A New Paradigm for a New Field: Communicating Representations of Engineering Education Research

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ABSTRACT

Based on a three-year experience of developing, facilitating, and assessing NSF-funded workshops on Rigorous Research in Engineering Education (RREE), the authors present four representations of engineering education scholarly work in the United States, specifically teaching and research. Many of the representations describe the relationships between engineering research, education research, teaching, and assessment. For each of the representations, assessment data are presented to evaluate which aspects resonated with workshop participants and which needed to be changed for wide acceptance by a U.S. engineering education audience. It was found that participants preferred continua to dichotomy and were more receptive to models that were introduced inductively through active learning exercises. Lessons learned, implications for the field, and future plans for further development of the paradigm are also included.

Keywords: education reform, engineering education research, new paradigm

I. INTRODUCTION

A. Motivation and Theoretical Grounding

These are exciting times to be involved in the engineering education community. While educational practice may not be changing as rapidly as we might like, engineering faculty and engineering education researchers are engaged in heated discussions regarding the purposes, methods, and important questions for engineering education research. While the content and participants of the debate vary across countries and regions, we present one version based on conditions in the United States.

An earlier publication by Borrego (2007a) contends that one can describe this early phase in the development of U.S. engineering education research as being *pre-paradigmatic*. In the terms used by Thomas Kuhn in his seminal book, *The Structure of Scientific Revolutions* (1970), a paradigm is defined by consensus about such vital issues as standards of rigor in research, including important questions, accepted methods, and forms of convincing evidence (Guba, 1970). Similarly, Burrell and Morgan (1979) define a paradigm as a "commonality of perspective which binds the work of a group of theorists together". Current and recent debate (Gabriele, 2005) suggests that the guiding philosophies or paradigms that will later guide engineering education research appear to be still in formation.

Paradigms change slowly. Kuhn explains, "rather than a single group conversion…what occurs is an increasing shift in the distribution of professional allegiances" as subscribers of the new paradigm "improve it, explore its possibilities, and show what it would be like to belong to the community guided by it" (1962). Masterman extended Kuhn's theory of scientific paradigms, explaining that social sciences are characterized by multiple paradigms competing for dominance (1970). Whether engineering education is developing its first paradigm, changing paradigms, or experiencing the struggle of competing paradigms, discussions to develop shared agreement about core issues are critical to the field's advancement.

In this paper, we argue that recent engineering education debate in the United States can be traced to transitioning from an historical paradigm, which we call the *reform paradigm,* to a *research paradigm.* While the reform paradigm stressed curricular change and improved pedagogy, the research paradigm emphasizes systematic investigations, rigorous methods, and convincing evidence. As is necessary in any Kuhnian paradigm shift, the initial research paradigm rhetoric highlighted the perceived shortcomings of the reform paradigm, perhaps most notably in Gary Gabriele's July 2005 *Journal of Engineering Education* (JEE) guest editorial (Gabriele, 2005):

> To encourage and support such efforts, the Engineering Education and Centers Division at the National Science Foundation has moved its engineering education programs from a focus on reform to an emphasis on research. Many years of reform efforts have not produced the breakthroughs we will need to find room for the new technologies and skills that are now being called for. We want to understand how students learn engineering. It is our hope that by supporting fundamental research, we can better understand how to

> create a more innovative, efficient, and enticing engineering curriculum that can attract a more talented, innovative, and diverse student body. We seek disruptive breakthroughs in moving engineering education out of its current mold and into new modes of thinking about engineering education. In a departure from past efforts, we are looking to transform, not reform engineering education.

Gabriele wrote this while at the U.S. NSF, which highlights another aspect of paradigm shifts—new paradigms are often developed and advocated by those who are new to a field, therefore not as invested in the current paradigm, and thus better able to see the field in a slightly different light (Kuhn, 1970). While Gabriele had substantial experience in engineering education to earn this position, he was not as directly involved in reform activities of the past. Similarly, Kuhn proposed that paradigms change when the old paradigm no longer explains phenomena, which in turn causes a "crisis" to occur (1970). The "crisis" in U.S. engineering education might have been the perceived lack of progress in changing engineering education practices as a "failure" of the well-funded reform paradigm (Borrego, 2007a; Gabriele, 2005).

At the height of these calls for rigorous research, Streveler, Smith, and Miller initiated an NSF-funded program to develop a community of practice around engineering education research (2005), called Rigorous Research in Engineering Education (RREE). Realizing (if not articulating) that followers of the new research paradigm would come from a reform paradigm, the team developed a series of representations encompassing both where participants were coming from and where they would be going as they participated in the research-focused workshop program. The conscious decision was made to incorporate a broader scope than rigorous research to recognize and value the contributions of both research (knowledge building) and reform (professional development, scholarly teaching) activities.

If the U.S. engineering education research community is indeed in the process of developing an accepted paradigm, then tracking the reaction to various representations of engineering education research is a useful exercise since it provides a window into the formation of the field. We are attempting to describe, and to some extent influence, the paradigm at a time when it is still developing. This is no small task. Specifically, the purpose of this paper is to describe a variety of representations of engineering education research—particularly with respect to its relationship to engineering education practice—which were used in the Rigorous Research in Engineering Education (RREE) project and to describe the reaction of the participants to those representations. Our assumption is that the reaction of the participants to the various representations will be one way of gauging the changing paradigm in the U.S. engineering education research community and ultimately arming us with strategies for further development, including expansion to a more globally inclusive dialog. Ultimately, this analysis may provide us with an understanding of which activities are most effective at advancing engineering education's goals through paradigm development. However, the fact that the paradigm is still actively changing may make this a particularly difficult piece of writing for readers to navigate (as it was to write).

Research questions addressed in this paper are:

1. Which aspects of the four representations, including the way in which they were presented, contributed to (a) acceptance and (b) rejection of the representations by the audience?
2. What general recommendations can be made for activities and representations designed to further develop the engineering education research paradigm?

We have carefully selected the term "representations" to refer to conceptualizations of key issues, topics, arguments, and relationships between engineering education ideas such as teaching, research, and assessment. The setting used to investigate these questions is the Rigorous Research in Engineering Education project. This participant population has self-selected to learn more about engineering education research through the program's workshops, at which participants commented on evolving representations of the engineering education research paradigm. The group is representative of U.S. engineering faculty with interest in engineering education research while having participated in a unique paradigm-building experience. Thus, they are an appropriate population for this initial study of the developing paradigm, at least in the United States. While this section presented the underlying theory of paradigm development, the remaining sections of this paper describe the setting and research methods used to collect reactions from participants, then review each representation in turn and present the relevant reactions for each. The final sections relate the findings to a broader context and summarize suggestions for next steps of engineering education research paradigm development.

