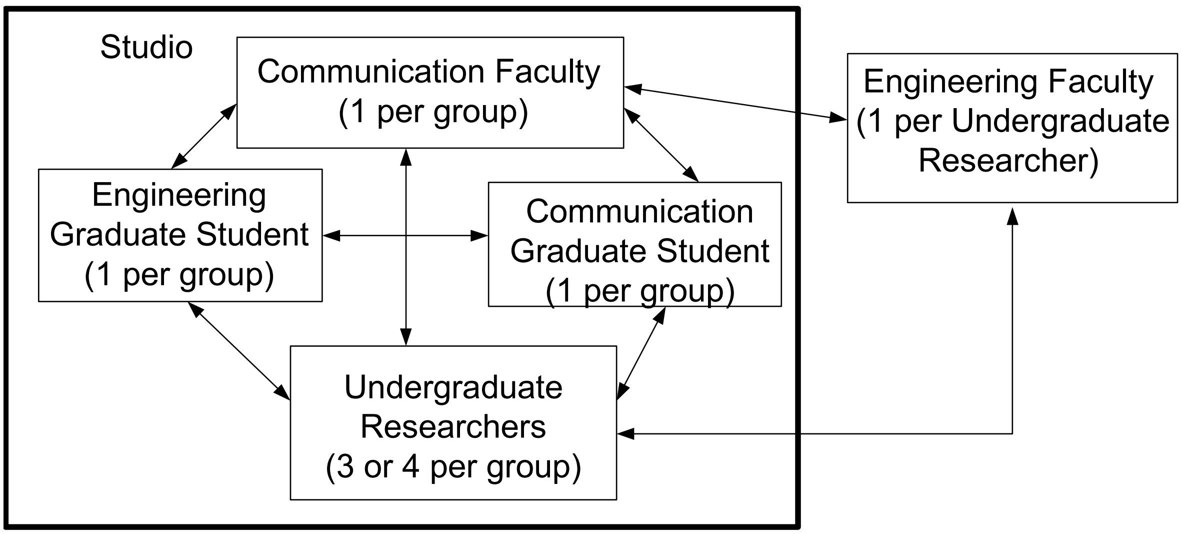

Figure 1. The Studio is an environment of distributed cognition, in which thinking and learning processes are distributed across the network of participants.

While each studio group has its own dynamics, the sessions have some elements in common. The staff encourages the students to take control of the discussion as much as possible. Staff-led discussions 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. In the Fall 2003 semester, for example, the RCS had three studio groups of four students, each of which met weekly for 75 minutes. In one group, all four undergraduates experienced problems with their research that kept them from moving forward for several weeks; as a result, this group spent more time than the other two on professional issues such as creating a resume and discussing what happens in a job interview. In another studio group, the majority of the focus was on written communication because the research advisor wanted the students to work on papers for publication. The third studio group had the most diverse mix of students with respect to the length and scope of their undergraduate research experiences. These students decided as a group to change the studio format; instead of a format that allowed each student's research to receive an equal amount of time for presentation and discussion each week—typically about 15 minutes—the group opted to allow 30 minutes every other week for each student's work. This kind of flexibility allows the studio to adhere to its mission of helping students increase their ability to communicate their research to a varied audience, in a variety of formats.

The research associated with the RCS project investigates the role of communications in participants' cognitive development by looking closely at what learners are doing in the learning environment, in order to gain evidence of how learning can best be engineered. Data collected include students' communications products in a variety of genres and media, analyzed via a rubric developed by the researchers. Also, RCS sessions are videotaped for studying the complex interactions that occur in this system of distributed cognition. The focus of the present paper is to describe coding techniques being developed to analyze these complex interactions in the small group sessions. The sections that follow describe a means of coding the qualitative data of the sessions to produce quantitative information that will allow for discovery of patterns of engagement. Eventually, these patterns will be used to identify events of distributed cognition.

The Studio as a Distributed Cognition Environment

Through the communications approach, the RCS seeks to enhance students' cognitive development. Herbert Simon[9] 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*". However, 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"[9]. The RCS takes into account this socially distributed nature of learning by building an optimal environment for research learning to occur. The learners' knowledge construction process is aided by an environment of distributed cognition in which participants at all levels—experts, mentors, accomplished novices, and novices—teach and learn from each other[1]. The RCS addresses both the learners' cognitive development and the development of communications abilities in 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. Speaking, writing, drawing, gesture, 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 guidance from a more knowledgeable member of the discipline 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[11] as the *zone of proximal development*. RCS groups 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 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.

As the concept of "distributed cognition" takes into account the social, situational, and cultural nature of learning, cognition "does not have a single locus 'inside' the learner," but instead is "jointly composed"[8]. However, we resist the extreme view that distributed cognition exists only in the group structure, and we believe that learning in this group context stimulates individual learning as well. Thus, use of small groups for creating a distributed learning environment provides “a means to cultivate the individual’s competencies”[8]. The social practices that produce distributed cognition “can be said to leave *cognitive residues* in the form of improved competencies, which affect subsequent distributed activities”[8]. The RCS approach seeks to exploit group interactions to build knowledge constructions, which can then be internalized by individuals. This approach exemplifies Vygotsky’s contention that learning occurs from the outside in.[11]

Methods for Quantifying Traditionally Qualitative Data

Two separate methods for quantifying traditionally qualitative data are presented. Each method is independent of the other and serves its own unique purpose. The first is an evaluation model that graphically shows how communication chronologically evolves during studio sessions. The second method utilizes a multi-dimensional rubric to assess the quality of the participants’ work (deliverables). The rubric is applied on a semester-to-semester basis to track each student’s progress over time.

