AC 2008-159: CONTENT ANALYSIS OF THE HISTORY OF NSF FUNDING FOR ENGINEERING EDUCATION RESEARCH

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Content Analysis of the History of NSF Funding for Engineering Education Research

Abstract

The National Science Foundation (NSF) was established in 1950 with the dual mission of supporting education and basic research in the mathematical, physical, medical, biological, engineering, and other sciences. Although engineering education research has occurred in some form for many years, only in the past 20 years has it received significant funding support from the NSF. More recently, engineering and engineering education have been reevaluated and charged with producing engineers who will function in rapidly evolving technical and business environments. In addition to new ABET criteria for engineering program accreditation, a 2004 National Academy of Engineering report on the future of engineering encouraged more scholarly research on engineering education. In light of these changes, and in an effort to evaluate some portion of both progress and the current funding environment in engineering education research, the NSF funding patterns for engineering education research were analyzed through a content analysis of the abstracts of awards according to directorate and topic to examine trends in NSF funding for rigorous engineering education research. Overall, both the number of and the money awarded to grants for engineering education research have increased substantially over the past 20 years, with most focused on teaching and learning. This analysis provides a global overview of the NSF-funding environment for engineering education researchers.

Background

Engineering education research has occurred in some form for many years, but only in the past 20 years has it received significant funding support. Engineering education research encompasses examination of not only teaching, learning and assessment, but also issues associated with faculty rewards and the organizational dynamics of engineering departments [1]. However, studies of teaching and learning are the most prevalent. For many years, such studies focused more on student and faculty opinions of curricular or pedagogical innovations rather than on assessment of student learning. More recently, researchers have begun to develop research questions related to the mechanisms underlying effective teaching and learning [2]. One common method of examining change and growth of an academic field is to analyze its publications for unifying themes and research methods [2]. One database devoted to research on attainment of student learning outcomes (http://www.pr2ove-it.org) includes over 400 research articles and conference papers from 1970-2005, although more than 95% were published after 1995. Many of the articles and conference papers in this database do not represent controlled research [3], although with the 1997 change in accreditation standards [4] came an increased focus on performing and reporting research assessing student learning rather than opinions. The articles included in the database were published in refereed journals from both engineering and non-engineering fields as well as the proceedings of a conference devoted to innovation in engineering education.

The National Science Foundation (NSF) was established in 1950 with the dual mission of supporting education and basic research in the mathematical, physical, medical, biological, engineering, and other sciences. This focus was later modified to drop the medical sciences and to add the geosciences and the social, behavioral, and economic sciences [5]. In 1952, the NSF began supporting new scientists through graduate and postdoctoral fellowships. In the late 1950s, when Russia successfully sent the Sputnik satellite into orbit, the nation and NSF became more concerned with increasing the effectiveness of scientific education. Grants for university and college infrastructure increased, although the NSF preferred to focus money on institutions with a strong research focus over those with a strong education focus. In 1972, the NSF received a larger budget for both applied and basic research, but decreased support for most of its educational programs such as scholarships [5]. While novel programs in engineering education began receiving NSF funding in the 1970s [6], the early 1980s saw increased support for engineering as a field separate from the other sciences. In 1980, NSF's education directorate was disbanded as part of the "Reagan Revolution." However, in 1986, a National Science Board Task Force report discussed the crucial need for quality faculty and instruction in STEM fields at the undergraduate level, which would enable graduates to contribute to the STEM industry. This "Neal Report" charged the NSF to create a set of funding programs that would improve STEM education by recruiting quality faculty and students, developing innovative curricula, and improving laboratories [7]. Precursors to the engineering coalitions were funded as curriculum development projects in 1998 (e.g., Enhanced Engineering Education Experience DUE-8854555 and Integrated First Year Engineering Curriculum DUE-8953553), with the first of the eight full fledged engineering coalitions funded in 1999 as multi-institutional experiments in innovation in engineering education. By 1991, an award was made to Richard Felder of North Carolina State University for a longitudinal study of the effects of innovative teaching (DUE-9150407) and in 1993 prestigious NSF Young Investigator awards were given to engineers Cynthia Atman of the University of Washington (DRL-9358516) and Martin Ramirez of Johns Hopkins University (DRL-9358518). Atman's research examined how first-year engineering students developed strategies for solving open-ended, ambiguous problems that closely resemble problems in the engineering workplace, while Ramirez used research from cognitive science and educational psychology to develop a framework for teaching engineering so students learned how to make appropriate judgments for their work.

More recently, engineering and engineering education have been reevaluated and charged with producing engineers who will function in rapidly evolving technical and business environments. In 1997, the Accreditation Board for Engineering and Technology (now known as ABET, Inc.) released new criteria for accrediting engineering programs called the Engineering Criteria (EC) 2000 [4]. Unlike prior frameworks, EC 2000 focused on assessments of what students learn rather than what their professors teach. In addition, EC 2000 stressed that individual institutions should continue to improve their programs based on their own internal goals.