II. Methods

A. Background and Setting

Consistent with good practice in qualitative research, this detailed description of the setting is given to aid readers in judging whether the findings transfer to other specific settings (Patton, 2002; Yin, 1984). The setting for this study was the Conducting Rigorous Research in Engineering Education: Creating a Community of Practice project, originally funded by NSF from 2004–2006. The one-year research experience for participants in each cohort began with a five-day workshop offered in Golden, Colorado, by facilitators from three professional societies: The American Society for Engineering Education (ASEE), the American Educational Research Association (AERA) Division I, and Professional and Organizational Development Network in Higher Education (POD). The first offering of this workshop was in August 2004 and the data for this study were collected at the August 2005 and 2006 sessions, reflecting updates to the presentation of topics based on the 2004 assessment data. Other publications describe the project and initial assessment in further detail (Borrego et al., 2006; Streveler, Smith, and Miller, 2005). In short, the workshops lasted five days. For the latter four days, participants learned the content of educational research methods. Day one was a framing day to get participants into a research mindset. It was during this first day that the representations described in this paper were presented.

The most substantial change in workshop content from 2004 to 2005 was the addition of new representations of engineering education research in relation to teaching. Table 1 lists the representations that were presented on the first day of the workshop each year. In considering 2004 assessment data at the 2005 planning meeting, it was clear to many of the facilitators that additional comparisons were needed to help participants focus on research rather than teaching and to specifically write research questions with broad scope (Borrego et al., 2006; Streveler, Smith, and Miller, 2005;

2004 Workshop	2005 Workshop	2006 Workshop
Engineering Research vs. Education Research (Section III.A)	Engineering Research vs. Education Research (Section III.A)	Engineering Research vs. Education Research (Section III.A)
	Levels of Inquiry (Scholarly Teaching, Scholarship of Teaching and Learning, and Rigorous Research) (Section III.C)	Comparative Organizer of Informal and Formal Research (in Engineering Education) (Section III.C)
	Research Questions and Assessment Questions (Section III.B)	Research Questions and Assessment Questions (Section III.B)

Table 1. Representations of engineering education research presented at each Rigorous Research in Engineering Education workshop in the order they were presented. The results sections of this paper in which each entry is described are listed in parentheses.

Streveler and Smith, 2006). This change was not identified by 2004 participants as a shortcoming of their workshop; rather, the facilitators with considerable experience in faculty development and educational research agreed that these important shifts in thinking needed to be emphasized on day one for quality learning to take place later in the week.

Other publications describe the discussion and conclusions from the 2005 planning meeting in greater detail (Borrego et al., 2006). Essentially, facilitators noted that workshop participants in 2004 were most interested in assessing a teaching method they were already using to prove that this method "worked" (Streveler, Smith, and Miller, 2005; Streveler and Smith, 2006). These participants needed to learn to reframe their questions for broader appeal. This is a similar finding to that described by David Labaree for training education doctoral students who often have significant teaching experience in his "The Peculiar Problems of Preparing Educational Researchers" (2003). Specifically, Labaree explains that since teachers have a moral responsibility to do what is best for students, they may see research as ignoring implications for practice when too much emphasis is placed on fully understanding the problem rather than solving it. The conflicting worldviews of teachers and researchers can prompt teachers to challenge the research perspective when they feel that their own teacher perspective is being invalidated (2003).

B. Study Participants

Participants of the 2005 and 2006 Rigorous Research in Engineering Education workshops served as study participants in the sense that their reactions to each of the representations were used to develop future iterations of the representations. Participants were funded through one of two separate grants with different selection criteria and different mechanisms for ongoing support. *Individual* participants[1] completed an application (Streveler, Smith, and Miller, 2005), and the workshop kicked off a year-long research experience for which these participants could earn a mini-grant by refining their workshop product and submitting it as a brief proposal. *Institutional team member* participants[2] were members of a three-person institutional team selected by the HBCU or HSI institution's dean of engineering. It was recommended that one member of the institutional team be an education or other social science faculty member to promote multidisciplinary approaches to research design. The year-long experience for institutional teams included this workshop and two other meetings (Watson and Fortenberry, 2006). In 2006, a supplement to the original grant covered travel for leadership teams, including some returning attendees from 2005, who participated fully in the workshop activities with the additional assignment of developing a dissemination activity on their home campuses.

The combined group of attending participants in 2005 was composed of 47 total participants, broken down as 19 selected as individuals, 28 as engineer-institutional team members, and five as social scientist-institutional team members. The group represented 36 different U.S. institutions which offer engineering undergraduate degrees. The breakdown was as follows: 25 percent of participants from doctoral extensive institutions, 21 percent from doctoral intensive institutions, 47 percent from master's institutions, and 6 percent from others (based on year 2000 Carnegie classifications). In 2006, the composition was similar: 56 participants broken down as 23 individuals, 17 engineer-institutional team members, three social scientist-institutional team members, and 13 leadership team members (five teams; three members returning from 2005). Carnegie classifications for the 2006 cohort were: 40 percent of participants from doctoral extensive institutions (~double 2005), 18 percent from doctoral intensive institutions (same), 25 percent from master's institutions (~half of 2005), and 16 percent from others (based on year 2000 Carnegie classifications).

C. Data Collection

All aspects of data collection were approved through human subjects (IRB) review, and participants signed informed consent forms as the first activity of the workshop. To ensure anonymity, each participant was assigned a randomly-generated ID number that is the only identifier in the archived data. Only the external evaluators have access to the list matching identities with ID

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[2]Funded by Strengthening HBCU Engineering Education Research Capacity (NSF HRD-0411994)

numbers. Data sources included:

1. Workshop handouts and presentation slides.
2. Observational field notes from the formal and unstructured work sessions of the workshop.
3. Participant pre-tests and post-tests dealing with workshop content.
4. Workshop journals of 17 engineering participants who volunteered to participate in this portion of the research. (All participants were asked.)

Observation data collection procedures are described elsewhere (Borrego, 2007b) in greater detail. At the end of the workshop, digital photographs were taken of each page of volunteered participant journals. In 2005, nine journals were collected: six from men and three from women, including two from institutional team members. In 2006, eight journals were collected: two from men and six from women, including one institutional team member and three returning leadership team members.

D. Data Analysis Methods

The two key data sources in understanding participants' understanding and acceptance of the various representations were observation field notes and participant journals. Observational data were used to develop the initial codes, categories, and working hypotheses. The systematic open coding procedure performed on the observation field notes is described in detail in a prior publication (Borrego, 2007b). In brief, a simple set of codes was established and applied to categorize passages in the data. An open coding approach was used, in which codes were developed based on the concepts emphasized by participants through their comments and questions. The terminology employed by the facilitators was used, since the workshop involved many new terms for the participants. Once this initial framework was developed, it was refined and expanded using data from participant journals and surveys (Strauss and Corbin, 1998). As a final check, five workshop facilitators, both engineers and educational researchers, reviewed the findings, and many served as coauthors in thoroughly refining the interpretation. It is this rigor in analyzing data that distinguishes qualitative research from anecdotal information (Tonso, 1996).

