Abstract - The purpose of this study was to determine the research priorities and publication trends in engineering education in the USA over the interval of 1996 to 2006, through an examination of the key peer-reviewed journals, professional organizations, government documents, and interviews with experts in the field. Analysis of the data identified engineering epistemologies, learning mechanisms, learning systems, diversity and inclusiveness, and assessment as the research priorities of the field of engineering education over the last decade. Analysis of the publication record of three key journals in the field revealed that the publication trends over that time interval were: 1) teaching, learning and assessment processes, 2) teachers and learners, and 3) courses, laboratories, curricula, instructional materials, and learning technologies. A comparison of research priorities versus publishing trends identified the following areas as deficiencies in the research base: 1) educational management and goal systems, 2) political, economic, and social influences on engineering education, and 3) diffusion of educational innovations.

Index Terms – engineering education, research priorities, meta-analysis

INTRODUCTION

In all areas of research, it is critical to examine and summarize the work that is being done, but the young age and rapid growth of engineering education research makes this even more important than ever. Even more important than identifying the research and publication trends is the need to identify the underlying research priorities and notable gaps in the research base. In order to address these needs and provide guidance to researchers, this study searches for and then compiles a categorical list of the most important research needs within the engineering education community in the United States. In a similar way, this study examines the publication trends of three of the most prestigious engineering education research journals over the past decade and the results of which were categorized and enumerated. A cross-comparison of the publication categories and the research priorities reveals a list of research deficiencies in engineering education that could be used as a basis for further research.

METHODS

The research priorities of the engineering education field were analyzed by examining several key articles that included calls for research, most notably The National Engineering Education Research Colloquies [1], published by Journal of Engineering Education [2]. Other sources included the Science and Engineering Indicators written by the National Science Board [3], the stated interests of the America Society for Engineering Education [4], [5] and the Institute of Electrical and Electronic Engineers Education Society [6], [7], the stated publication interests of the Annuals of Research in Engineering Education [8], [9], and the opinions of experts in the field [10]-[12]. The publication trends were identified by means of a categorical analysis of articles published by the Annuals of Research in Engineering Education (AREE) [6], the Journal of Engineering Education (JEE) [2], and the Journal of Professional Issues in Engineering Education and Practice (JPIEEP) [13] over the interval of 1996 to 2006. The gaps were then identified, by identifying which of the priorities had not been addressed by a significant number of publications.

DATA ON RESEARCH PRIORITIES

I. The National Engineering Education Research Colloquies

The National Engineering Education Research Colloquies [1] was identified as the leading authority on the subject of research needs in engineering education, due to the fact that it involved seventy experts and a series of three national colloquia to reduce fifty-five desirable engineering education outcomes down to nineteen research clusters and then down to five research categories. They identified the main categories of needed research as:

1. Engineering Epistemologies – Research on what constitutes engineering thinking and knowledge within social contexts now and in the future
2. Engineering Learning Mechanisms – Research on engineering learners’ developing knowledge and competencies in context
4. Engineering Diversity and Inclusiveness – Research on how diverse human talents contribute solutions to the social and global challenges and relevance of our profession
5. Engineering Assessment – Research on, and the development of, assessment methods, instruments, and metrics to inform engineering education practices and learning [1]

II. The Research Agenda for the New Discipline of Engineering Education

The...
Another article that was examined due to its call for research is the article titled The Research Agenda for the New Discipline of Engineering Education [14]. Within this article, the editors of the JEE identified the following research priorities:

2. Socially Relevant Engineering – Research on how diverse human talents contribute to the social and global relevance of our profession.
3. Learning to Engineer – Research on developing knowledge and expertise in practice.
5. Engineering Assessment Methodologies – Research on, and development of, assessment methods, instruments and metrics to enhance engineering education [14].

III. Government Reports

The investigation into research priorities also examines government reports. In 2006, the National Science Board published the Science and Engineering Indicators [3]. Science and Engineering Indicators is a volume of records comprised of quantitative data on the science and engineering industry in the United States. The report gives several statistics, which can be used to draw implications about the type of educational research needed in engineering. The following are implications of educational research for engineering made from the report, followed by correlating data (indicators) given by the Science and Engineering Indicators report:

1. Engineering Diversity – Research on engineering diversity and the role of cross-cultural problem solving
   - The number of women enrolling in science and engineering graduate programs has continued to increase for the past 2 decades
   - The number of underrepresented minority students enrolling in science and engineering graduate programs has increased each year since 1985
2. Engineering Diversity Pedagogy – Research methods to recruit and retain students from diverse backgrounds
   - Underrepresented minorities (Blacks, Hispanics, and American Indians/Alaska Natives) do not enroll in or complete college at the same rate as whites.
   - The percentages of blacks and Hispanics in 2003 who completed bachelor’s or higher degrees in science and engineering were 18% and 10%, respectively, compares with 34% for whites
3. Engineering Educator Recruiting – Research methods to attract more engineering educators to sustain the increase in student enrollment
   - The numbers of science and engineering bachelor’s and master’s degrees reached peak of 415,600 and 99,200 respectively, in 2002
4. Engineering Retention – Research methods to retain students in the study and field of engineering
   - Retention rates of science and engineering students declined since 1995 and 2001 [3].

IV. Professional Organizations

In order to gain the perspective of as many professionals in the field as possible, the two leading professional organizations in engineering education were examined. Those two organizations are the American Society for Engineering Education (ASEE), and the Institute of Electrical and Electronics Engineers (IEEE) Education Society.

American Society for Engineering Education (ASEE). Although the interests of the ASEE are diverse, it manages to balance those diverse interests by sorting those interests across a variety of subgroups and topic specific journals. For this study however only the general societal goals were examined, and not those of the specific sub-groups. Some highlights of the ASEE constitution can be paraphrased and abbreviated as an interest in the advancement of all forms of engineering education, the adjustment of curricula to changing needs, the development of effective teachers, the enhancement of professional ideals, fostering of research as a function collateral to teaching, the coordinating institutional aims and programs with industry, and the cultivation of a kindred spirit among teachers, counselors, researchers, administrators, practitioners and corporate and government representatives [5].

IEEE Education Society. Similar to the analysis of the ASEE, the society’s constitution provided a precise list of their interests.

Article II, Section 1—The Education Society's FIELD OF INTEREST shall be:
Educational Methods, Educational Technology, Instructional Materials, History of Science and Technology, and Educational and Professional Development Programs within Electrical Engineering, Computer Engineering, and allied disciplines [7].

Please note the similar interest in educational methods, instructional technologies, materials, and professional development programs.

V. Publication Interests of Annuals of Research in Engineering Education (AREE)

The Annuals of Research in Engineering Education is a journal which defines its own primary purpose as “to link multiple journals reporting research on engineering education and related work in science disciplines through a single interface” [9]. This study includes the stated publication interests of the AREE as a source of insight into the research priorities within engineering education. AREE defines its list of publication interests as:

1. Teaching, Learning, and Assessment Processes

   - The number of science and engineering doctoral degrees rose in 2003
   - The number of science and engineering doctoral degrees rose in 2003
2. Teachers and Learners  
3. Courses, Laboratorie s, Curricula, Instructional Materials, and Learning Technologies  
4. Educational Management and Goal Systems  
5. Political, Economic, and Social Influences on Engineering Education  
6. Diffusion of Educational Innovations [8]

VI. Research Priorities Identified Through Interviews Of Experts In The Field

In order to gain another perspective into the research priorities, three experts in the field of engineering education were briefly interviewed. The first two of those three experts, Dr. Jenny Lo and Dr. Richard Goff, both from the Virginia Tech Engineering Education Department, both stated that the article titled “The National Engineering Education Research Colloquies” already contained such a list and that they did not have any additional information to add [10,11]. Dr. Goff felt particularly strongly about this in that he himself was among the seventy experts who had contributed to the article. The third expert interviewed was Dr. Vinod Lohani, who is also from the Virginia Tech Engineering Education Department. Just like his peers, he too recommended the aforementioned article and stated that it already contained a list of the most important research priorities [12].

When pressed for more information on his opinions on significant research priorities, but perhaps not quite important enough to make it onto the short list identified by that article, he explained that engineering education has a unique opportunity, and thus a unique burden, to research ways of reusing existing engineering knowledge within the context of education [12]. As a specific example, he described one of his own research projects, in collaboration with an expert from electrical and computer engineering, which studies the formative assessment process using electronic feedback control theory. Although this was not identified among the most important research categories, it is still an important area of research because it is unique to engineering education (meaning that it is not found in other STEM Ed research areas) and due to the obvious benefits of reapplying existing knowledge.

DATA ON PUBLICATION TRENDS

I. Publication Trends within the Annuals of Research in Engineering Education (AREE)

In order to determine the existing publication trends, the articles published in the AREE were examined, categorized, and counted. Fortunately, the editors of the AREE presort articles in their online table of contents to match their stated publication interests [8]. Numerically summarizing the articles in each category, within each issue, and then adding up those numbers across all six of the issues published thus far (Summer 2006 through Summer 2007), produced the following results, shown in Table I.