The Evaluation Model

Because communication is both one of the main skills taught in the studio and the main teaching method, we assume that the students' progress will be evident in their communication during studio sessions. Therefore, we undertake a close analysis of the linguistic interaction in studio sessions, using theoretical constructs and techniques from conversation analysis and discourse analysis. Among the most important constructs are those of the linguistic turn, the floor, and the communicative act.

In order to analyze how the engineering students contribute to and benefit from the distributed cognition environment of the studio, both audio and video records of each session are kept. These records are the qualitative data that are so rich in the interactions of the participants, which are vital to enhancing their learning. An obvious approach to monitoring these interactions is through transcripts of each session. However, the transcription process can be quite cumbersome and the transcripts do not fully describe the true dynamics of group. They often lack the ability to capture key aspects of communication such as body language or other non-verbal means of communication such as drawing, writing, etc. This evaluation model provides an efficient means to adequately track many of the communicative actions of each person, individually, and of the group as a whole, while indexing the session for more detailed study. Note that the focus of this work is limited to demonstrating the abilities of such an evaluation model and to providing ideas of the ways in which it could be utilized. The evaluation model is an efficient means to quantify many qualities of what takes place in the distributed cognition environment of the studio. However, in the current state of the project, no claims are being made as to what the quantitative data show with regard to how the participants are learning.

Fundamentally, this evaluation model is used to chronologically map how information is exchanged between studio members during a session. It records the direction and duration of communication flow between studio members on an event-by-event basis, and even goes as far as detailing the type of event taking place. 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. However, events sometimes have more than one speaker or no speaker at all. In general, events begin when a new speaker addresses the group and end when the new speaker stops speaking. To make the system manageable, 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; however, more easily identifiable non-verbal 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.

The principle that one-speaker talks at a time (i.e., in a one speaker floor) has formed the basis for much linguistic research. However, Edelsky[2] 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 (i.e., in a collaborative floor or during schisming). A collaborative floor has multiple speakers controlling the floor in a single conversation. Schisming occurs when the conversation among all the participants present splits into two or more conversations. While each conversation has its own framework, Egbert[3] demonstrates that in the simultaneous conversations interface, each can only be fully understood by considering it as a conversation that is coupled to the other in progress.

One group member typically controls an event. The controlling member decides who to direct his/her communication to and the forms of communication to use. For instance, during one event a member might read aloud an excerpt from an article and then ask the other members to comment about it. In this case, the flow of communication is directed to the whole group and the controlling member communicates by reading aloud and asking a question. For demonstration purposes, various possible flows of communication are depicted graphically in *Figure 2* using icons to represent group members and arrows to represent communication flow among them.

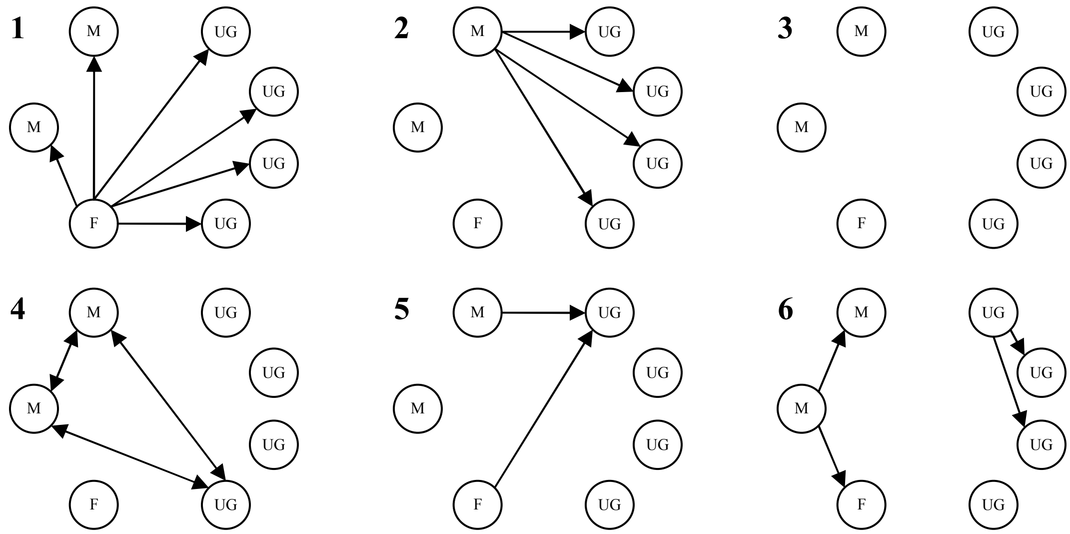

Figure 2. Graphic examples showing a snapshot of ways communication may be directed between faculty (F), mentors (M), and undergraduates (UG) during a single event.

