AC 2007-241: QUANTITATIVE AND QUALITATIVE MEASURES OF COMMUNITY DEVELOPMENT THROUGH A STRUCTURED WORKSHOP CURRICULUM

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Quantitative and Qualitative Measures of Community Development through a Structured Workshop Curriculum

Abstract-- This paper presents example quantitative and qualitative measures for evaluating a program aimed at developing an engineering education community of practice. Specifically, social network analysis is presented as a quantitative method. Assessment and research results are from the NSF-funded *Conducting Rigorous Research in Engineering Education: Cultivating a Community of Practice* project. The workshops are funded for three years (from 2004 to 2006), and the experience includes both a 5-day summer workshop and a year-long experience that allows participants to conduct a small education research project guided by a more experienced mentor. This paper reviews community of practice literature and evolution of the workshop design to promote a community of practice in engineering education, presents quantitative analysis of the evolution of the 2006 community, and provides assessment evidence that the community has been evolving as a valued outcome of the program since 2004. Implications are drawn and specific assessment methods presented for those interested in building engineering education research capacity.

1. Introduction

For the past three years, the National Science Foundation has funded "Rigorous Research in Engineering Education: Creating a Community of Practice" (DUE-0341127) to respond to recent calls for embracing more rigorous research in engineering education[1-5]. The goals of this project are to:

- Create and present workshops for engineering faculty on conducting rigorous research in engineering education. Five-day workshops are held in Golden, Colorado each summer from 2004 through 2006 to train faculty participants. For more details see the project website[6] and prior publications describing the project[3, 7-10].
- Sustain the development of this project through establishing a community of practice. The foundation for this aspect of the project is the work of Wenger and his colleagues[11, 12].

The program uses Wenger, McDermott and Snyder's model of a community of practice (CoP)[12]. A previous publication[3] describes how the RREE workshops were initially structured and updated to create a community of practice. Other similar programs are aimed at developing communities of practice in engineering and computer science education[13, 14]. A potential weakness of the community of practice literature is that it does not suggest quantitative methods for evaluating the impact of community-building efforts. This paper focuses on (1) summarizing assessment results from 2004-2006 relevant to community development, (2) quantifying and analyzing the emergent social network between 2006 participants, and (3) implications of this work for others interested in evaluating engineering education research capacity efforts.

2. The Community of Practice Model applied to Engineering Education

Wenger et al. define a Community of Practice (CoP) as a unique combination of three fundamental elements: a *domain* of knowledge which is defined by a set of issues; a

community of people who care about this domain; and the shared *practice* that they are developing to be effective in their domain[12]. Table 1 summarizes how the RREE workshop was structured based on the CoP model.

Table 1. Structure of the RREE Workshops integrating Community of Practice Literature. Reference[3] provides additional detail.

Community of Practice Recommendation from Wenger et al.[12]	**Corresponding RREE Workshop Feature**
"old-timers" welcome and mentor the "newcomers"	• "old-timers" from ASEE, AERA and POD as workshop facilitators • funding provided to attendees as honorarium for mentors from ASEE, AERA, or POD
members of community have a variety of informal spaces to meet in ad hoc pairs or small groups for further discussion	• workshop location allows for small group exercise and reflection (hotel next to a stream and bike/walking path) • time scheduled in the middle of the day for assimilation/reflection and unstructured discussion • reception to kick off the event on first evening • daily common meals (breakfast, lunch and dinner) • workshop room was set up with round tables, for (changing) discussion groups • workshop features interactive sessions (e.g., active and cooperative learning)

In June 2005, the executive committee and facilitators met to discuss changes to the 2005 workshop program based on the experience and assessment results of the 2004 cohort. The discussion at this meeting was wide-ranging and produced several changes in the 2005 workshop format. Among these changes were:

1. Allowing participants to group themselves into "intellectual neighborhoods" by self-selecting other participants with similar or complementary interests.
2. Participant-created posters used both as performance outcomes, and as a venue for sharing ideas and obtaining feedback from fellow participants and workshop facilitators[14]. (This included formal presentations to small groups at the end of the workshop.)
3. Structuring a research methods session around participant groups with similar research interests (e.g., qualitative studies, experimental intervention studies, and correlational studies).