In 2004, the National Academy of Engineering released a report envisioning how the engineering profession would change by the year 2020 [8]. It was followed in 2005 by another Academy report on how to best educate these future engineers. Among other recommendations, this report suggested that higher education institutions should encourage their engineering faculty members to conduct research in engineering education [9]. In light of this plan, and in an effort to evaluate some progress in engineering education research, the NSF funding patterns for engineering education research were analyzed.

The analysis presented here considered only the abstracts submitted for funded research through NSF. As a starting point, two searches of the NSF Awards listing were performed in January 2007. First, the term "engineering education (EE)" was used to search active, expired, and historical (pre-1976) awards. Second, the term "engineering education research (EER)" was used for all three categories. The earliest projects found to the EE search criteria was 1954 for two conferences on Physics in Engineering Education, one focused on Nuclear Physics and one focused on Solid State Physics. In addition, a project entitled "Study of Physics in Engineering Education" was awarded funding in 1955. It is possible that these projects were linked, although none included an abstract. The first two grants for the EER criteria were in 1985, with one that year for a planning grant for future electrical and computer engineering research and education and one for a conference about environmental engineering education. The EER Active search returned approximately 1280 hits, while the EE Active search returned only 1004. Similarly, the EER Expired search returned 1545 hits and the EE Expired returned 1004. The EE Historical search returned 34 hits, while the EER Historical search returned 0 hits. As expected, there was substantial overlap between the two searches in each category, and deleting duplicate entries resulted in a database of approximately 2900 entries spanning the years from 1986 to 2006. These award abstracts were content analyzed based on several criteria.

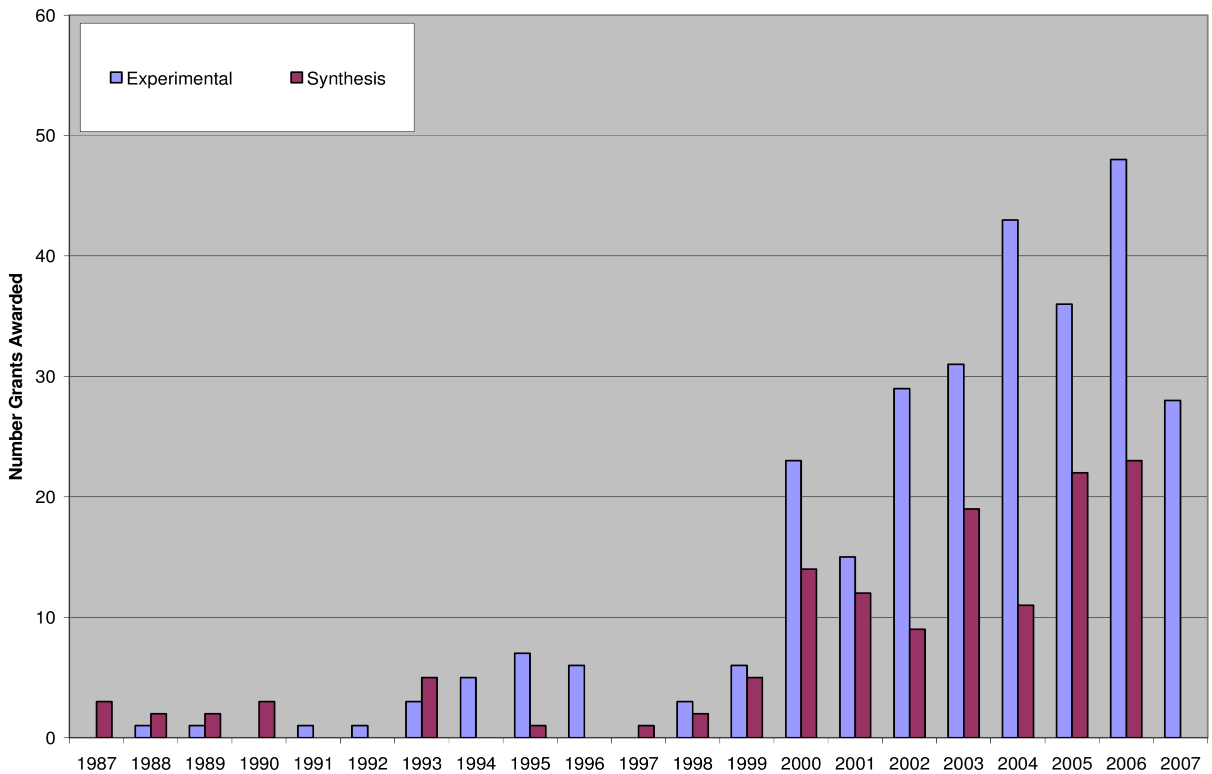
The primary qualification for retaining the grant in the database was whether it seemed to directly support engineering education research. Thus, several types of grants were excluded from the analysis for various reasons. For example, although both scholarships and fellowships may support individuals who conduct engineering education research, they were not included because their primary focus was on monetary support to individuals rather than to research per se. Grants aiming to increase the recruitment and retention of engineering students were also not included unless they specifically tested programs that encouraged recruitment or retention. Similarly, although workshops, conferences, and planning grants may eventually lead to educational research, they were not included in this analysis because the grant itself was not supporting the research. Abstracts that described informal educational components or those that made only vague reference to an educational component were also removed. Finally, grants that primarily supported engineering research activities, such as the Research Experiences for Undergraduates or grants to buy equipment, were excluded.