In these examples, seven members participate in the studio session, including one faculty member (F), two graduate student mentors (M), and four undergraduate participants (UG). The first and second graphics demonstrate a *one-speaker floor (*OSF) event, where just one member communicates to other members in the group. The third graphic shows a *pause* (Ps) event, corresponding to no communication occurring between members. For this instance, no one controls the floor. The fourth and fifth graphics demonstrate a *collaborative floor* (CF) event where more than one member is controlling the floor while they direct the flow of information[2]. The sixth graphic shows an *schisming* (Sch) event where the group is divided into smaller groups carrying on their own conversations. The list below describes each event in more detail:

1) The faculty member addresses all of the other studio members, with communication possibly occurring either verbally through conversation or visually through some material means such as an illustration or article.
2) One mentor addresses just the undergraduates in the studio group. The other mentor and faculty member are bystanders who only receive information indirectly.
3) This is an example of a pause in conversation.
4) Three members of the group are conversing together in rapid succession or simultaneously such that it is not clear who controls the flow of communication.
5) One mentor and the faculty member speak simultaneously to one of the undergraduate students.
6) Two separate conversations occur simultaneously dividing the grouping in two.

Table 1 depicts the coding of a session. The events are numbered chronologically and marked by their start times. The type of each event is noted. Initials are used to indicate the speaker(s) and the recipient(s) (audience). Each event is then further classified, based on the form of communication being employed.

Table 1: Sample Coding for a Single Research Communications Studio Session

Event No.	Start Time	Event Type	Speaker(s)	Audience	Code
1	0:01	OSF	NT	all	G,S,Q
2	0:37	OSF	MC	NT	S
3	0:38	Ps	N/A	N/A	N/A
.	.	.	.	.	.
.	.	.	.	.	.
70	16:21	OSF	CH	NT	S,Q
71	16:32	CF	CL, NT	CH	S
.	.	.	.	.	.
.	.	.	.	.	.
241	1:16:02	OSF	NT	all	D,Q
242	1:16:11	OSF	JA	NT	Q
243	1:16:13	OSF	NT	all	S

Keys for both events and forms of communication are provided for the coding system. The keys are presented in *Table 2* and *Table 3* below:

Table 2: Coding Key for Event Types (Interaction Structures)

Symbol	Event	Definition
CF	collaborative floor	occurs when the conversation is controlled or developed by several speakers at the same time
OSF	one speaker floor	occurs when one identifiable speaker at a time controls or develops the conversation
Sch	schisming	more than one conversation proceeding simultaneously
Ps	pause	period of no communication
W	writing	participants are simultaneously writing silently, as with an in-class writing activity (no communication)
R	reading	participants are simultaneously reading the same material, such as a handout (no communication)

Table 3: Coding Key for Forms of Communication (Communicative Acts)

Symbol	Form of Communication	Definition
G	greeting	a phatic utterance with no referential function such as "hi", "good-bye", "thank you", etc.
S	statement	utterances that give new information and utterances that point out information already known to the group
Q	question	an utterance that requests information from another participant
D	directive	utterances intended to elicit behavior; includes commands, suggestions, requests, etc.
P	presentation	a participant practicing a formal presentation in a Studio session
R	reading	a participant reading aloud in order to communicate with another participant, e.g. sharing a definition from an article
Wp	writing	a participant writing something in order to communicate, e.g. writing an equation that is relevant to the topic under discussion
Wd	drawing	a participant drawing in order to communicate, e.g. sketching a diagram to illustrate something he/she has said)
RS	repeated speech	an utterance that is repeating a previous speaker

The categories for both the event type (in effect, the interaction structure) and forms of communication (communicative acts) arise from a combination of prior research findings and preliminary investigation of our own data. The taxonomies are by no means meant to be comprehensive, regarding interaction in general or even the interaction examined in this study. That is, the interaction structures and communicative acts forming the coding system of this study represent a small subset of all such structures and acts, selected according to their potential usefulness in describing the interactions of the studio and in showing how these interactions enhance the learning of the undergraduate participants.

The information collected through the coding process can be used to monitor many aspects of the studio dynamics. The model provides results on numerous levels. Macroscopic information can be gained on the studio as a whole. The involvement of each role (i.e., undergraduates, mentors, and faculty) can be seen, as well as that of each individual person. Once coded, each event and form of communication is countable and therefore the frequency and timing of each can be studied with hopes of revealing promising trends in studio activity. In addition to identifying any trends that are common in the studio sessions, the evaluation model can be used to flag specific portions of the studio sessions that could be of particular interest. A small sampling of the information that can be gained from the evaluation model is presented.

A measure of the frequency of events taking place as the session evolves is shown in *Figure 3*. The average event frequency is calculated as the number of events taking place in a sliding two-minute window for the duration of the session. That is to say, a single data point is determined by counting the number of events occurring in a two-minute window centered on the time for which that point is being calculated. In this graph, the peaks show periods of high interactivity (many short events). Lulls in event frequency can be attributed to periods of silence or even a few lasting events. It is obvious here that the RCS environment differs from traditional undergraduate classroom or lab settings in that control of the floor changes often.