Observation notes rather than journals were used to develop the initial framework for a number of reasons. First, the journals represent a subset of participants' experiences. Second, participants used the journals in different ways: to take notes on workshop content, to respond to brainstorming activities, to record references or names, or to reflect when prompted or unprompted. In some cases, it is unclear whether a passage refers to initial thoughts by a participant or conclusions generated by the group or facilitator. An important exception was a journal prompt assigned at the end of the first day of the workshop to write important insights and muddiest points for each representation presented that day:

Process "paradigm day"

Regarding EACH of the three topics we've discussed today

- Engineering vs. Ed[ucation] research;
- ST - SoTL - RREE; informal vs. formal research (On the 2005 version of the slide, the words "informal vs. formal research" were not included. Otherwise the slide was identical to 2006.)
- Assessment vs. Research;

Write in your journal

1. what was the most important thing you learned today about this topic
2. what was the most unclear or the muddiest point about this topic

"ST-SoTL-RREE" (scholarly teaching, scholarship of teaching and learning, rigorous research in engineering education) is the notation used within the workshop for Levels of Inquiry. Each journal collected responded to this prompt, and this was an important data source. Participant responses to these six prompts (two for each of three representations) were analyzed as a complete data set (as opposed to each representation separately) for three reasons. First, two participants wrote only one "most important thing learned" and one "muddiest point" to cover all three representations. Second, various other participants discussed concepts presented in one session when describing their learning within other sessions. Third, several important common themes were mentioned for different sessions by different participants. Thus, the data were recoded to correspond to the session in which the material was actually presented, and the relevant comments are presented in each of the representation sections below.

III. The Representations and Assessment Results

A. Engineering Research vs. Education Research (2004, 2005, 2006)

1) Description and Initial Reactions: For a workshop aimed at engineering faculty, comparing engineering research to education research is an obvious starting point to bridge where most participants are coming from with where they are going. In fact, the title slide for this session actually depicted a bridge. The purpose of this session was to point out to participants that despite some obvious surface differences, education research and engineering research share some basic characteristics.

In this session, two main active learning exercises helped participants develop understanding of these concepts. First, participants worked alone and then in groups to generate a list of the rigorous research criteria for their respective engineering disciplines. Groups reported back to the facilitator, who recorded a master list on a flip chart until no new items were volunteered. Then, the facilitator presented the six guiding principles for scientific inquiry, referred to hereafter as the "NRC 6" from the 2002 National Research Council (NRC) report *Scientific Research in Education* (Shavelson and Towne, 2002). Table 2 presents the lists generated by 2005 and 2006 RREE participants alongside the NRC 6. It should be noted that many of the NRC 6 were anticipated by the participants. As is the case in the NRC publication, the facilitator worked to convince participants that the NRC 6 apply to both engineering and education research.

In between the two active learning activities, the facilitator discussed each of the NRC 6 in detail and provided an analogy to help participants understand links between theory and practice. This diagram is presented in Figure 1.

The second active learning exercise asked participants to discuss and fill in a chart comparing various aspects of engineering research to education research. The chart is included in Table 3. Given limited time, the aim of this brief exercise was to spark

Characteristics of Rigorous Engineering Research generated by 2005 RREE participants	Characteristics of Rigorous Engineering Research generated by 2006 RREE participants	Six Guiding Principles for Scientific Inquiry from *Scientific Research in Education* (Shavelson and Towne, 2002)
• Clearly stated hypothesis • Validity of research • Good understanding of background and lit review to frame the question • Quantitative • Awareness of errors and biases • Defining methodology of approach, rationale • Tells a convincing story • Applicability and context • Significant control over environment • Grounded in established principle or theory	• Identify a problem that is useful to the community • Integrity, honesty in research, reproducible; also some problems with plagiarism • Must be grounded in the literature • Methods aligned with the questions, reliable and reproducible • Procedures clearly described for replication • Statement of problem converted to testable hypothesis • Novelty • Usually quantitative data • Experimental design for statistical significance • In the end, analysis should be interpretation and synthesis • Peer review, making it public • Equations, math expressions • Report positive and negative results, in the same font size • Use of a control group • The right mix of qualified people for a multidisciplinary research team • Do no harm (in interventions)	1. Pose significant questions that can be investigated empirically. 2. Link research to relevant theory. 3. Use methods that permit direct investigation of the question. 4. Provide explicit, coherent chain of reasoning. 5. Replicate and generalize across studies. 6. Disclose research to encourage professional scrutiny and critique.

Table 2. Lists generated by RREE workshop participants, compared with NRC 6 guiding principles. Participants anticipated many of the NRC 6 principles.

discussion, not necessarily to list a specific item in each cell. During the report-back phase in 2005, groups of participants were asked to list one interesting revelation from their conversation. Some participants mentioned that their groups consisted of such novices that they had difficulty addressing the chart. Engineers in particular struggled with the meaning of the terms (categories) on the handout. The main difference identified by multiple productive groups was grounding in theory and the variety of educational theories from which to choose. The facilitator took the opportunity to emphasize this point in anticipation of a theory session later in the week. The final group to report said that they found more in common than different between engineering and education research.

In 2006, the same chart was used, but groups were assigned a specific row of the chart to discuss and fill in. This arrangement appeared to focus groups on constructive discussion of one aspect, as all were actively engaged during the allotted time. Large group discussion again focused on education and psychology theories. Participants asked which learning theories are relevant to engineering:

> In theory, there are volumes of work on education, but some are relevant to engineering. They aren't done by engineers.

	Basic Science	Linking Science	Application
Engineering Research →	Physics →	Mechanics →	Mechanical Engineering, Civil Engineering
Education Research →	Psychology (Learning Theories) →	Instructional Theory →	Instructional Design

Figure 1. Links between theory and practice in engineering and education research.

Aspect	Engineering Research	Education Research
Purpose		
Subject Of Inquiry		
Research Context		
Values		
Theoretical Perspectives		
Research Methods and Tools		
Measurement Techniques		
Threats To Validity		
Ethical Considerations		
Evaluation of Research Process		
Evaluation of Research Outcomes		

Table 3. Second active learning exercise for engineering research vs. education research.

> There's basically nothing being done over in engineering. What would you say about the relevance of these theories? Do people really learn engineering differently, or do we all just learn basically the same?

(The facilitator responded that he thought many were relevant to engineering.) Other participants asked whether some learning theories are discarded as evidence for others mounts. There was an extended discussion of the processes of theory development through comparisons with science and engineering.