Grants were then classified into categories based on whether student learning or opinions (or both) were assessed following an educational innovation, whether the research was primarily synthesis research, or whether the research aimed to discover or apply new techniques. The preliminary analysis led to a final pool of 1010 awards, with 588 of those involving some innovation of engineering education that did not describe student assessment of any kind, which were removed for lack of explicit research rigor. However, there were 287 grants that introduced an innovation and then assessed either student learning or opinions, or both (coded as "experimental"), and 134 grants that synthesized past research but did not include assessment of students or faculty (coded as "synthesis"). Although most experimental research focused on student assessment, projects that were aimed at faculty learning were also included. The abstracts of this final pool of 421 grants were examined to assess broad themes as well as NSF areas supporting them. Each abstract was coded by one of the authors (EC). The dates given throughout this analysis are based on when the project was scheduled to begin according to the NSF database, rather than the date the final decision was made to fund the proposal.

Results

Although the present analysis includes the years 1988 through 2007, the majority of the projects were funded after 2000. Figure 1 presents the total grants from these years. As shown, the years leading up to 2000 included fewer than 10 funded engineering education projects per year, while each year since has seen 10 or more funded projects. It should be noted that this analysis took place in the spring of 2007, so the low number for that year should not be considered a trend toward fewer grants for engineering education research.

Figure 1. Number of grants analyzed by year.



Experimental Research

The NSF supports advances in engineering education via several program units, including the Division of Engineering Education and Centers (EEC) of the Engineering Directorate (ENG), and the Division of Undergraduate Education (DUE) in the Education and Human Resources Directorate (EHR). These two divisions supported the majority of the 287 Experimental projects analyzed here. A list of acronyms for the NSF programs discussed in this analysis is in the appendix. Over half of the projects (144, 59.5%) were funded through EHR, and most of those (116, 47.9% of the total) were funded through DUE. Just over a quarter (65, 28.9%) of the projects were funded by ENG. Figure 2 indicates the grants funded per directorate between 1988 and 2007. Figures 3 shows the grants funded per year in the EHR directorate broken down by division, and Figure 4 shows the same information for the ENG directorate.

Figure 2. Experimental grants by directorate, 1988-2007.

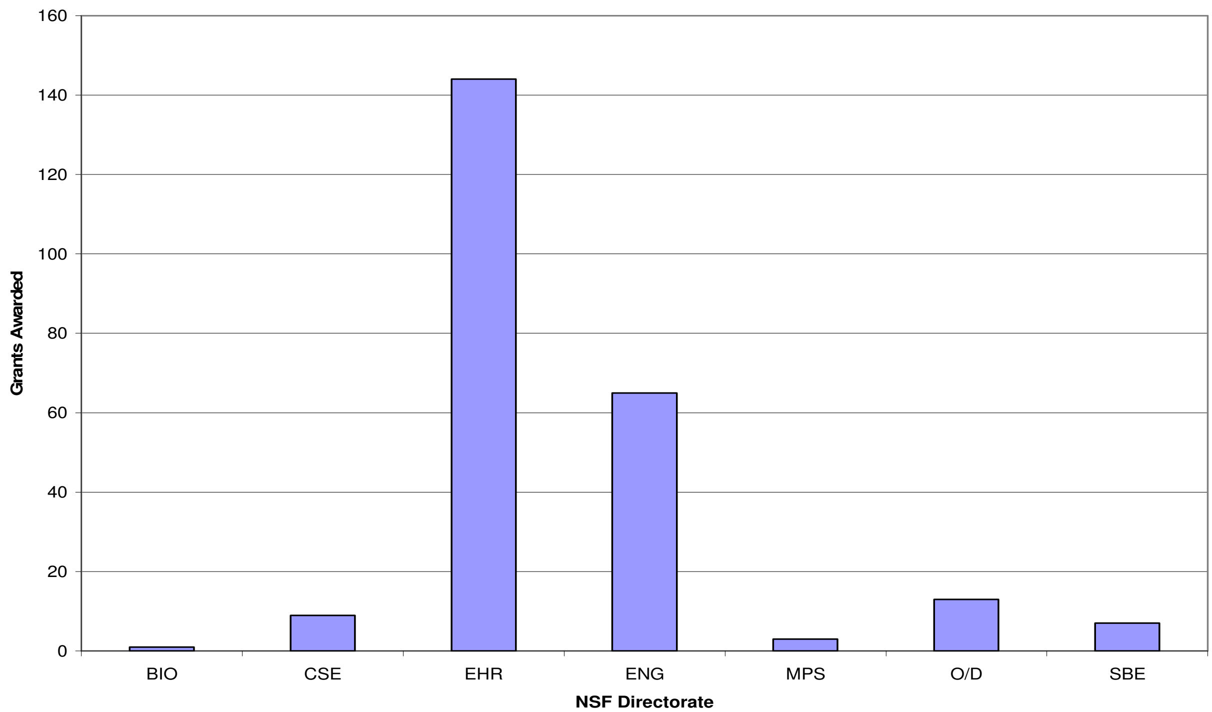


Figure 3. Experimental grants by division of the EHR directorate, 1988-2007.