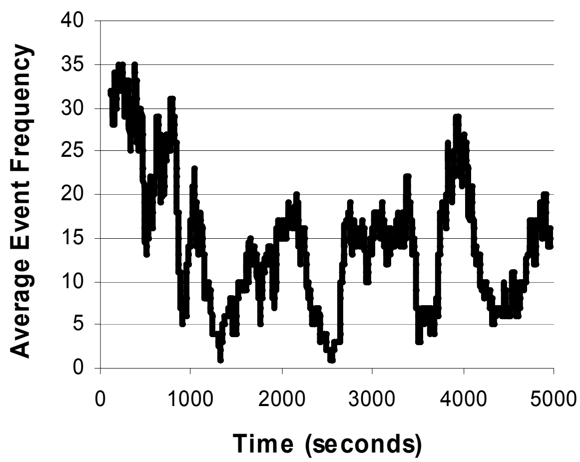

Figure 3: Event Frequency Measured as a Moving Average of Events Occurring in a Sliding Two-Minute Window for the Duration of a Session

As mentioned before, the activity of a session can also be monitored on a role basis. By looking at the role of the person that controls the floor, event by event, a simple measure of activity by role can be seen for the session as a whole (*Figure 4*).

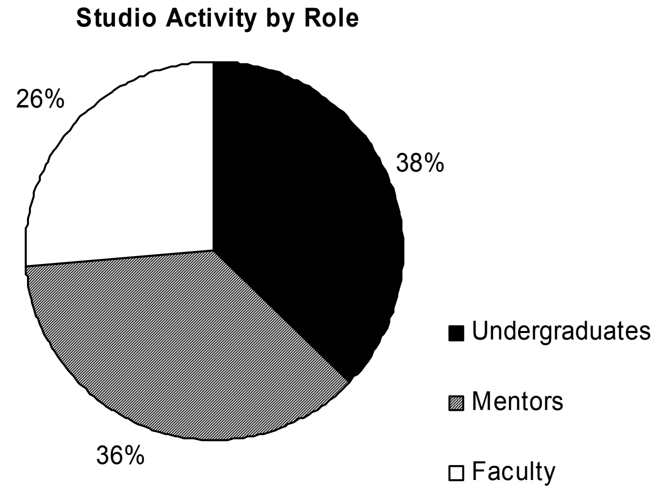

Figure 4: Activity in a Single Studio Session based on a the Percentage of Events in which a Person with a Specific Role Controlled the Floor

Figure 4 shows that during this particular session, the undergraduates had the floor for the majority of the time, followed by their near-peer graduate mentors and then the faculty. The fact that the students control the floor for substantial periods of time is consistent with the nature of the RCS. This differs greatly from usual classroom instruction, in which the instructor traditionally dominates the floor. In the studio, the undergraduates play a more active role in their own development. However, note that there are more undergraduates than mentors, and more mentors than faculty, so on a per person basis these numbers still indicate that the faculty and mentors play an active role in driving the discussion.

The role activity analysis can be expanded to incorporate the recipient (audience) of each event in addition to the speaker (the one who controls the floor). By monitoring both the roles of the speaker and audience, the number and type of interactions can be counted. If undergraduates are addressing undergraduates, the interaction is strictly on a peer level. If undergraduates and mentors are interacting, the interaction is referred to as near-peer. A third category of interactions by role is the faculty-student interactions. Interactions among mentors and between mentors and faculty also take place, but receive less attention here as the focus of the work is on undergraduate learning. *Figure 5* provides a distribution of the types of interactions in the session as a whole.

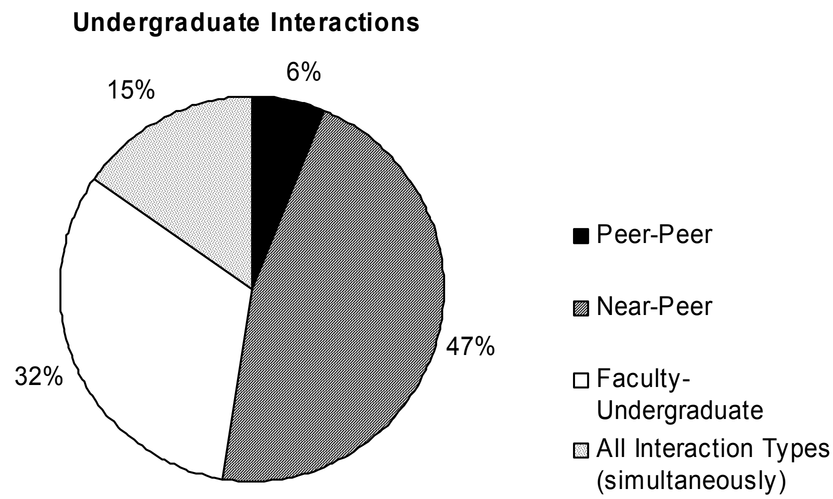

Figure 5: Breakdown of the Undergraduate Interactions to Peer-Peer, Near-Pear, and Faculty Undergraduate Level

Of all interactions involving an undergraduate, the majority (47%) is between the mentors and the undergraduates on the near-peer level. Also note that the undergraduates interact amongst themselves 6 % of the time. The faculty interacts with the undergraduates 32 % of the time. The fourth piece of the pie represents events in which the speaker is addressing everyone. In this case, all types of interactions are going on simultaneously. This is significant because this communication between students is strongly encouraged in the RCS but often frowned upon in the traditional classroom environment.