> Participant: "When I see frameworks, like the model of the solar system, in science we discard the ones that don't work. There's only one model of the solar system and the older ones are discarded. That doesn't happen in psychology. [Facilitators object.] Both theories can't be right."

> Facilitator: "Psychology is very messy, and we have no grand unifying theory yet, but we have important pieces. Part of the holdup has been the instruments. We have much better instruments now. Neuroscience has given us some good grounding that supports some of our theories but not others."

During this session, the topics of theory and "messiness" came up most often. (Participants responded to another journal prompt earlier that day regarding their comfort level with the "messiness" of education research, which actually came immediately after the discussion of the chart in Table 3.) Sometimes messiness came from theory issues described above, other times from human subjects, which led into a brief discussion of ethics and IRB issues. However, the IRB discussion was limited by facilitators because time was set aside for it later in the week.

2) Reflections, Assessment Results, and Discussion: Although theory and messiness specifically were present in participant journals, the most prominent overall themes in the journals were similarities and differences between engineering and education research. Seven participants commented on a characteristic of education research that was learned (e.g., "A clear methodology of research exists and is widely accepted for educational research."). Two from 2005 stated that engineering and education research are more similar than suspected (e.g., "Engineering vs. educational research—they are more similar than different. There is considerable overlap"). Two from 2006 gave a balanced explanation of both similarities and differences: "These two fields have many similarities. Research methods & measurement techniques may vary." Participants appeared to understand the distinctions and similarities, as they listed for muddiest points how best to apply this knowledge to a research project and how to locate specific resources (e.g., relevant educational theories), rather than requesting additional clarification of the content presented.

Theory and transferability emerged in participants' journal responses across all three representations as the most prominent distinguishing characteristic of rigorous/formal/education research. Theory and transferability are related because if a study is supported by theory or contributes to expanding the theory, then the results are more likely to be transferable or generalizable. Participants discussed theory and transferability in their journals as both an important concept learned and a muddiest point. For example, one participant wrote for this representation, "part of what makes the research rigorous is its tie to theory" as learned, but "Not quite sure how the theories will fit in to the ed[ucation] res[earch]" as the muddiest point. A participant in the other cohort wrote very similar responses to this session. Other participants addressed theory and transferability as either learned or a muddiest point, but not both. Theory was mentioned by seven participants for engineering vs. education research; by three participants for in/formal or Levels of Inquiry; and three participants for assessment and research questions. A related analysis of the 2005 cohort revealed difficulties stemming from fundamental differences in the way theory is viewed and discussed in engineering and education research. However, comparing engineering research to education research via the active learning exercises described here helped most participants overcome the conceptual difficulty and cite theory as their greatest learning gain over the course of the week (Borrego, 2007b).

How would you rate your knowledge of the following? (5-point Likert, 5 = highest)	Pre- 2004	Pre- 2005	Pre- 2006	Post- 2004	Post- 2005	Post- 2006	Change 2004	Change 2005	Change 2006
How engineering research and educational research differ	2.90	3.00	2.97	4.31	4.14	4.13	1.41	1.14	1.15

Table 4. Pre- and post-workshop results for engineering research and education research. All three cohorts who participated in this session saw substantive learning gains.

A second distinguishing characteristic of education research from engineering research was "fuzziness" or "messiness." Some participants described this as a distinguishing feature, while others expressed increased understanding because the messiness had been explained. In discussing it as a difference, one explained, "I understand better the differences (fuzziness of ed[ucation] res[earch] due to confounding variables, etc.)", while another wrote, "Ed[ucation] research has so many more confounding factors and limitations." One participant that had the fuzziness explained by this session wrote, "Reaffirmation of why results fuzzy" as the important point learned.

Overall, the fact that the muddiest point in the journals focused on next steps (locating resources and applying this knowledge) suggests that participants understood and accepted this framework. Assessment data from pre- and post-tests, listed in Table 4, confirm this conclusion. While self reported knowledge may not be entirely accurate, these data indicate the level of confidence participants had with this material. Self reported learning gains (differences between pre- and post-test scores) ranged from 1.14 to 1.41 points on a 5-point Likert scale. There is little variation from cohort to cohort, which is to be expected because comparing engineering research to education research was presented at the beginning of the workshop for all three years, leading to similar increases.

In summary, comparing engineering research to education research works reasonably well as an introductory activity focusing on similarities and preparing participants for work on their research questions of interest. Among the 2005 and 2006 cohorts, issues of theory, transferability, and "messiness" were raised and discussed in a non-contentious manner. Although these activities serve as a good opening, the experience of the 2004 facilitators suggests that this approach alone is insufficient to focus participants on engineering education research (Streveler, Smith, and Miller, 2005; Streveler and Smith, 2006).

B. Assessment and Research Questions (2005, 2006)

1) Description and Initial Reactions: Since the introduction of ABET's new engineering accreditation criteria in 2000, assessment has been a fact of life for nearly all U.S. engineering faculty (Prados, Peterson, and Lattuca, 2005). In light of the importance of and familiarity with assessment of engineering faculty, a separate session was added to the workshop in 2005 to compare assessment to research. This activity began with a journaling prompt: "What sorts of questions does assessment (and evaluation) try to answer? What sorts of questions does education research try to answer?" Then, the facilitator presented content distinguishing the goals, guiding principles, and steps in conducting assessment from educational research. While educational research is guided by the NRC 6 (Shavelson and Towne, 2002) and the scientific method for the purposes of deep understanding in new areas (Diamond and Adam, 1993), assessment is a more systematic data collection addressing learning outcomes for the purposes of program improvement (Wiggins and McTighe, 2005).

The key group activity to aid understanding was distinguishing research questions from assessment questions and rewriting the assessment questions as research questions. Both cohorts were given a list of 10 questions adapted from those in their applications and those of the previous cohort(s). They worked in small groups and reported back to the facilitator. Table 5 summarizes the questions discussed by the large group and the reasons they cited for their categorizations. There were basically three criteria applied in this activity: (1) whether a specific setting was identified; (2) whether the mechanisms or outcomes were emphasized; and (3) whether a theoretical framework was implied. Unfortunately, these criteria were not spelled out for participants as clearly as they are here; the facilitator was applying them implicitly but never made them explicit to participants as a concise list. Two participants from 2005 cited confusion arising from this activity in their journals.

2) Reflection and Assessment Results: In their journals, five 2005 participants and four 2006 participants listed distinctions between assessment and research as the most important thing learned. Five cited the difference in focus, e.g. "Research is the 'how' or 'why'… assessment is the measure of 'to what extent.'" One participant drew a schematic in her journal of a "black box" with notations that assessment is concerned with outputs (not what happens in the box), while research focuses on the mechanisms within the box. Four participants described scope and transferability to broader contexts, while only one mentioned theory explicitly. It appears that all journal participants were able to articulate at least one criterion applied in the categorization activity.