The 2005 and 2006 workshops were structured around helping participants to develop a plan to research a question of personal interest with plenty of feedback from facilitators and fellow participants. The principal place to record evolving ideas and present them to others was a participant poster displayed throughout the week. An example of a final poster is presented in Figure 1.

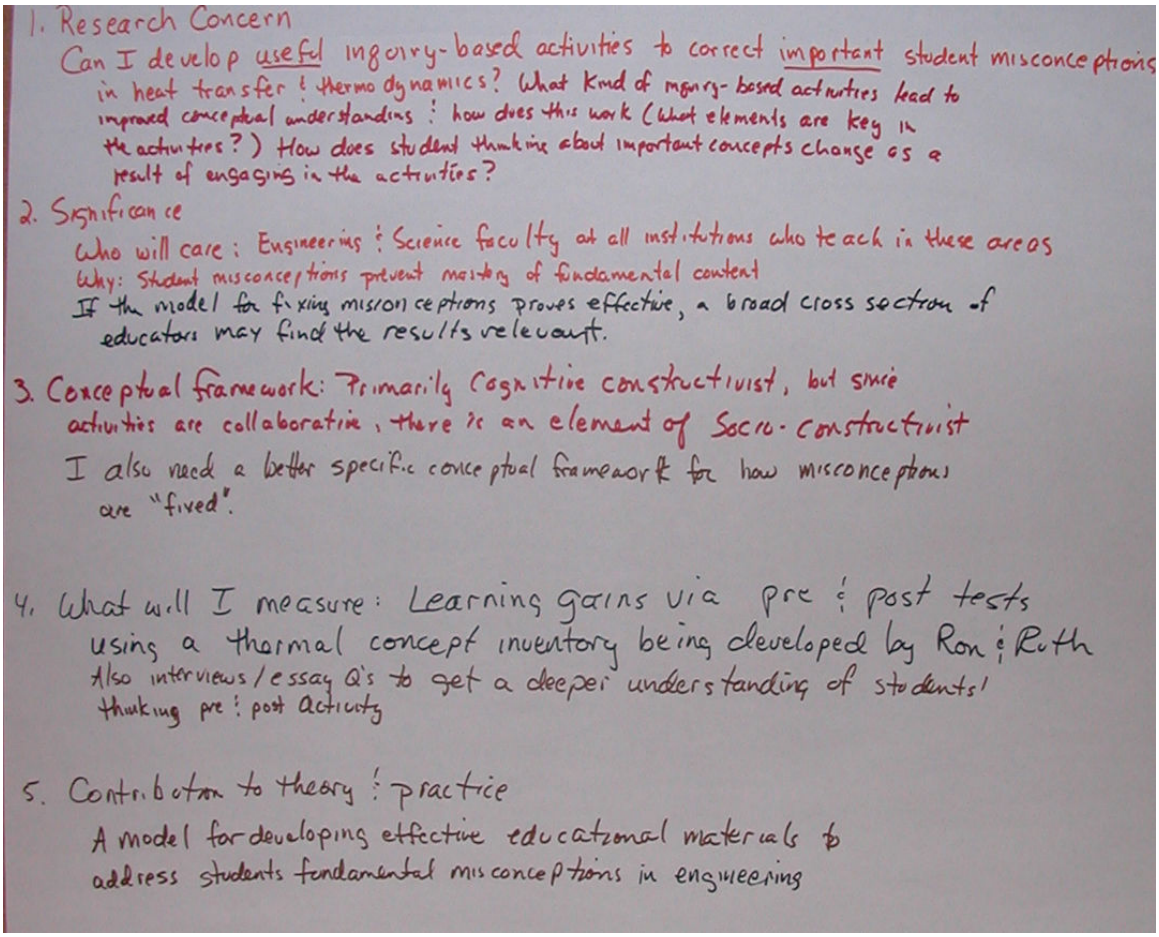

Figure 1. Example of Participant Poster.