Figure 6 presents a measure of the types of interactions that the undergraduates are involved in as the session evolves. A similar moving average approach is taken in *Figure 6*, where the percentages of events in a sliding two-minute window corresponding to a particular type of interaction are shown. Note that at any given time the percentage of peer-peer, near-pear, and faculty-student interactions may sum to more than 100 %. This is attributed to situations in which multiple speakers or multiple recipients cause an event to have multiple interaction classifications. Similarly, they may sum to less than 100 % as “pause” events have no speaker or recipient.

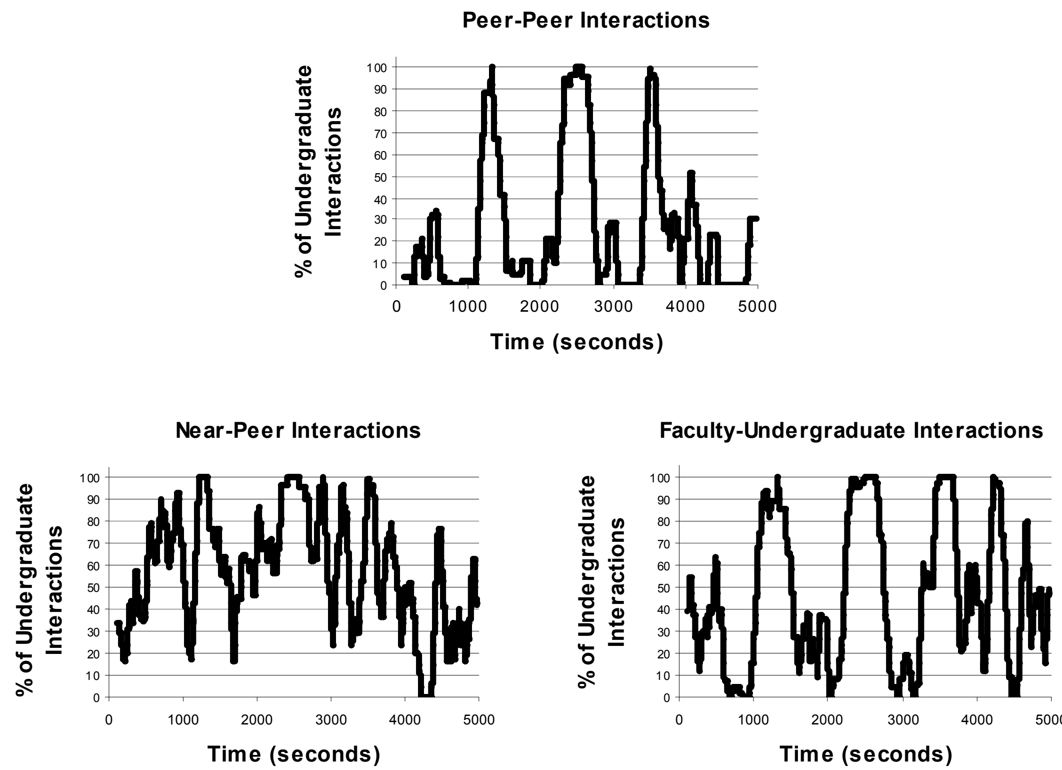

Figure 6: Frequency of Interaction Types Measured in a Sliding Two-Minute Window throughout the Session

The graph of peer-peer interactions in this figure shows that the interactions between undergraduates peak to 100% at three distinct times. During these three different periods, which span at least two minutes each, every event involves communication on the peer-peer level. However, that is not to say that the other types of interactions are not taking place. On the subsequent plots it can be seen that at these times, both near-pear and faculty-undergraduate interactions are also taking place at a high rate. By referencing the event frequency shown in Figure 2, it can be seen that at these three times the relative number of events occurring is low. This suggests that at these moments, an undergraduate is likely addressing the entire group for a substantial period of time, and therefore causing the simultaneous occurrence of all three types of interactions. Along these same lines, at approximately 4000 seconds into the session, the peer-peer interactions seem to peak again to a value of 50%. However, this time the frequency of the other interaction types is low and the total event frequency is relatively high. This indicates a significant time period where much of the communication is directed between just the undergraduates themselves. Overall, the plot of near-peer interactions indicates that the mentors work closely with the undergraduates consistently throughout the session. The level of faculty-undergraduate interactions is seen to fluctuate greatly during the session. Although periods of time pass in which there is no interaction between faculty and undergraduates, they are often closely followed by periods in which this interaction dominates.

Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition

In addition, any one speaker's individual level of participation can be studied. *Figure 7* shows the individual involvement of each participant in the session coded as a moving average of the percentage of events in the two-minute window in which the person was acting as a speaker, recipient, or bystander throughout the session.