However, for their muddiest points, most participants also described difficulties distinguishing between assessment and research (five participants in 2005 and three in 2006) or applying the distinction to transform assessment questions into research questions (one participant in each cohort). For this representation, a few of the participant journal comments suggested that facilitators were artificially creating or overemphasizing to sharp a distinction, when the true situation was

Question	Categorization	Reasons
What is the impact of active learning on student retention in my department? (2005)	Assessment	• "What" instead of "why" or "how" • Focus on impact rather than mechanisms • Focused on a single department
Does solving an open-ended design problem accelerate students' cognitive development? (2005)	Research	• Nonspecific student population/setting • Theoretical grounding
Do results on the Fundamentals of Engineering (FE) exam correlate with job success? (2005)	Assessment	• Narrowly focused on correlation • No theoretical grounding
How can distance delivery methods be used by my students as a way to reduce faculty teaching time without reducing student learning? (2006)	Assessment	• Specific, local student population • Focus on a few methods, not advantages and disadvantages • No indication of theoretical framework
What level of cognitive development is required for engineering graduates to be successful in their careers? (2006)	Assessment	• Simple correlation of two variables • "What" instead of "how" focus

Table 5. Research and assessment questions discussed as a large group and reasons for categorization.

How would you rate your knowledge of the following?	Pre-			Post-			Change		
(5-point Likert, 5 =highest)	2004	2005	2006	2004	2005	2006	2004	2005	2006
How assessment and educational research differ	2.90	2.86	2.83	3.59	3.93	4.09	0.69	1.07	1.26

Table 6. Pre- and post-workshop results for assessment and research. Higher learning gains were reported in 2005 and 2006 when a session was added to address this directly.

really a matter of degree:

> The overlap btw [between] assessment vs research made this difficult to navigate [2005].
>
> Isn't assessment simply a subset of research, i.e. to conduct research, don't we have to conduct a series of assessments[?] [2006]
>
> It is sometimes difficult to differentiate between what is assessment and what is research. It seems there is likely some, if not considerable, overlap. The purpose seems clear, but sometimes the questions could be interpreted as research or as assessment depending on scope and measure [2006].

This concept of artificially sharp distinctions is an important one which appears even more prominently for the representations described in the following section. Later results indicate that the sharpness of the boundaries or contrasts can have an important impact on whether a representation will be accepted by the intended audience.

Overall, participants were willing to accept the recommendation of the facilitators that they work toward answering research questions rather than assessment questions. Similarly, they worked later in the week to identify theories and methods which would make their investigations more relevant to engineering education settings similar to their own. It is important to note here that conflict over *methods* throughout the week arose from participants trying to understand educational research norms (Borrego, 2007b). Later sections describe conflict over *audience* and *inclusivity* occurring on the first day which, in contrast to methods, was not resolved by the end of the workshop and remain a source of tension in the broader engineering education community.

Pre- and post-test scores indicate that this was a successful addition to the 2005 and 2006 workshops. Table 6 compares

Level of inquiry	Attributes of that level
Level 1: Excellent teaching	Involves the use of good content and teaching methods
Level 2: Scholarly Teaching	Good content and methods *and* classroom assessment and evidence gathering, informed by best practice and best knowledge, inviting of collaboration and review.
Level 3: Scholarship of Teaching	Is public and open to critique and evaluation, is in a form that others can build on, involves question-asking, inquiry and investigation, particularly about student learning.
Level 4: Rigorous Research in Engineering Education	Also is public, open to critique, and involves asking questions about student learning, but it includes a few unique components. (1) Begin with a *research* question not an *assessment* question. Assessment questions often deal with the "what" or "how much" of learning, while research questions more often focus on the "why" or "how" of learning (Paulsen, 2001). (2) Tying the question to learning, pedagogical, or social theory and interpreting the results of the research in light of theory. This will allow for the research to build theory and can increase the significance of the findings. For example, studies about teaching thermodynamics can be redesigned to become studies, based on cognitive theory, which can help explain why certain concepts in thermodynamics are so difficult to learn. (3) Paying careful attention to design of the study and the methods used. This will enable the study to hold up to scrutiny by a broad audience, again creating a potential for greater impact of results.

Table 7. Levels of rigor in inquiry representation. Reproduced from Streveler, Borrego, and Smith (2007). The authors credit Hutchings and Shulman (1999) for levels 1–3.

the average scores and gains for the item focusing on assessment and research. Although for all three cohorts, the learning gains were statistically significant, the gain for 2004 is notably lower than for the 2005 and 2006 cohorts who participated in this session. This is to be contrasted with the scores listed in Table 4 related to engineering research and education research, in which all three cohorts exhibited learning gains greater than 1.0 after participating in the session. As might be expected, adding sessions directly addressing learning outcomes resulted in higher gains.

Although differentiating between research and assessment resonated with participants, the facilitators were not entirely comfortable with the way it limits definitions of assessment and dichotomizes assessment and research. Particularly in educational settings, assessment can be an important component of a research study or lead to more in-depth investigations. In the volume *Building a Scholarship of Assessment* edited by assessment expert Trudy Banta, a number of authors draw parallels between good research and good assessment. One frames assessment as a form of inquiry featuring hypotheses, educational context, data collection, and decision making (Gray, 2002). Similarly, another author argues that the assessment process mirrors research, as both involve asking good questions, identifying appropriate methods, selecting participants, applying measures and communicating results (Pike, 2002). These authors contend that there is more to be learned from focusing on the similarities than the differences between assessment and educational research. Ultimately, this activity was so successful with the 2005 cohort, it was repeated in 2006. As described in the following sections, dichotomy proved an even greater problem in informal/formal research than it did in assessment and research.

C. Levels of Inquiry (2005) and Informal/Formal Research (2006)

As illustrated in Table 1, Levels of Inquiry and informal/formal research are two separate representations. Levels of Inquiry was presented in 2005, and reworked to become informal/formal research for 2006. They are combined in this section because the most fruitful analysis of assessment results lies in comparing participants' responses to these two representations in 2005 and 2006.

1) Description of Levels of Inquiry (2005) and Initial Reactions: Of all the representations, Levels of Inquiry is the most direct response to ongoing paradigm discussions within the field of what engineering education has been in the past and what it should be in the future. A recent increase in calls for rigor, advocating a research paradigm, peaked in 2005 (Fincher and Adams, 2004; Shulman, 2005; Streveler, Smith, and Miller, 2005) as the *Journal of Engineering Education* celebrated its repositioning as a research-based journal (*Journal of Engineering Education*, 2005) and featured a number of editorials by U.S. authors calling for the same standards of rigor applied to technical engineering research to be applied to engineering education research (Gabriele, 2005; Shulman, 2005). Initially, these calls for rigorous research were so strong they all but completely dismissed the reform efforts and paradigm of the past, including but not limited to the engineering education coalitions funded by the NSF from 1990-2005 (Borrego 2007a). More recently, the pendulum has swung back to less radical rhetoric that values the integration of both reform and research efforts, especially through transforming the engineering education research agenda, e.g., Kemnitzer and Pimmel (2007). Valuing and encouraging quality among all types of contributions was the intention with the Levels of Inquiry representation; however, refinements are necessary, for example, since the terminology "rigorous research" may imply that none of the other levels are or can be rigorous.