At the end of day one, participants started their posters by attaching a sheet of paper to the wall with their name and "research concern," or nascent research question. Participants then walked around the room reading all of the other posters and leaving a sticky note with their own name if they thought the author was a potential intellectual neighbor. By the end of this session, nearly all participants had established intellectual neighborhoods with multiple other participants. Many were even slow in moving to dinner that evening because of the lively conversations. The next morning, as instructed, participants sat with their identified neighbors. The structure for the remaining activities followed the general pattern of presenting content using cognitive apprenticeship, giving participants time to reflect or discuss, and asking participants to apply the knowledge to their own projects and add it to their posters. In this manner, posters were built up over the course of the week to include all sections shown in Figure 1. The session on research methods toward the end of the week consisted of a brief presentation followed by facilitator-led consulting sessions in which participants were grouped based on interests and research designs: qualitative methods, experimental intervention, correlational studies, and miscellaneous. The final formal activity of the workshop was for participants to present their posters to their intellectual neighbors.

3. Social Network Analysis to Quantitatively Study Community Development

While participants in an engineering education program often have good things to say about their opportunities to network, sometimes more quantitative, objective measures are helpful in evaluation. Social network analysis is particularly useful for this purpose. Social network analysis is a method in social and behavioral science that focuses on *relationships*. Network models help to conceptualize the structure of a system, including interdependent relationships between the actors (e.g., workshop participants) and their actions. Ties within the network are channels for the flow of resources, while the network structure itself imposes constraints on individual action. Examples of the wide range of systems that have been studied using network analysis include: the world political and economic system, group problem solving, diffusion of innovations, markets, and the sociology of science[15]. Previous applications in engineering education include evaluating a computer science faculty workshop program[13] and quantifying K-12 outreach relationships between universities and schools[16].

Before actual measures of network growth can be discussed, the concept of strong and weak ties must be defined. Within a network or community, there are variations in the strength of the connections between different members. For engineering education, here are some example ties, listed in order of increasing strength:

1. heard of a person and/or her work
2. met that person once
3. talk with that person semi-regularly, regularly or frequently
4. cite the other person's scholarly work
5. collaborate with the person on proposal(s) or conference paper(s)
6. coauthor a journal article with this person

To run a social network analysis, the researcher must decide which level is most appropriate to the study. For example, Fincher and Tenenberg defined strong ties as coauthor ties for evaluating a workshop built around a collaborative research project[13]. This illustrates the importance of selecting the appropriate level of analysis to evaluate the goals of the program. In the case of Rigorous Research in Engineering Education community of practice, there are multiple levels to study. These are listed in Table 2.

Table 2. Definition of weak, intermediate, and strong ties for the RREE community.

Type of Tie	Definition within RREE Workshop	Pre-Workshop Measure	Post-Workshop Measure
Weak	Met this person once	Roster survey	Evaluation survey question
Intermediate	Worked together in the same "intellectual neighborhood"	Roster survey	Observation of neighborhoods
Strong	Collaborated on a research idea (poster)	Roster survey	Observation of posters

Network data can be collected through a variety of methods. Perhaps the most common is a survey, in which participants can name others in an open response, or rate a list (roster) of participants. Observation and document analysis methods can also be employed, for

example in coauthorship studies. In the case of the RREE workshop, an initial roster study was used in conjunction with observations of participant working groups and a self-report estimate of the number of connections made by participants on the last day of the workshop.

Once the data are collected, the network can be visually represented as a sociogram and quantitatively and statistically analyzed. There are multiple ways to quantify the quality of the network. The simplest is density, or the number of actual ties divided by the total number of possible ties. Most networking engineering education programs seek to increase the density of social networks. However, researchers might also want to understand other qualities of the network, whether some participants are more isolated than others, and whether new links are being formed. Sophisticated statistical procedures have been developed to run quantitative analyses on networks.

The types of research questions that can be answered using social network analysis are:

- How many new (strong, weak or intermediate) relationships can be attributed to the community-building intervention [RREE workshop]?
- Did workshop participants work with people they knew before the workshop, or did they form new working relationships?
- How lasting are these new relationships?
- What is the optimum density of strong ties between engineering education community members?

To comment on the final question, allowing communities of practice to develop on their own is one of the tenets of Communities of Practice. Though there are environmental characteristics that can be engineered to foster developing communities (see Table 1), the community itself cannot be forced. Allowing participants to self-select their working groups and evolve to form the appropriate groups was an important component of the RREE workshop. The optimum density of ties will be discussed further in the results section below.