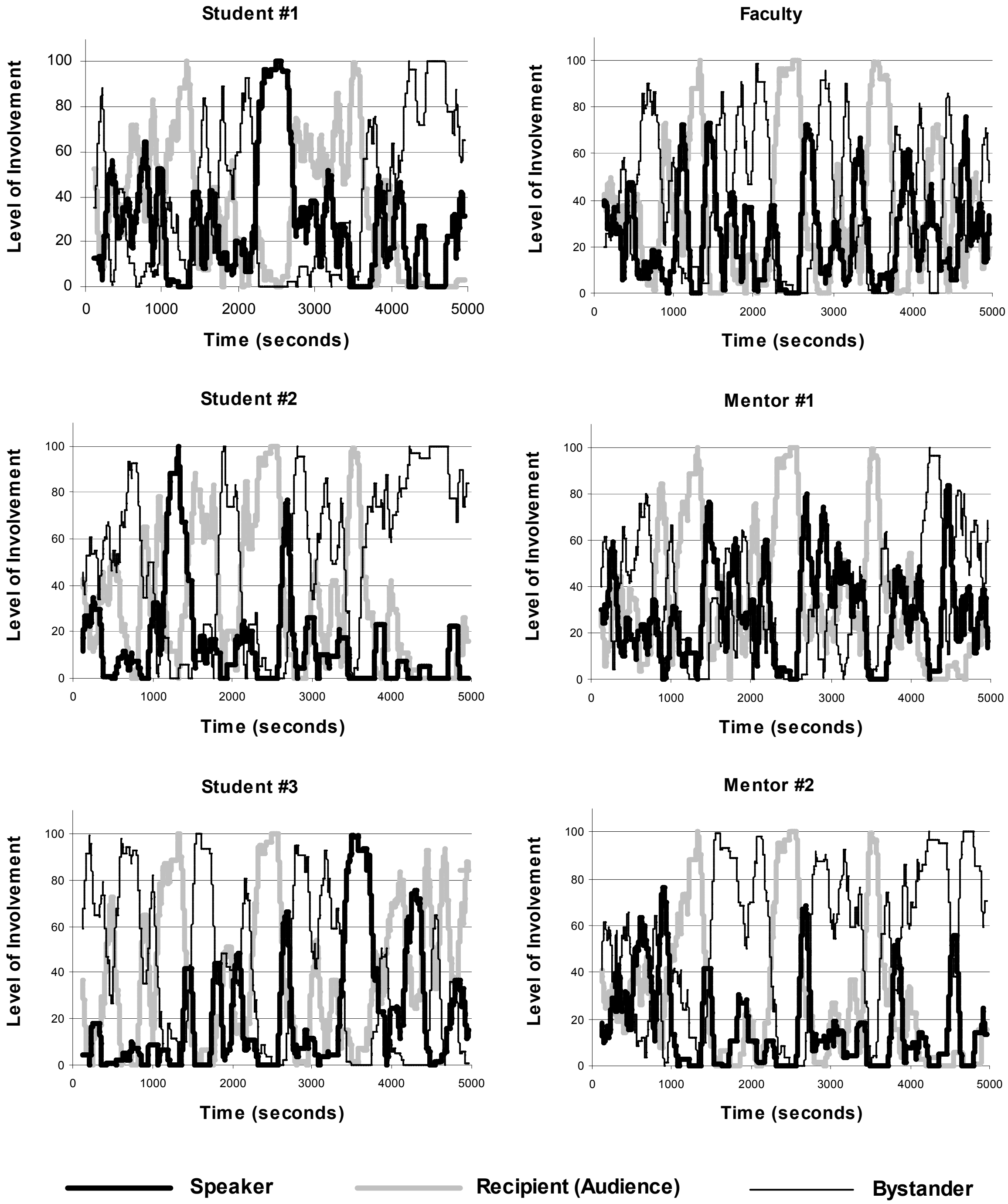

Figure 7: Frequency of Participation Measured as a Moving Average of the Percentage of Events in a Sliding Two-Minute Window in which an Individual is Acting as a Speaker, Recipient, or Bystander

Student #1 seems to be involved for the majority of the session. It is not until the last 15 minutes that the student seems to be less active, spending more time as a bystander. Midway through the session this person controls the floor for a significant amount of time. Similarly, Student #2 remains active until the last minutes of the session, and seems to have major speaking roles at two distinct times in the session. Student #3 is most active towards the end of the session. This is consistent with the roles of the other students at this time. Both the faculty member in the session and Mentor #1 are quite active throughout the session. Mentor #2 is less active in general, but has moments of controlling the floor. The differences in the mentors' involvement can be attributed to their differences in background. If a given session is more heavily focused on the research aspect of the students work, as opposed to the presentation or communications aspect, it would be expected that the engineering mentor could contribute more at that time than the mentor from English.

The forms of communication used during each event are also countable. *Figure 8* shows a breakdown of the number of instances in which each role within the RCS hierarchy utilizes a specific form of communication. The specific forms of communication are defined in *Table 3*. The data shows the balance of the forms of communications utilized by each role in the studio. Students are able to openly discuss their work through the use of questions, statements, writing, drawing, etc. as opposed to the traditional classroom environment where they are limited to answering questions posed by an instructor or asking question to get clarification on something that is otherwise unclear to them.