The Levels of Inquiry representation is listed in Table 7. Level 2, scholarly teaching, is distinguished from level 1, excellent teaching, by the act of gathering assessment data supported by knowledge of best practices and collaboration and review by colleagues. Scholarship of teaching (level 3) makes the work public, often by publishing results in a form others can use, thereby inviting public critique. The first three levels were originally presented by Hutchings and Shulman (Hutchings and Shulman, 1999), although not in the form of levels. The fourth level, rigorous research, was added by the facilitators and executive committee as a natural extension of inquiry in engineering education (Streveler and Smith, 2006).

These levels of inquiry were presented to participants through a series of journaling and discussion activities. First, they were asked to personally define scholarly teaching, scholarship of teaching and learning, and rigorous research in their journals. Several participants offered their definitions to the group. Many of the participant definitions were close to those listed in Table 7. Participants were then assigned to discuss the NRC 6 and differences in applying them based on whether one is doing scholarly teaching, scholarship of teaching and learning, or rigorous research in engineering education. The groups' overall response was to compare the cost in terms of time and effort to the benefit obtained. When the facilitator asked why faculty do not do a more rigorous job on assessment (associated with levels 2 and 3), participants answered with constraints on time and rewards. They expressed the view that assessment usually gets in the way of the activities faculty are rewarded for such as teaching and research. As in the sessions discussing the other representations, the participants decided that the major distinguishing characteristic of research is transferability. Overall, this session was particularly uneventful because participants were so accepting of the representation.

2) Description of Informal/Formal Research (2006) and Initial Reactions: Since the use of "rigorous" labels in Levels of Inquiry implies value judgments and does not fully recognize the contribution of scholarly teaching activities, the representation was reworked into the format of a simpler comparative organizer in the attempt to remove unnecessary complexity and value-laden language. The resulting representation of informal and formal research in engineering education is presented in Figure 2.

When 2006 participants were first exposed to this representation, the facilitator's instructions were to:

> Find yourself on here and think about what you need to do to become more formal. This isn't just about us, this is what's happening in the field. I'm just avoiding calling it rigorous because I think both of these can be rigorous. Then later we will talk about how assessment fits in.

Participants were then given a journal assignment to look at the representation and write about which categories make sense, which are most confusing, and why. The facilitator then ran an open discussion of participant responses.

The most vehement responses and lively discussion of informal and formal research focused on which community should be the audience for engineering education work. Participants seemed to have interpreted informal research to address students and engineering faculty (practitioners) while formal research addresses an isolated education research community. Their comments conveyed alarm that formal research results would never be made accessible to practitioners. Consider comments made by three different participants:

> "I think students are more important than the educational community."

> "We are all trying to do the right thing here. This research is a means to an end. We can't just do research if it never makes it into the classroom. It's easy to lose sight of why we are doing this."

> "I fear that universities might split into having technical and education research faculty, but no practitioners, where the rubber meets the road."

More importantly, the participants allied themselves with the values of the practitioner community and not those of the research community (the latter of which is a goal of the RREE workshop program, to build a research community of practice). One participant asserted, "But the ultimate goal is not to impact some research community, but impacting the education community." The language suggests this participant identifies better with what she terms the education community. When asked by a facilitator how impacting the education community would occur, the participant replied, "There's dissemination conferences, web sites, textbooks; not just the education literature. You don't want to be closed. You want to impact the other group." Again, the language implies more comfort and preference with resources other than educational research literature. The sharp distinction drawn by participants was unexpected and surprising to the facilitators, who designed the workshop using a community of practice model to draw newcomers into the practice of engineering education research (Streveler, Smith, and Miller, 2005; Wenger, 1998 and 2002). Perhaps semantics issues were raised and exacerbated by the facilitators' assumption that engineering faculty participants would share the values of the research community.

Comments from other participants clarified their interpretation of who constitutes the distinct communities. One stated:

> As an engineer, I am interested in the application of the work I do. I don't want to be doing the research for some community where we just pat each other on the back. I also don't want to be too closed with our own lingo that excludes people. We already have this small community of research already at ASEE, where I was unfamiliar with some of the words they used.

It appears that this participant views ASEE (or at least specific divisions of the organization) as a small, esoteric research community that is not reaching practitioners. Immediately following this comment, another participant pointed out, "That's like engineering, where the practitioners really don't read the literature." There was a definite preference for focusing on practitioners. However, it was unclear whether participants labeled themselves practitioners or not: "I think we are preaching to the choir to some extent because the people in this room are all interested in students. The problem is other faculty, who will eventually change as they retire, but also how to encourage graduate students early on." This participant differentiates between two groups of practitioners, implying

Category	informal research	formal research
Motivation and purpose (what will the results be used for?)	improve teaching and learning in my class	identify basic processes of understanding including common misconceptions held by different learners
Question to be answered	Why don't my students remember how to use material from their pre-requisite course?	What misconceptions arise as students learn about it and attempt to apply it?
Use of the education research literature	teaching practice literature from books and articles used to inform thinking about classroom approaches	evidence-based literature from education (including engineering education) to explore relevant theories and use theoretical frameworks to design study and explain results
Feedback sought and given with colleagues	informally with interested colleagues	through peer review process for conferences and journals on engineering education
Study site	instructor's class	students studied in clinical or natural settings across institutions and contexts
Sampling	the entire class	representative sample of students chosen according to quantitative (random, controlled) or qualitative (purposeful) research
Human subjects in research (IRB approval)	none or exempt review	Yes
Measurement tools/methods	classroom assessment techniques and surveys; exam questions	appropriate methods for experimental, quasi-experimental or naturalistic design (surveys, observation, collection of scores on performance measures, interviews, focus groups, analysis of student work products)
Data analysis	pattern analysis of student opinion and satisfaction; pre-post comparison of student performance	multiple forms of data analysis (statistical or text) to inform research question
Reporting of results	anecdotally with colleagues; at regional or national engineering education conferences and conference proceedings	archival education research literature
Impact on engineering education	informs the individual faculty member and other faculty members; improves learning of future students	informs the education research community in engineering and other fields
Transferability	other engineering educators teaching thermodynamics and related topics	education and engineering communities

Figure 2. Informal vs. formal engineering education research.

that those currently unconcerned with improving engineering education should be the target group.