4. Data Gathering and Analysis Methods

All aspects of the study were approved through human subjects (IRB) review, and participants signed informed consent forms as the first activity of the workshop. Data sources include:

1. A roster survey as the first activity of the workshop in which participants identified existing relationships with each other (Figure 2).
2. Observational and interview field notes from the formal and unstructured work sessions of the workshops.
3. Participant workshop evaluations.
4. Photographs of the evolution of each participant poster prepared to make public the evolving research design process (2005 and 2006).

Participants in the 2004 cohort completed all forms anonymously. To ensure anonymity, each 2005 and each 2006 participant was assigned a randomly-generated ID number that is the only identifier on the evaluation forms and photos of posters. Only the external evaluators have access to the list matching identities with ID numbers.

ID Number (from the back of your badge):

Social Network Survey

For each of the workshop participants listed below, indicate your level of interaction with each **prior to the workshop or workshop-related interactions**.

	We talk monthly or more often	We talk a few times a year	We talk once a year	I have met this person once	I have only heard of this person	I do not know this person	This is me
Maura Borrego, Virginia Tech							
Ron Miller, Colorado School of Mines							
Lynette Osborne, National Academy of Engineering							
Karl Smith, University of Minnesota and Purdue University							
Ruth Streveler, Purdue University							

Figure 2. Top Section of the Social Network Roster Survey given to 2006 RREE participants. Authors' names and institutions are given as examples.

5. Results: Participant Responses

On the workshop evaluations, there were three questions that might offer insight into participants' perceptions of the community-building activities. The first is an open-response question: "What did you like best about the workshop?" Table 3 summarizes the responses. Each year, a substantial portion of the participants mentioned the interaction, networking or community-building activities.

Table 3. Participant Responses to "What did you like best about the workshop?"

Cohort	Responses about community	Representative Comments
2004 (n = 38)	66%	• "The opportunity to learn about a concept & then discuss its impacts with peers." • "The size of the workshop (the number of participants) was not too large so I was able to meet and get to know many people; also the presenter:student ratio was good." • "The opportunity to exchange ideas."
2005 (n = 44)	77%	• "Being surrounded by so much expertise and perspective and having time to reflect" • "Meeting other people who share the same interests." • "Interacting with others and meeting people with similar interests"
2006 (n = 49)	45%	• "relaxed and fun without cheesy stuff; freedom to have a lot of time to self with neighbors" • "Great opportunity to meet intellectual neighbors; helpful introduction and resources related to educational research" • "Realization that my thoughts, understandings about the subject were held by

		other attendees"

The other two questions which describe participant satisfaction with community-building activities were Likert-scale ratings of interaction with fellow participants and facilitators, summarized in Table 4. Though the ratings are high, there is overlap in the error ranges that indicates the ratings were similar from year to year. Significant changes were made from 2004 to 2005 that might be expected to be reflected in these results.

Table 4. Responses to workshop evaluation questions dealing with community.

How would you rate the quality of the following: [5-point Likert scale: 5 = excellent]	Opportunities to interact with other participants	Opportunities to get feedback from experts/facilitators
2004 (n = 39)	4.69 ± 0.57	4.26 ± 0.82
2005 (n = 43)	4.86 ± 0.41	4.35 ± 0.65
2006 (n = 55)	4.67 ± 0.55	3.91 ± 0.93

While participant responses provide some insight into community-building and networking initiatives, the quantitative, objective data are limited. Self-report data are inherently biased and ineffective in convincing skeptics of the value of a particular program. A key component to illustrating the effectiveness of a program, particularly an engineering program, is quantitative results of the type that social network analysis can provide.

6. Quantitative Results: Social Network Analysis

In order to quantitatively address the research questions, we are using Social Network Analysis to show ties (relationships) between participants prior to and during the workshop. As such, appropriate measures relate to the density and strength of the networks. The density of a network is simply a ratio of actual ties to the total number of possible ties. For example, we would not predict (not desire) 100% strong ties within an engineering education or other type of network because this may be associated with a static network where people are active within the network but do not experience an infusion of novel ideas from different perspectives.

6.1 Weak Ties: Who has met Whom

On the pre-workshop roster survey, participants identified 183 ties between pairs that met each other at least once. In order to determine whether or not participants grouped themselves primarily with persons who they already knew or with new colleagues, participants were asked as part of the workshop evaluation form:

> "Of the 67 workshop participants, how many have you met (or already knew) by the end of the workshop?"