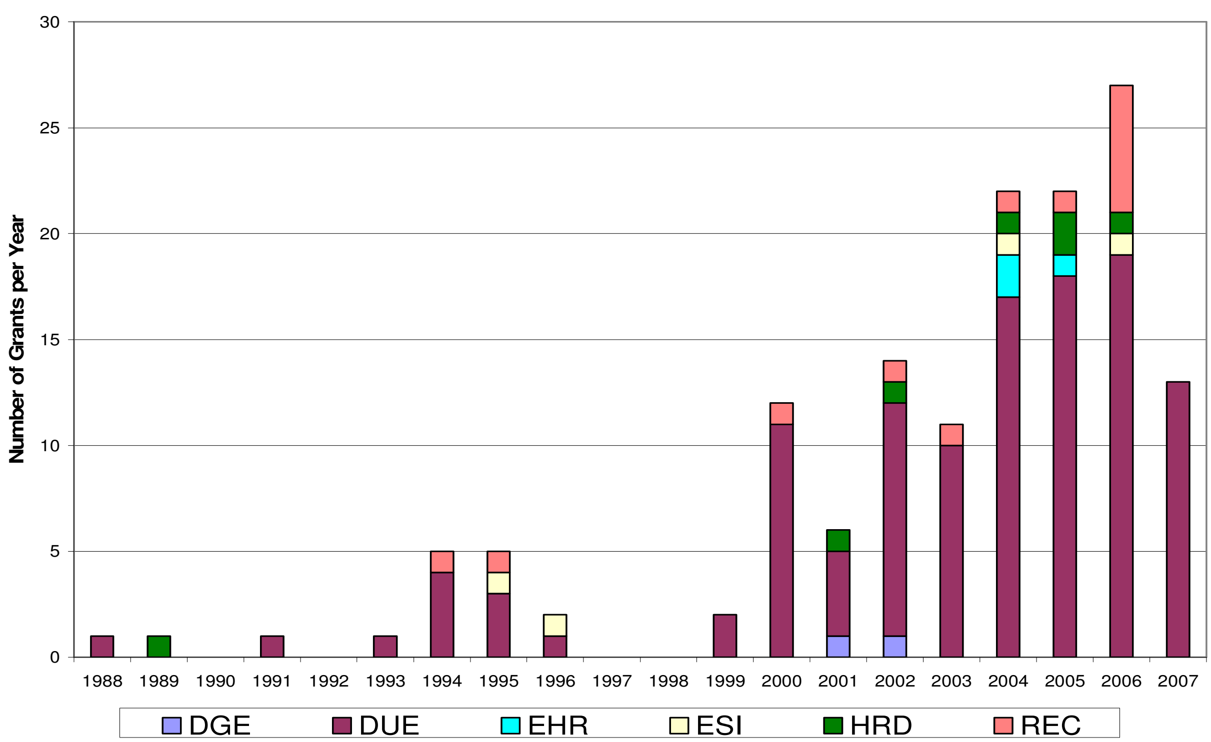
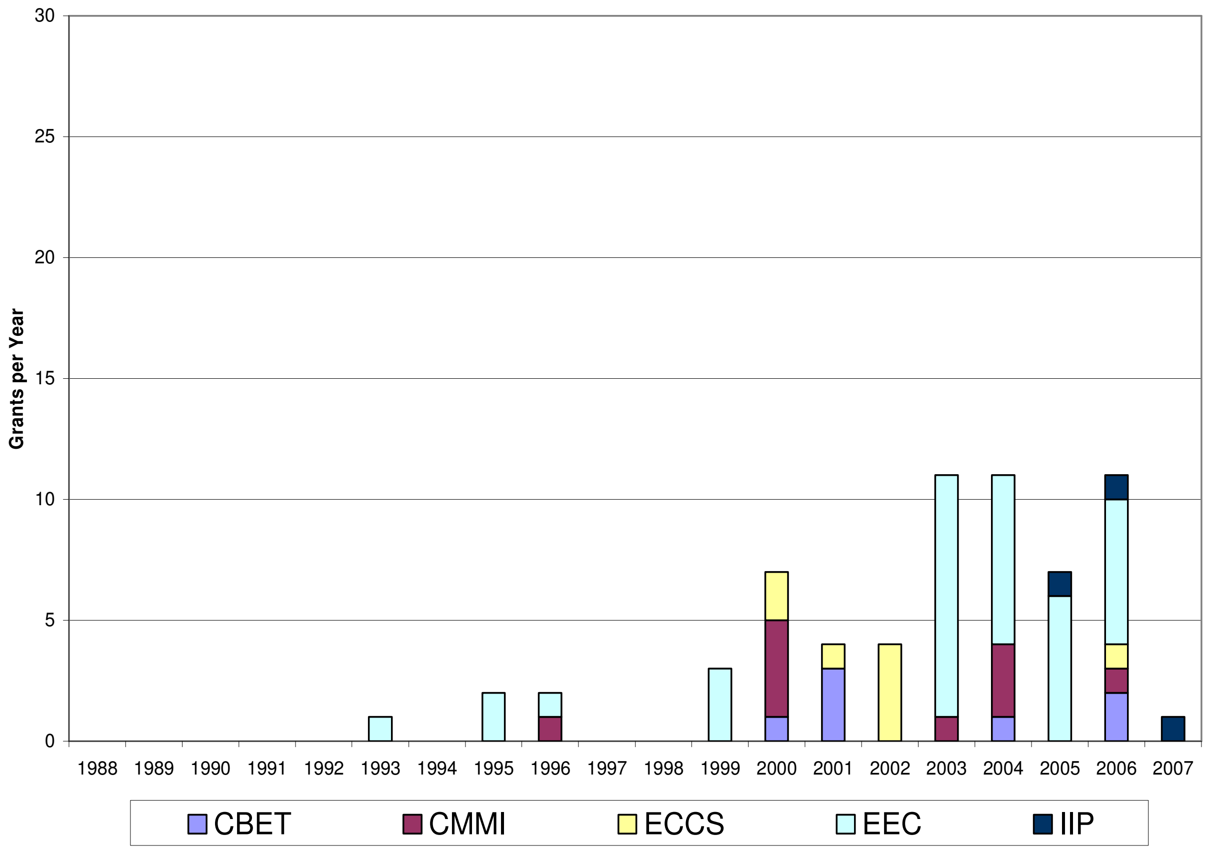