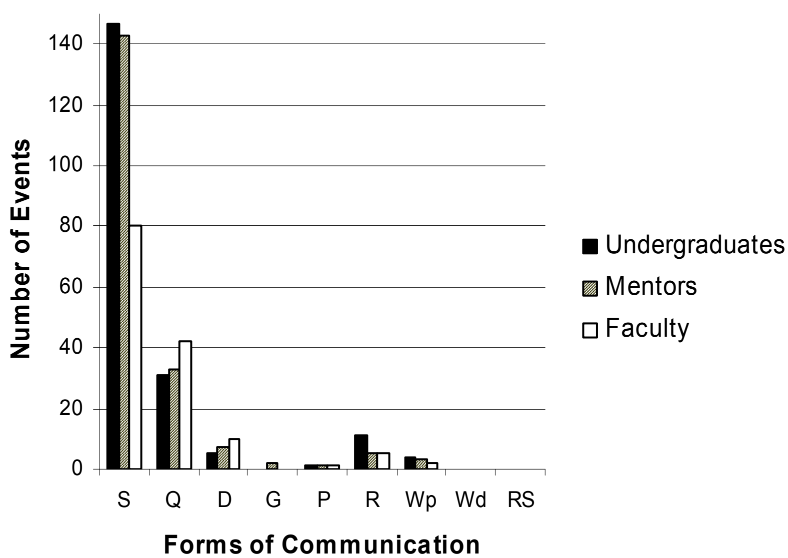

Figure 8: Breakdown of Forms of Communication used in a Single Studio Session

In this work, quantitative data from a single session are presented. However, the evaluation model can be used as a tool to monitor the occurrence of single events in small portions of a session, trends that arise in a given session, as well as trends that span a series of sessions stretching over one or more academic semesters. If data are collected over a substantial period of time, they could be used to track individuals' progress by the amount and type of their involvement in the meetings. Similarly, provided that a sufficient amount of data are collected, a demographic study can be carried out to show how participants of different ages, sex, ethnicity, disciplines, research experience, etc. benefit from their participation in the RCS. If a more complicated model is needed, additional layers can be incorporated into the model by noting more details or different aspects of the interactions taking place.

Assessment of Student Products

Recalling Simon's observation that all cognition takes place within the learner's mind even though most often within a social environment, no constructivist interpretation of learning can be complete without attending to individual cognitive development. The Research Communications Studio program seeks to address individual cognitive development as evidenced in communications, especially communications that involve writing, interpreted drawings, and other symbolic inscription, such as equations and formulae.

Rubric for Analyzing Students' Deliverables

Rubrics are widely used in education for scoring writing, both for mass placement and for grading in individual classes. With the advent of ABET 2000's emphasis on assessing outcomes, including communications skills, numerous engineering educators have seen the practical value of rubrics for evaluating writing produced by engineering undergraduates in their laboratory and lecture courses. Likewise, using a rubric to score RCS participants' written deliverables seemed a practical approach. However, there were numerous challenges in developing a rubric for deliverables that were unique in content and varied in genre, such as posters, slide show presentations, papers, and formal reports.

The rubric developed refers to three dimensions: *Organization; Words, Sentences, and Other Semantic Units;* and *Conventions.* The Organization dimension focuses on the writer's expertise in structuring a document to achieve a particular purpose through communication to an identified audience. Key elements examined in this dimension include a specific, informative title, a precise identification of the topic, a clear statement of purpose, adequate contextual information, and logical arrangement of sections. The second dimension, *Words, Sentences, and Other Semantic Units,* not only addresses word choice, but also organization at the sentence level, as indicators of fluency and clarity in conveying information. Coherence, sentence variety, parallel structure, transitions, captions, and bulleted items are included among the measures of competency in this dimension. The final dimension, *Conventions*, refers to standard conventions of writing, such as usage, grammar, punctuation, and spelling, plus a few conventions of technical writing, such as correct labeling and placement of graphics, equations, and formulae.

Each dimension is accompanied by a scale that describes student performances along a continuum from 1 (Not Yet [Proficient], 2 (Developing), 3 (Proficient), and 4 (Advanced). The approach in designating the different levels of performance attempts to reflect stages of development in learning to apply principles of communications that are often discussed in RCS sessions. To generate the rubric domains, faculty reviewed the six-trait writing rubric designed by Spandel[10] for the purpose of assessing students' written communications and the performance outcomes that Plumb and Scott [7] developed for the review of engineering writing.

Four graduate students with degrees in English were trained to serve as raters of the student products at the end of the 2002-2003 academic year. During training, raters reviewed the rubric developed by the RCS faculty. To guide raters' decision-making processes in scoring products, the lead evaluator introduced the concept of the Gordian wedge. In applying the Gordian wedge, raters ask a central question to decide initially whether a student product reflects a performance in the upper or lower half of responses before making a final judgment[12]. For the RCS evaluation at the end of the 2002-2003 academic year, raters were instructed to ask for each dimension, "Is this aspect of the student's response most similar to the rubric descriptors for the two highest ratings or the two lowest ratings?" After making the initial decision, raters were instructed to ask themselves, "Is this aspect of the student's response most similar to the descriptor for the high rating or the highest rating? Is this aspect of the student's response most similar to the lowest rating or the next to lowest rating?"