Please note the lack of balance between the numbers of articles published within each category. (These differences will be addressed again in the Conclusions and Implications sections of this report.)

II. Publication Trends within the Journal of Engineering Education (JEE)

Due to the prominence and long life of the Journal of Engineering Education, it too was selected for an analysis of publication trends. Unlike the AREE, the JEE does not sort its own articles by category, so that was the first step in the process of identifying the JEE’s publication trends. A quantitative analysis of article titles and abstracts in the 1996-2006 interval was performed, with codes ultimately grouped into categories. The resulting categories were similar to those found by Whitin & Sheppard [15] in their five-year study. The results of our study and their study were found to correlate to within a few percentage points in most categories, even though the research methods were different. The results of the categorical analysis of the Journal of Engineering Education are presented below in Figure 1.

III. Publication Trends within the Journal of Professional Issues in Engineering Education and Practices (JPIEEP)

The Journal of Professional Issues in Engineering Education and Practices (JPIEEP), is a journal targeting contributions made within the civil engineering community, however its purpose is to investigate the relationship between civil engineering and other disciplines, extending...
its research throughout all silos of engineering and engineering education [13].

The JPIEEP sorts its submissions into the following categories:

1. Ethics – researching the emphasis on the engineer’s obligations and responsibilities. In this section, papers highlighting social, economic, and ecological implications of technological achievements.
2. Teaching and Learning – Specific subject areas encompass applications of artificial intelligence in civil engineering and recent developments in civil engineering education.
3. Engineering History – Highlights the evolution, progress, and future directions of civil engineering as a whole from the promotion of ethics to the impact of systems analysis to the monitoring of the profession’s current and future well being.
4. General/Other – Highlights the professional practices, achievements and studies within the engineering community [13]

The results of the categorical analysis of the Journal of Professional Issues in Engineering Education and Practice are presented below in Figure 2.

FIGURE 2
A GRAPHICAL REPRESENTATION OF THE PUBLICATION TRENDS IN JPIEEP.

RESULTS

I. Analysis of Research Priorities

As stated in the methods section, the research priorities identified within journal article titled The National Engineering Education Research Colloquies was selected as the primary means of organizing the research priorities. It is important however to confirm the validity of that selection and of the authority of the list of priorities that it identified. In order to accomplish those two goals, the research priority data gathered from all of the other sources were compared to the priorities identified in The National Engineering Education Research Colloquies, which are:

1. Engineering Epistemologies
2. Engineering Learning Mechanisms
3. Engineering Learning Systems
4. Engineering Diversity and Inclusiveness
5. Engineering Assessment [1]

As shown in the data section, the next source of information that was examined was the article titled “The Research Agenda for the New Discipline of Engineering Education,” which contained the following list of research priorities:

1. Engineering Thinking, Knowledge, and Competencies
2. Socially-Relevant Engineering
3. Learning to Engineer
4. Engineering Education Pedagogies
5. Engineering Assessment Methodologies [14]

The titles of these priorities create an easy way to map many of these priorities to those identified by the National Engineering Education Research Colloquies. For example, “Engineering Assessment Methodologies” is the same as “Engineering Assessment.” Similarly, “Engineering, Thinking, Knowledge, and Competencies” correlates directly to “Engineering Epistemologies.” “Socially-Relevant Engineering” is broader than “Engineering Diversity and Inclusiveness,” but still reinforces the importance of that category. When “Learning to Engineer” and “Engineering Education Pedagogies” are placed together they cover approximately the same content as the combination of “Engineering Learning Mechanisms” and “Engineering Learning Systems.” Even though this article provides a different way of organizing the priorities, it actually covers the same topics, and thus supports the authority and validity of the list provided by the National Engineering Education Research Colloquies.