The facilitators and observers believed the dichotomous format of the informal/formal representation may have forced participants to choose a side (researcher or practitioner) with which to ally themselves. One participant bridged the topics of dichotomy and community alignment at the beginning of the group discussion:

> There is a danger of dualism in talking about moving from one to the other. Many of us are teachers and new researchers. In some cases I want to be the consumer. In others I want to do the research, but I can't be high level in every area. The other levels will exist for me, too.

The facilitator responded that while much of participants' teaching activities will remain scholarly teaching, the hope is that during the workshop, interests in one area will move into a more formal approach. Other participants expressed preference for a more flexible continuum. One asked, "What happens when you have elements of column a and column b? This is presented as discrete when really it's a continuum." After explaining that some statistical studies yield a higher significance level than others, a different participant explained, "You cannot view it as separate; sometimes people do some of both." A third directly stated, "I prefer the language you used last year. There was a continuum."

The goal in labeling the columns informal and formal was to avoid judgments of the value of each type of work that were present in previous representations with the term "rigorous" in some categories but not others. Nonetheless, a few participants had difficulty with the labels. One interpreted the titles to imply that "one is better than the other," while another participant stated the opposite view: "I see in some of the categories where the informal entry is not negative. But in order to be motivated to go to the next level, you need to be negative." Others made suggestions for titles they althought would be more descriptive: "'Action research' is an education term that I have heard for things done in the classroom, or 'applied research.' Those are two suggestions for renaming the informal column." Another offered, "I don't like calling it formal. I prefer 'objective' or 'policy-oriented.' The informal research that teachers do, I would like to call 'subjective' or 'narrow.'" One participant reflected in her journal, "While these distinctions can be helpful in advancing EE research, I would hate to see them used in an exclusive, arrogant way, because we as a community <u>also</u> want to (or ought to) encourage much more 'informal research'/scholarly teaching/SoTL among our colleagues." This participant was an unusual case in referring to the engineering education research community in terms of "we as a community" and later "our community" rather than a separate group not represented among participants.

3) Comparison of Reflection and Assessment Results: As expected based on the only major content change from 2005 to 2006 discussed in this paper, the biggest difference between the two cohorts' journals lay in their responses to either Levels of Inquiry or informal/formal research. Responses from 2005 participants appeared to have focused more on the representation as a continuum. Both cohorts discussed issues of value judgments, acceptance, and why one pursues engineering education work.

The 2005 journal responses to the Levels of Inquiry nearly all focused on either the distinction between the items or the continuum. One participant cited the distinction as the most important thing learned. Two others emphasized that the relationship is a continuum ("There is a continuum from ST-SoTL-RREE [scholarly teaching to scholarship of teaching and learning to rigorous research in engineering education]"), while another gave a more balanced summary: "Very clear distinctions, a progression." Three others listed a specific distinguishing characteristic of rigorous research in engineering education, e.g., the NRC 6. Muddiest points asked for clarification of the distinctions and wondered how one can move oneself toward rigorous research.

In 2006, positive discussions of the value judgments intentionally avoided in the informal/formal representation were more prominent in participants' journals. As similarities, two participants listed that both informal and formal research are contributions: "Both can be rigorous, & both can benefit students/teaching/learning" and "Both inform[al] & form[al] are worthwhile research processes. It is unclear the exact distinction between the two but That's OK!" Another stated, "assessment has its place (not 'bad')." These comments indicate that for some the value judgments were avoided or rejected. Two others listed theory and transferability as defining characteristics of formal research. Only one participant stated, "This is a continuum."

While the research and assessment questions activity described in previous sections focused on a specific step of the research process, these representations addressed more fundamental personal identity issues including credibility within the research community, value systems, and rewards. One participant from each cohort expressed concern within his or her journal about developing their own credibility in education research arenas:

> What are the expectations of the larger community of practitioners of education research of "newbies" coming from engineering technical research? Will application of existing theories be seen as sufficient for academic value[?] [2005]
>
> How to overcome these [confounding] factors and create work that is credible to both fields…Given that educ[ation] research tends to be fuzzier and less controllable, how does one make it credible & persuasive? [2006]

The 2006 journals included far more discussion of these issues, but much of it was supplied by returning leadership team participants who may have been more reflective about their and others' reactions to the material. One observed, "I was surprised at some (but not all) of the controversy over the comparative analysis provided." Another returnee explained:

> I found the discussion on formal and informal research both useful and an important area of discussion for the engineering ed[ucation] community. If the body of knowledge is going to move [forward] and if we [are] going to begin to see systemic change, this is an important discussion to have. What is the balance between teaching and research? What is the role of the engineering researcher vs the classroom practitioner?

Other participants also questioned the value of this work, qualifications (expertise of engineers) and rewards. A 2005 participant asked, "Should engineers be doing RREE [rigorous research in engineering education]?" Similarly, a 2006 participant questioned, "Given the previous statement [both can be valuable], & the understanding that formal research is WAY more time-consuming & difficult than [in]formal, why do it?" Another 2006 participant asked, "who uses ed[ucation] research?"

4) Discussion: In comparing the formal/informal research representation to the Levels of Inquiry, there are several differences that could have contributed to the observed differences in participant receptiveness. The first, noted explicitly by some participants, was the dichotomous nature of the informal/formal representation. It should be noted that the handout given to participants was formatted was formatted with a double line separating with a double line separating the informal column from the formal column. This formatting, coupled with the instructions to locate oneself on the chart, may have been interpreted by participants as more rigid than facilitators intended. The facilitator's instructions continued, stating that participants should focus on what they need to do to become more formal. The language of "you," rather than "your work" in the area of interest identified for this workshop may have also exacerbated the situation. Participants' reactions suggest they felt they had to locate themselves squarely in one column or the other. Those that brought continua into the discussion may have felt that a more fluid structure would not require strict categorization. In contrast, when the Levels of Inquiry were presented in 2005, focus was on defining and distinguishing the levels from each other. If examples were given, they were not linked to individual participants' research interests. In fact, there was no explicit discussion of mapping participants or their work to the continuum.

The session on assessment and research questions serves as an interesting counterargument to the explanation that the informal/formal research representation was rejected by participants simply because it is dichotomous. Assessment and research questions were particularly successful in 2005 and were repeated in 2006 immediately following the informal/formal session with no objections from participants. This counterargument was raised when 2006 facilitators and NSF program officers in attendance discussed participant reactions during a break later the same day. One of the program officers pointed out that critiquing and rewriting questions (as in assessment and research) is a concrete activity, whereas reacting to the informal/formal representation addresses core personal reasons why engineering education work is pursued. As such, it would have been the point where participant misconceptions about education research would be revealed. Indeed, during this middle session each year was when issues of value judgments, reward systems, and why one pursues engineering education work emerged. While this makes for potentially heated discussion, it also indicates that these representations get to the heart of engineering education paradigm debate.