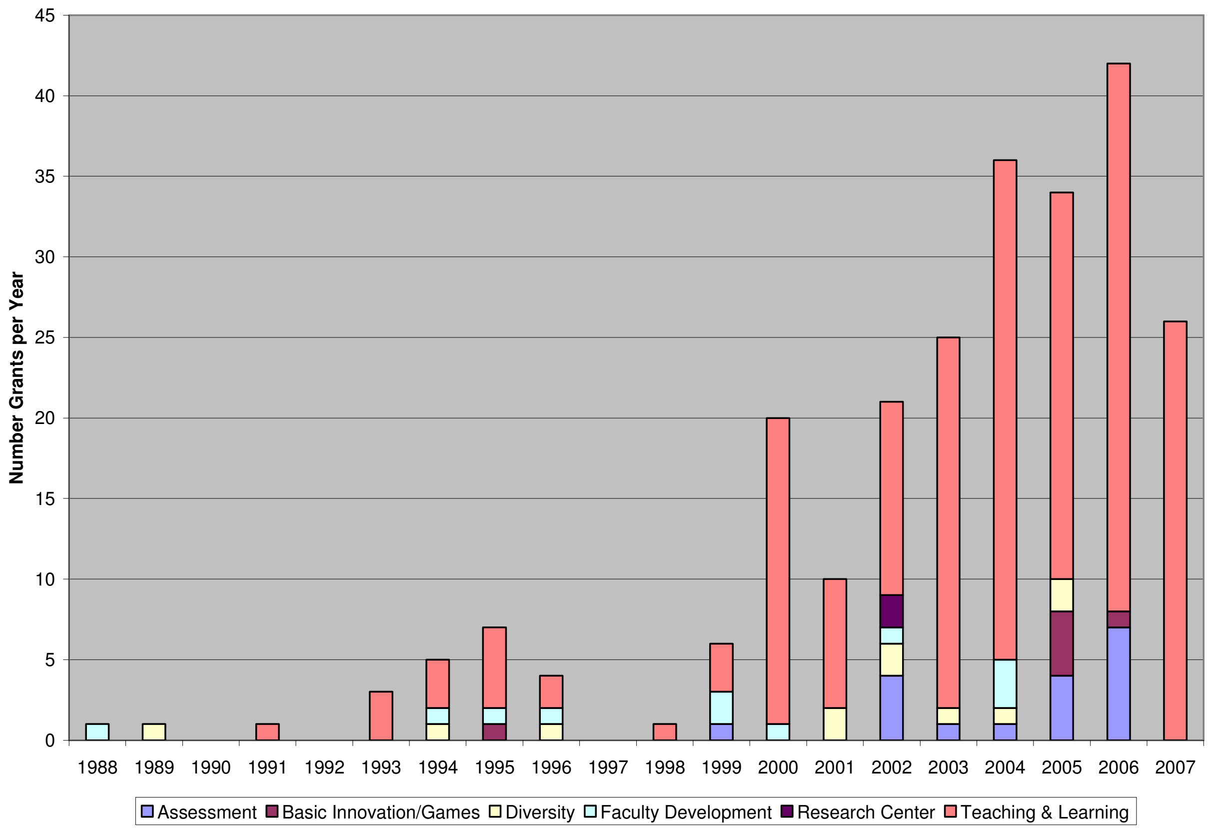