From the 53 participants who completed the question, 1441 relationships were indicated. Subtracting the 183 existing ties from this number yields 1258 new ties. In order to identify the density of the new relationships, we can divide the sum of ties (1258) by the number of possible ties (3127) and get a density of 0.40. The density of the post-conference network (all 1441 existing and new ties) is 0.46.

The sociogram for participants who met each other at least once prior to the workshop is very dense and conveys little information. In contrast, Figure 3 depicts a "strength of ties" relationship between workshop participants who interact at least once a year. This network depicts 64 ties. From this diagram, readers can see that some participants were relatively unconnected to any others coming into the workshop, while others had working relationships with as many as 6 other participants.

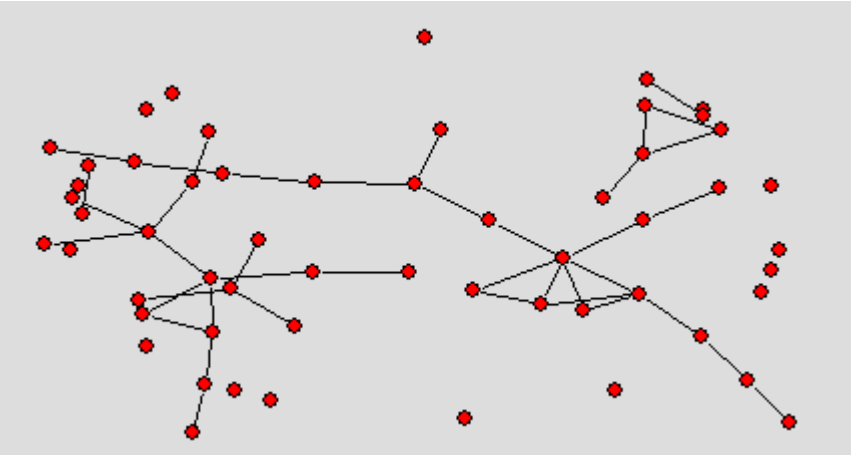

Figure 3. Sociogram of network prior to workshop. Ties illustrated are between participants who talk once a year of more often.

6.2 Intermediate Ties: Intellectual Neighborhoods

In order to measure Intermediate Ties, three measures over time are available. First, the sticky notes that participants left on others' to indicate interest produces a very dense sociogram which serves to indicate interest in another person but is not an indication of a strong relationship. Second, the first iteration of neighborhoods, can be illustrated as large clumps of people; not as dense as the "sticky note" sociogram, rather more defined and separated with no links between neighborhoods. Third, the second iteration of neighborhoods serves as a better indicator of intermediate ties as these groups are smaller and ended up as more cohesive work groups for the rest of the workshop.

To estimate the density of the intellectual neighborhoods network, we can use participants' responses to another evaluation question:

> "How many [participants] did you work with closely as an intellectual neighborhood?"

Participants identified 326 relationships. The density was calculated as 0.10 for 326 relationships identified by 54 participants (with 60 possible participants as options for relationships).

A preliminary look at the quantitative and qualitative data show that people tended to work in neighborhoods mixed with people they knew prior as well as new colleagues they met during the workshop. This situation, theoretically, seems like a more productive model. For example, when networks or groups have ties only to other people within their

network or group, conversation and innovation may grow static as there is little influx of novel ideas from outside sources with different experiences. Especially within a community such as engineering education faculty, working within sub groups yet drawing from a larger network seems to be a more logical approach than working solely within one network.

6.3 Strong Ties: Research Collaborations evidenced by Posters

For the purposes of this research, Strong Ties are defined as collaboration on a research project, and the evidence is coauthorship of a poster on the last day of the workshop. Some teams were built-in to the workshop structure. One source of funding for participants was as part of an institutional team from an HBCU or HSI institution[17]. Three-person teams were selected by the institution's dean of engineering, in many cases as a combination of two engineering faculty and an education or other social science faculty member. Most of these teams worked together all week to develop a study of engineering students at their home institution. The other types of teams built into the workshop structure in 2006 were leadership teams. These attendees had two goals for the workshop: to design a rigorous research study and to develop a dissemination activity at their home institution for the workshop content (rigorous research methods). To varying degrees, these team members worked together or entirely separate for the research design activities of the workshop.