During scoring, the raters were split into two independent teams. Raters within a team initially scored the student products independently. They were instructed to review a response quickly, but thoroughly, and to refrain from re-examining a response. Raters were asked to use the rubric as their reference point, to record their initial, independent rating on a record form, and to write comments about the evidence that supported the rater's initial score for that dimension. Raters were asked to use the rubric to consider relevant types of evidence. After the raters in a team finished scoring a set of student products independently, they compared ratings. They resolved scores when ratings differed by more than 1 point (i.e., 1 & 4, 1 & 3, 2 & 4). In the resolution process, raters were asked to resolve discrepant scores based on a mutually respectful discussion[4,5] in which they:

1. reviewed the written response and the language of the relevant dimenson(s) in the scoring guide
2. shared the evidence supporting the initial ratings
3. considered evidence that challenges the original judgments by searching for counter examples
4. reached a final consensus on a performance level

Raters recorded their consensus score on the score recording form. They were instructed not to change their initial ratings because their independent, initial ratings were to be used to estimate interrater reliability for the scores.

Analysis of Student Communication Scores

Eight of the RCS students submitted written deliverables for 2002 and 2003. *Table 4* shows the average dimension score for the two time periods. Scores increased across all three dimensions. The scores for *Organization* and *Semantics* increased on average 0.6 of a point on the 4-point scale and increased for *Conventions* 0.5 of a point.

Table 4. Average Dimension and Total Scores for Student Communication Products. Note. The scores reflect those of the 8 students with communications products for the two time periods.

Year	Organization	Conventions	Semantics	Total
2002	2.0	2.2	2.0	2.1
2003	2.6	2.7	2.6	2.6

Caution in interpretation is required because of the low interrater reliability associated with the scoring. All student products were scored by at least two raters. However, as seen in *Table 5*, interrater reliability based on two raters ranges only from 0.51 to 0.56 for the three dimensions. Some authors indicate that research studies and low stakes assessments require a minimal reliability of 0.70, while in applied settings with high-stakes, tests require a minimal reliability of 0.90.[6, 9] Only with four raters do interrater reliability coefficients approach 0.70. Thus, change in scores over the two time periods due to student participation in RCS is confounded with change attributable to differences in the manner which raters' score.

Table 5. Interrater Reliability for Dimensions and Total Scores

Number of Raters	Organization	Conventions	Semantics	Total
1	0.37	0.39	0.34	0.42
2	0.54	0.56	0.51	0.59
3	0.63	0.66	0.61	0.68
4	0.70	0.72	0.67	0.74

The raters' means shown in *Table 6* reflect that part of the variability is due to rater differences. For the *Organization* dimension, raters' scores range from 2.1 to 2.6. For the *Conventions* dimension, the means for raters range from 2.4 to 2.6. Finally, the *Semantics* dimension shows the most variability with raters' means ranging from 2.1 to 2.7.

Table 6. Interrater Reliability for Dimensions and Total Scores

Dimensions	Rater 1	Rater 2	Rater 3	Rater 4	Total
Organization	2.6	2.6	2.3	2.1	2.4
Conventions	2.4	2.6	2.6	2.4	2.5
Semantics	2.6	2.4	2.7	2.1	2.4

Conclusion

The publication of *How People Learn*, along with the ABET 2000 criteria for outcomes-based assessment, has intensified engineering educators' search for evidence of connections between methods of instruction and desired outcomes. One outcome specified in the ABET a-k list, the ability to communicate, poses difficult questions for engineering faculty: how do students learn to communicate; how can we teach communications; how can we assess communications ability, etc.?

The development of educational research methods, such as those described in this paper, are fundamental for exploring these questions.

Modeling of peer, near-peer and faculty interactions in a small group environment graphically represents inquiry-based learning as it progresses. Starting with fairly basic measures such as frequency and type of interactions has potential to identify research areas worthy of further, deeper investigation. The work described in this paper supports that likelihood. Initial analysis of videotapes of student interactions in the studio groups revealed the following such areas:

- the studio environment encourages undergraduates to discuss their work on a peer level
- near-peer graduate mentors play a significant role, while receiving support from the faculty, in the guidance of these undergraduates
- the studio environment allows the undergraduates to interact openly, and sometimes leading discussions, as opposed to the classroom setting in which they typically only are able to ask questions.

Creation and continuing refinement of analytic rubrics is a critical step in identifying evidence of developing expertise in the writing of engineering undergraduates. Scoring undergraduate researchers' written work using a 4-scale, 3-dimension analytic rubric revealed that evidence of progress can be identified. Scores increased in all three dimensions: organization, conventions, and semantics. The scoring experience also revealed the variability among raters, as evidenced by a low interrater reliability associated with the scoring. Plans for addressing this issue include use of exemplar texts in training raters; exemplars were not available in the initial year of the project.

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