Figure 4. Experimental grants by division of the ENG directorate, 1988-2007.



There were six topical categories of grants coded for the Experimental Research award abstracts, although the Teaching and Learning category encompassed 194 (80%) of the grants analyzed. This broad category included any research on classroom topics or methods of teaching. In addition, 18 (7%) projects were categorized as Assessment, which was related to developing new methods of assessing learning or education. The categories of Diversity and Faculty Development each included 11 (4.5%) of the total pool of grants. The former category related to cultural, racial, or gender differences or encouraging more participation by individuals from populations underrepresented in STEM. To be coded as Experimental, these programs must have included a way to measure increases in the participation, learning, or enjoyment of engineering activities by underrepresented minorities. The latter focused on improving faculty effectiveness. Six (2.5%) grants were categorized as Basic Innovation/Games, which included projects introducing serious games or other technological innovations into classrooms and assessing their effects on learning. Finally, two (<1%) of the grants provided money for specific Centers focused on engineering education research. The topic categories for the Experimental grants are presented in Figure 5.

Figure 5. Experimental research topics, 1987-2007.



Synthesis Research

The 134 abstracts coded as Synthesis were also primarily from the EHR and ENG Directorates. Figure 6 shows the grants funded per directorate between 1987 and 2006, as there were no Synthesis research awards in 2007 as of the analysis. Of the 69 (51%) grants awarded through the EHR Directorate, 33 (48%) were funded through DUE, 16 (23%) through the Division of Human Resource Development (HRD), and 12 (17%) through the Division of Research, Evaluation, and Communication (REC). Figure 7 indicates the Synthesis awards made through the EHR Directorate. Thirty-two (24%) of the Synthesis awards were funded by the ENG Directorate, and 23 (72%) of those were through the EEC Division. Figure 8 shows the Synthesis grants made by the ENG Directorate. Finally, the Directorate for Social, Behavioral, and Economic Sciences (SBE) funded 21 (16%) of the Synthesis awards, with 17 (81%) of those funded through the Division on Social and Economic Sciences (SES).

Figure 6. Synthesis grants by directorate, 1987-2006.

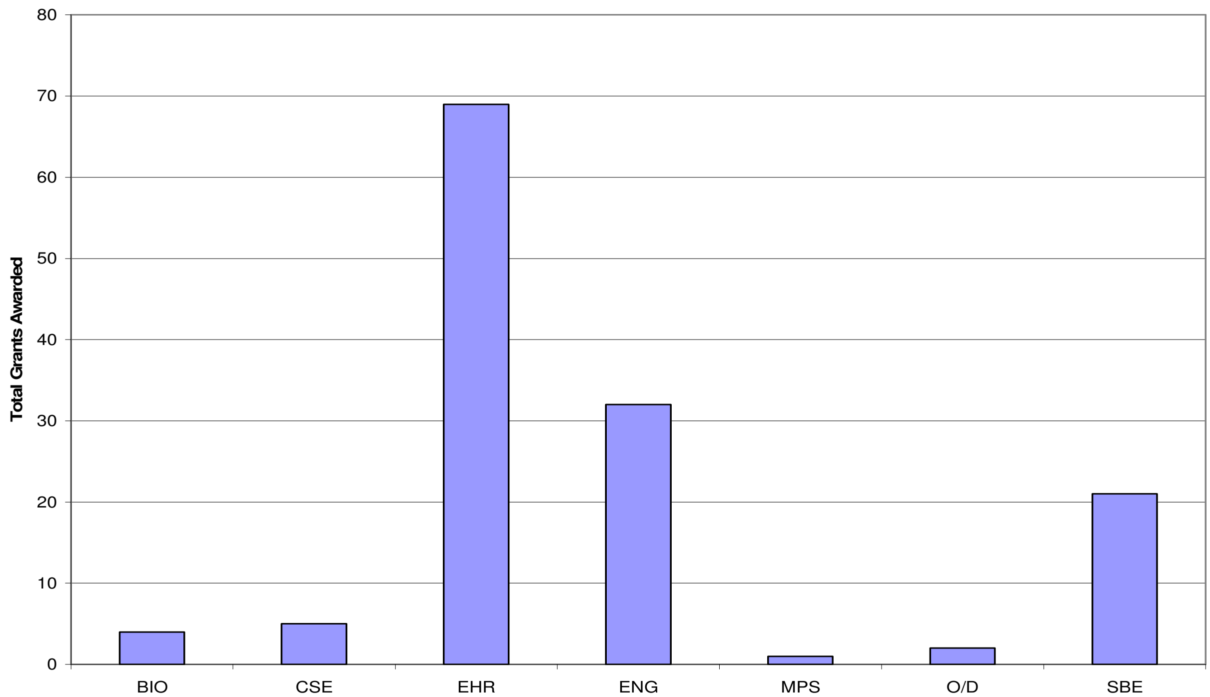


Figure 7. Synthesis grants by division of the EHR directorate, 1987-2006.