For further data on the authority and validity of the priorities identified by The National Engineering Education Research Colloquies the purpose and priorities of the American Association for Engineering Education were examined and compared to the findings of the National Engineering Education Research Colloquies. Although the ASEE provides a list of eight broad purposes and priorities, the ones immediately relevant to education research can be summarized as the following:

1. Goals and responsibilities of engineering education
2. Curriculum and educational processes
3. Instructional materials and instructional methods

Although this list does not map directly on the list identified by the National Engineering Education Research Colloquies, there is still a close match. “Goals and responsibilities of engineering education” is included within “Engineering Epistemologies.” “Curriculum and educational processes” combined with “instructional materials and instructional methods” covers approximately the same areas as “engineering learning mechanisms” and “engineering learning systems.” This list does not explicitly include the areas of “engineering diversity and
Although this list is substantially different in appearance, it too maps onto the findings of the National Engineering Education Research Colloquies. “Teaching, learning, and assessment processes,” which covers a lot of topics, is similar in content to the combination of “engineering learning mechanisms” and “engineering assessment.” “Teachers and learners” is also a broad category and actually contains content that would be distributed among “engineering epistemologies” (if the research was on the culture of engineering educator, for example) and “engineering learning systems” (an example of this would be research on teams or class sizes) and “engineering diversity and inclusiveness” (for example, research on what types of assignments affect retention of minorities). “Courses, laboratories, curricula, instructional materials, and learning technologies” is nearly the same as “engineering learning mechanisms.” “Educational management and goal systems” is similar to “engineering learning systems.” “Political, economic, and social influences on engineering education” is another category, which does not have a one to one relationship with the categories identified by the National Engineering Education Research Colloquies. It however is heavily related to the category “engineering epistemologies” and some of the articles published under it actually relate to one or more of each of the other categories as well.

For additional data, three engineering education researchers (Dr. Richard Goff, Dr. Jenny Lo, and Dr. Vinod Lohani) at Virginia Tech were also interviewed very briefly on the subject of engineering education research priorities. Without being asked, all three of the experts that were interviewed expressed strong support for the findings of the National Engineering Education Research Colloquies, which adds additional support for the authority and validity of the list of research priorities it identifies [10]-[12].

II. Analysis of Publication Trends

The trends in the three journal publications researched varied, however they did follow major patterns. For convenience those trends were mapped into the categories specified by the AREE:

1. Teaching, Learning, and Assessment Processes
2. Teachers and Learners
3. Courses, Laboratories, Curricula, Instructional Materials, and Learning Technologies
4. Educational Management and Goal Systems
5. Political, Economic, and Social Influences on Engineering Education
6. Diffusion of Educational Innovations [9]

The numbers in the first column of Table II (shown below) refer to this list of publication priorities. The second column of Table II shows the percentage of AREE articles published as of March 2008 in each category. Comparing the publications of the Journal of Engineering Education (JEE) to the publication interests of the Annuals of Research in Engineering Education produced
the results shown in the third column of Table II. Please note that as with the AREE, the numbers of journal articles in each category is far from evenly distributed, and some categories have almost no publications at all.

Comparing the publications of the Journal of Engineering Education (JPIEEP) to the publication interests of the Annuals of Research in Engineering Education produced the results shown in the fourth column of Table II.

### Table II

<table>
<thead>
<tr>
<th>Publication Priority</th>
<th>Percentage of Publications by Category</th>
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<tbody>
<tr>
<td></td>
<td>AREE</td>
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<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>24%</td>
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<tr>
<td>3</td>
<td>52%</td>
</tr>
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<td>0%</td>
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<tr>
<td>5</td>
<td>5%</td>
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<tr>
<td>6</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Conclusions

As the Data Analysis section shows, the broad categories of “learners,” “teachers,” “assessments,” and “methods” contain large numbers of published articles, but other categories, such as “long-term education plans,” “long-term engineering education goals,” “how to organize engineering education,” “effects of the world on engineering education,” “what it means to be an engineer,” “effects of engineering education on the world,” and “how to spread the benefits of research in engineering education,” all receive very little attention and can thus be counted as gaps between the desired research and the research that is being done.

Even worse, and yet more obvious is the research gap in the area of diversity, and especially its benefits. Although “The National Engineering Education Research Colloquies,” has included “Engineering Diversity and Inclusiveness” as one of the five most important categories, and although most of the other sources included in this study do agree with its importance, the number of publications on research in diversity is still small. But, the lack of publications is not the true indicator of a research gap; to find that gap it is important to compare the articles that are published on this topic to the definition of “Engineering Diversity and Inclusiveness” as provided by the “National Engineering Education Research Colloquies,” which is “Research on how diverse human talents contribute solutions to the social and global challenges and relevance of our profession.” Although that definition clearly states a need for research on the benefits of diversity, nearly all of the articles that are published on diversity focus on the “burden” of creating and encouraging diversity and not on the benefits of diversity.

### References


[12] Lohani, V., Personal interview, 2007, Blacksburg, VA.


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