By the end of the week, there were eight multiauthor posters. Six of these groups did not change membership at all during the course of the week; two were leadership teams and the rest were KBCU or HIS institutional teams. One group of individuals who developed as a team during the workshop changed members within the first two days (gaining four and losing one). The third group was an HBCU institutional team which worked together all week and had designed a multi-institution study with other participants by the last day. This larger project was summarized on a combined poster.

7. One Year Later: Is the Community of Practice Sustained?

Once a networked community is established, an important next question is whether it is sustained over time. This necessarily requires waiting until longitudinal data can be collected. However, there are some results from the earlier 2004 and 2005 cohorts that suggest the RREE community is being sustained.

Table 5 summarizes the responses to quantitative questions on the follow-up e-survey completed one year after the workshop by the 2004 and 2005 cohorts. In both cases, participants continued to engage in a variety of engineering education activities. Most relevant to the current discussion of networks and communities of practice are responses to questions about intellectual neighbors and collaboration. More than two-thirds (69%) of 2005 participants stayed in touch with their intellectual neighbors in the year following their workshop, and 31% collaborated with someone they had met or contacted as a result of the workshop.

Table 5.

Engagement in Professional Activities Following the RREE Workshop (2004 N = 19; 2005 N = 26)	2004 Yes	2005 Yes
Discussed teaching with colleagues	100%	96%
Discussed any kind of research with colleagues	90%	100%
Discussed engineering research with colleagues	N/A	100%
Attended a conference including engineering education research	59%	88%
Presented engineering education research at a conference	37%	65%
Prepared or submitted an engineering education article for journal publication	11%	31%
Prepared or submitted a proposal to fund engineering education research	68%	73%
Been awarded new external funding to conduct engineering education research	10%	23%
Discussed engineering education projects with intellectual neighbors from the workshop	N/A	69%
Collaborated with someone you met or contacted as a result of the workshop	N/A	31%

Responses to two of the open-ended questions on the same survey provide additional insight. One item asked participants to name those things that facilitated their project work. 50% of 2005 cohort respondents (13/26) and 37% of 2004 respondents (7/19) indicated the help of local mentors or collaborators. In a separate question, they were asked what the RREE team can do to facilitate project work. In 2005, the most popular response (13/26) was various ideas for networking: electronic, meeting at conferences, discussion/critique circles. In 2004, only one respondent mentioned networking, which might be expected since neighborhoods were not introduced until 2005. These responses are particularly supportive of the community-based workshop format, since they addressed open-ended questions about research project work in general.

At the end of the 2006 workshop, participants were asked to estimate how many other participants they "expect to contact regularly about engineering education." Participants estimated 319 ties to be lasting, which yields a density of 0.10 when divided by the possible ties (3068). This can be compared (indirectly, since the calculations are different) to 69% of 2005 participants who actually did stay in touch with intellectual neighbors after the workshop.

9. Implications

We end with some implications for those interested in applying social network analysis to evaluating efforts to build engineering education communities.

- Communities of Practice literature recommends a variety of environmental characteristics which can foster community and network development.
- Social network analysis provides a more objective, quantitative complement to participant evaluations which can support changes to program structures.
- A number of creative methods for collecting and triangulating network data exist: surveys, observation, and archival data from publications.
- Sociograms are a powerful tool for visualizing network densities and distributions.

- Potential collaborators with expertise in these methods reside in computer science, sociology, public policy and many other departments on university campuses.

Acknowledgements

We wish to thank the National Science Foundation for supporting this work through grant number DUE- 0341127, which funds "Conducting Rigorous Research in Engineering Education (RREE): Creating a Community of Practice." Dr. Devon Hensel was particularly helpful in discussing network data analysis. We also thank Dr. Norman Fortenberry, Director of the National Academy of Engineering's Center for the Advancement of Scholarship in Engineering Education, for his partnership in this project. The authors also thank the RREE Executive Committee members who participated in the revisions of the 2005 RREE: Robin Adams, George B. Forsythe, Frank Huband, Marcia Mentkowksi, and Marilla Svinicki.

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