Finally, there are other aspects to the way the material was presented to participants that could have contributed to their acceptance of the representations as valid. In the case of the levels of inquiry, participants were given the terms, wrote their own definitions in their journals, and offered them to the group before the accepted definitions were presented. In most cases, the definitions aligned. Only one participant offering his own definitions opened by explaining he transformed the terms from "jargon and buzzwords" to phrases that made more sense to him. This gave the facilitator an opportunity to assert that the terms and their definitions are standardized and well-accepted. In this way, the credible authorities (Boyer, 1990; Hutchings and Shulman, 1999) behind the material were subtly identified to participants, which may have pre-empted any further objection. The informal/formal representation, in contrast, was developed by the facilitator team, so at no point could a more credible source be invoked. Perhaps more importantly, participants were not given an opportunity to anticipate the material before it was presented. In this session, Figure 2 was handed out, and participants were assigned a journal reflection as described above. Not only was the representation in one sense presented as "fact," but also, the reflection and discussion invited criticism. As the facilitators were in the process of developing this representation, they desired feedback and consciously designed the journaling activity to elicit it; they just did not expect the representation and related underlying issues to be so controversial.

One other possible explanation is differences between the 2005 and 2006 workshop cohorts. In terms of pre-test knowledge, the 2005 and 2006 cohorts are remarkably comparable. However, differences in background, experience, identity and motivation that might have resulted in differential reactions were not captured in the pre-tests or applications which focused on experience level and content knowledge.

V. General Discussion

The result of this analysis which has the most important implications for the broader discourse in engineering education is that the most contentious debate took place when participants felt their personal reasons for pursuing engineering education were being challenged. When engineering education work was more abstractly categorized as assessment, research, scholarly teaching, and scholarship of teaching and learning, participants worked to align their understanding of these categorizations with that of the facilitators. It is not clear that facilitators' valuing work at all stages and levels was transferred to participants. In 2006, when participants were asked to identify personally with one category or another, controversy erupted. These discussions quickly shifted from valuing all types of work to questioning the fundamental goal of engineering education research. More importantly, there was an underlying implication that there is one goal and one strategy for accomplishing this goal. In other words, participants subscribed to one paradigm while rejecting another. We believe participants' personal reasons for pursuing engineering education research were conflated with overall goals of engineering education research and their implications for journals, conferences and other venues. Specifically, participants raised concerns that engineering education research does not directly impact practice because it does not disseminate results to all engineering faculty, particularly those uninterested in improving engineering education. Thus, the goal to most participants was to improve (reform) engineering education through broad dissemination. The view—or paradigm—they opposed was that rigorous research standards and results would ultimately improve engineering education, perhaps because the change would not come quickly enough. It is worth noting that this reaction to research perspectives is similar to that described by Labaree (2003) for new doctoral for new doctoral education students with significant teaching experience (section II.A). This is likely the same phenomenon which describes tensions over *Journal of Engineering Education* and the few other venues available for publishing engineering education work.

The high visibility of *JEE* makes it the most desirable journal for U.S. engineering faculty to publish their engineering education work. However, to maintain its status as a top journal, *JEE* has had to uphold increasingly high standards for the research it publishes. Standards and review processes necessarily exclude some from presenting their work, and in the broader context of the field, maintaining quality lies in direct opposition to inclusiveness. Individuals who do not feel they have a voice or that their work is not valued by the community may not participate for long. (Similarly, if the work does not have clear implications for practice, practitioners will not use it as a resource.) Thus, there exists a tradeoff in maintaining high standards of research quality at the expense of reaching a wide audience, or vice versa. As another example, the ASEE conference, which is inclusive of a much larger population than *JEE* authors, has been criticized by some as lacking in rigor and usefulness. It is clear from the experiences with this workshop that paradigm debate in engineering education centers on the core goals of engineering education scholarship. It is through resolution of conflicting issues of inclusiveness and standards of quality that the next paradigm of U.S. engineering education will emerge.

VI. Recommendations and Conclusion

We have presented several representations which describe aspects of the U.S. engineering education research paradigm that the new field of engineering education is in the process of creating. We hope to use updated representations to extend discussion and consensus-building to a wider, more international audience. Through this analysis we have identified content and presentation strategies which promote consensus and those that provoke heated debate. Both types of discussions will be important as the community identifies areas of agreement and more directly addresses divergent views.

First, there is evidence of consensus in that the research paradigm is gaining momentum, e.g., the expanded research criteria in 2006 over 2005 listed in Table 2. But these new standards should not invalidate the past work of the engineering education community. A useful evolving paradigm respects past efforts for their contribution in moving us forward, as reform efforts have (Borrego, 2007a). We are reminded that in physics, the creation of quantum theory extended the Newtonian paradigm but did not invalidate it. (It is Newtonian physics after all, that still guides manned spaceflight.) It is in the spirit of extending constructive paradigms that this article offers these suggestions. Good representations focused on consensus-building:

- Are developed through continuing dialog with different groups (balance the high representation from engineering with educational perspectives and values)
- Contain value-free labels, preferably building on terminology established in the literature
- Use proper labels but avoid confusing or confounding jargon
- Are otherwise inclusive of all groups that can contribute to engineering education
- Value work in all categories as contributing to positive (documented, systemic) change in engineering education
- Define good practice at each stage or category
- Focus on the work, not people or their value systems
- Provide flexibility for bridging levels, growth, and individuals having projects and interests at different levels simultaneously
- Are presented inductively to show alignment with audience values and systematic development of representations

The development of engineering education as a field is likely to be impeded if alternative viewpoints are not resolved or at least framed with respect to one another and discussed openly. The key tension identified in this data lies between broad inclusiveness and high standards of research quality. Those subscribing to a reform paradigm feel strongly that if the purpose of engineering education research is to improve engineering education, then a wide audience of all engineering faculty should be targeted. In contrast, a research paradigm is far less inclusive because high standards and their inevitable consequence of exclusivity are given higher priority than a vast audience or community. What may be viewed as either a backlash or a softening of the rigorous research rhetoric since its peak in 2005 could actually be the beginnings of yet another paradigm—a *systems paradigm* for transforming engineering education that values both knowledge building (research) and professional development (reform) as necessary components to achieving lofty goals. If the paradigms of research and reform do indeed lie in direct opposition, then neither may ever dominate before a new paradigm emerges. The idea of a systems paradigm steps away from a single way of thinking about the problems of engineering education and is more likely to value the contributions of many groups pursuing related goals and complementary strategies. If we are to better prepare engineering students and attract more of them to engineering, then we will need both fundamental knowledge and enthusiastic practitioners skilled in applying it.

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