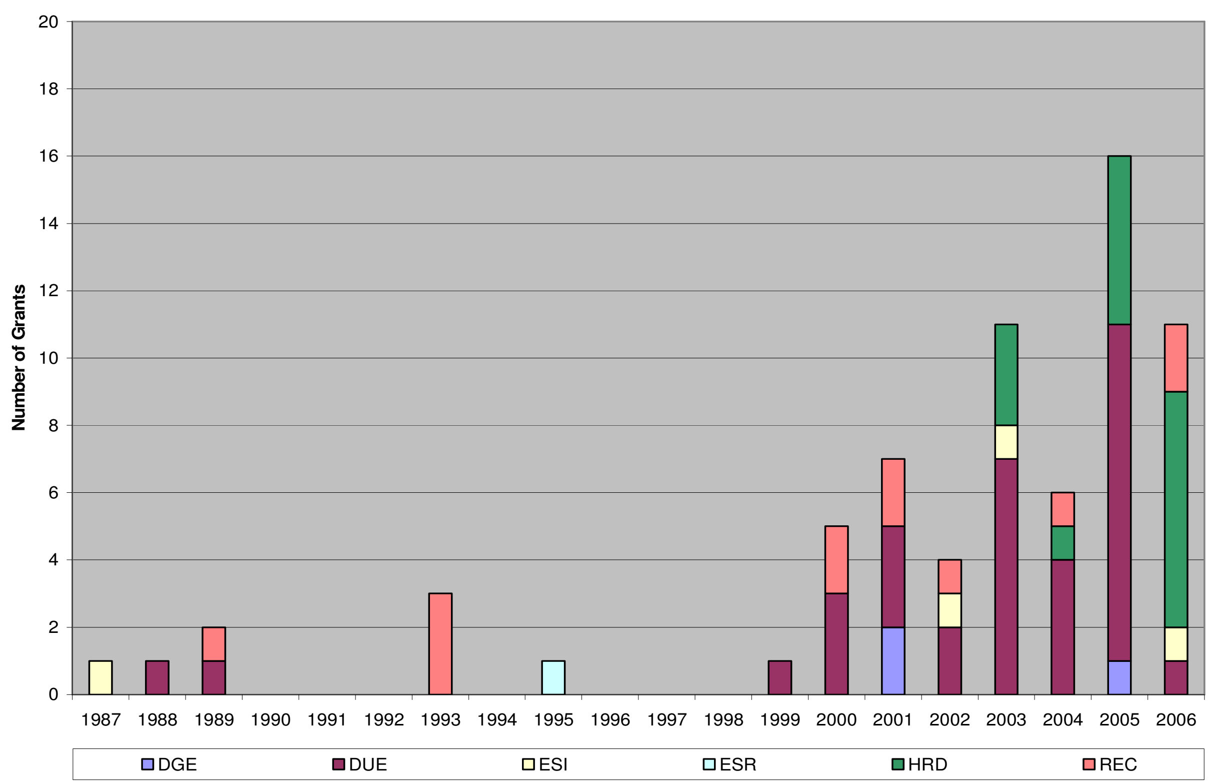
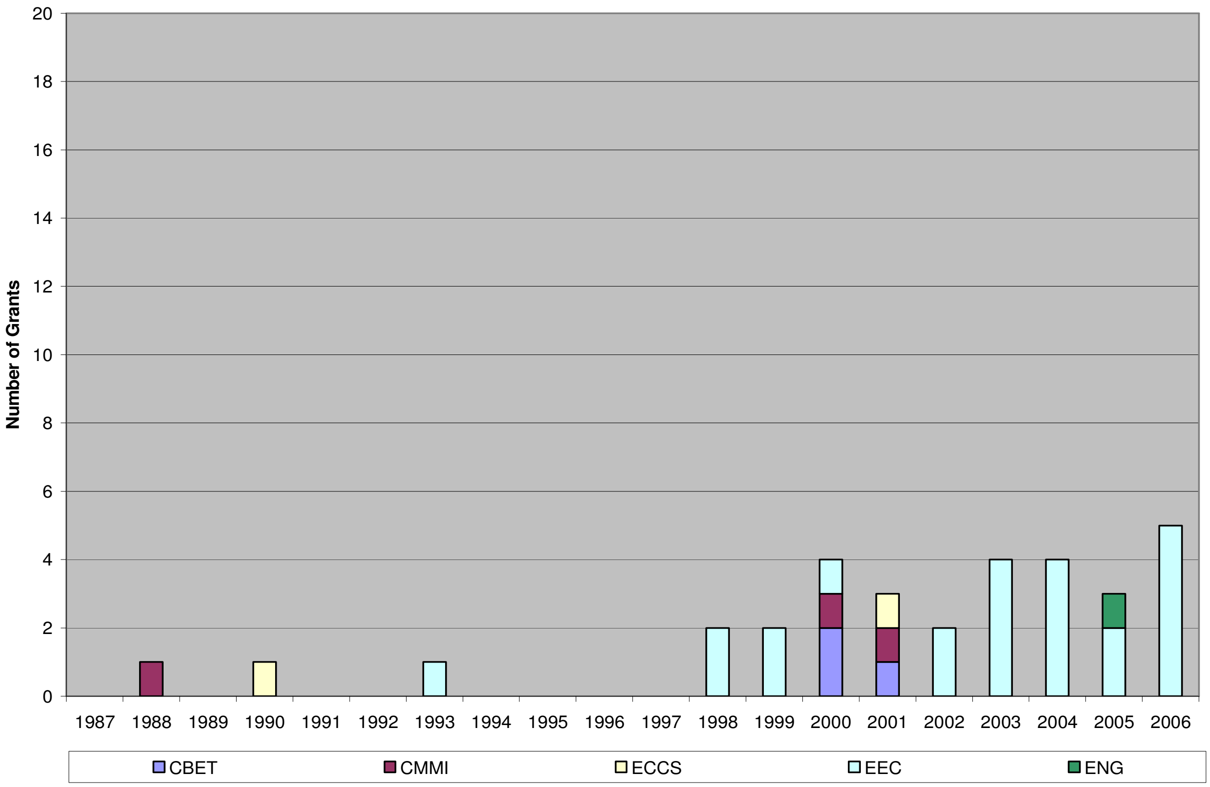
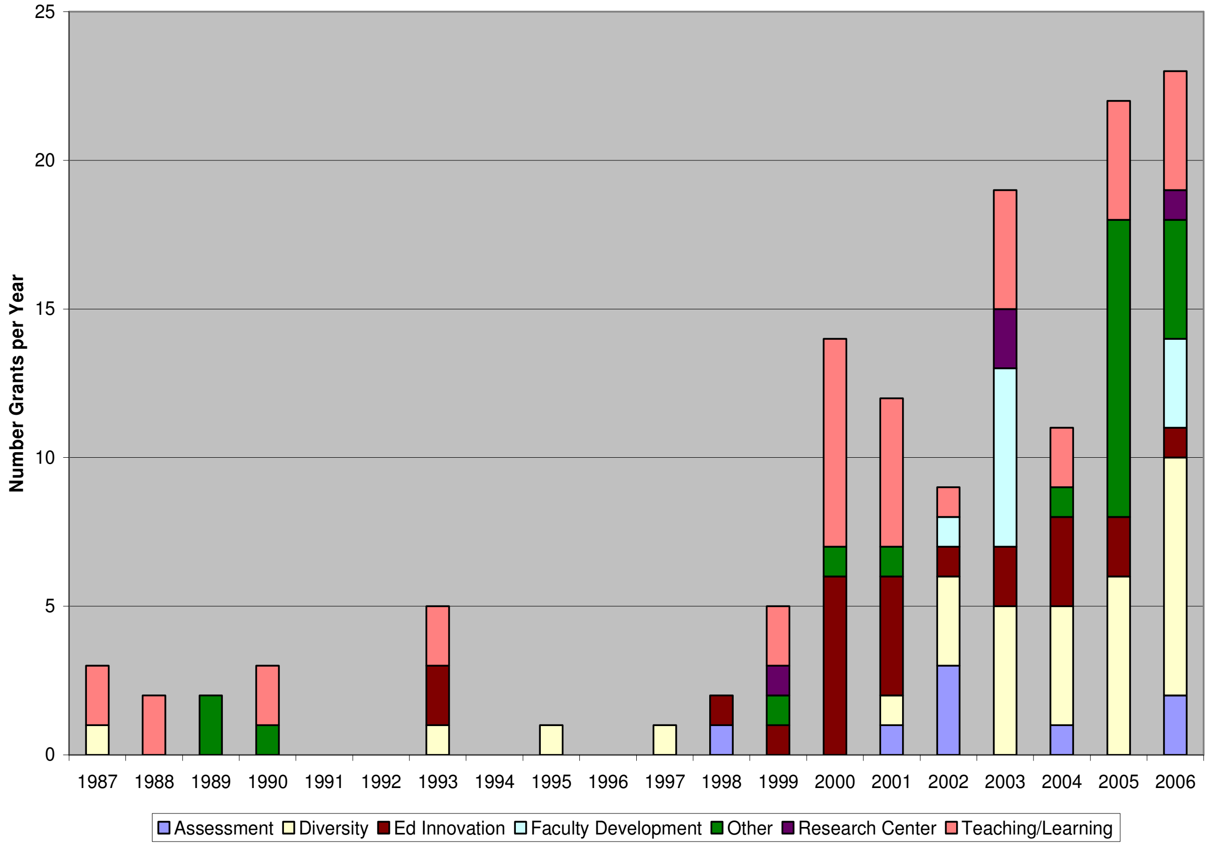


Figure 8. Synthesis grants by division of the ENG directorate, 1987-2006.



Like the Experimental research awards, content analysis for the Synthesis awards produced 6 main categories, although an "Other" category also emerged that consisted of themes mentioned two or fewer times. The Teaching and Learning category included 37 (28%) of the grants, while the Diversity category included 31 (23%). Educational Innovation was the theme of 23 (17%) of these grants, while the Other category included 21 (16%) of the grants. Finally, Faculty Development (10 grants, 7%), Assessment (8 grants, 6%), and Research Center (4 grants, 3%) were themes of the Synthesis research awards. The topics for these awards are presented in Figure 9.

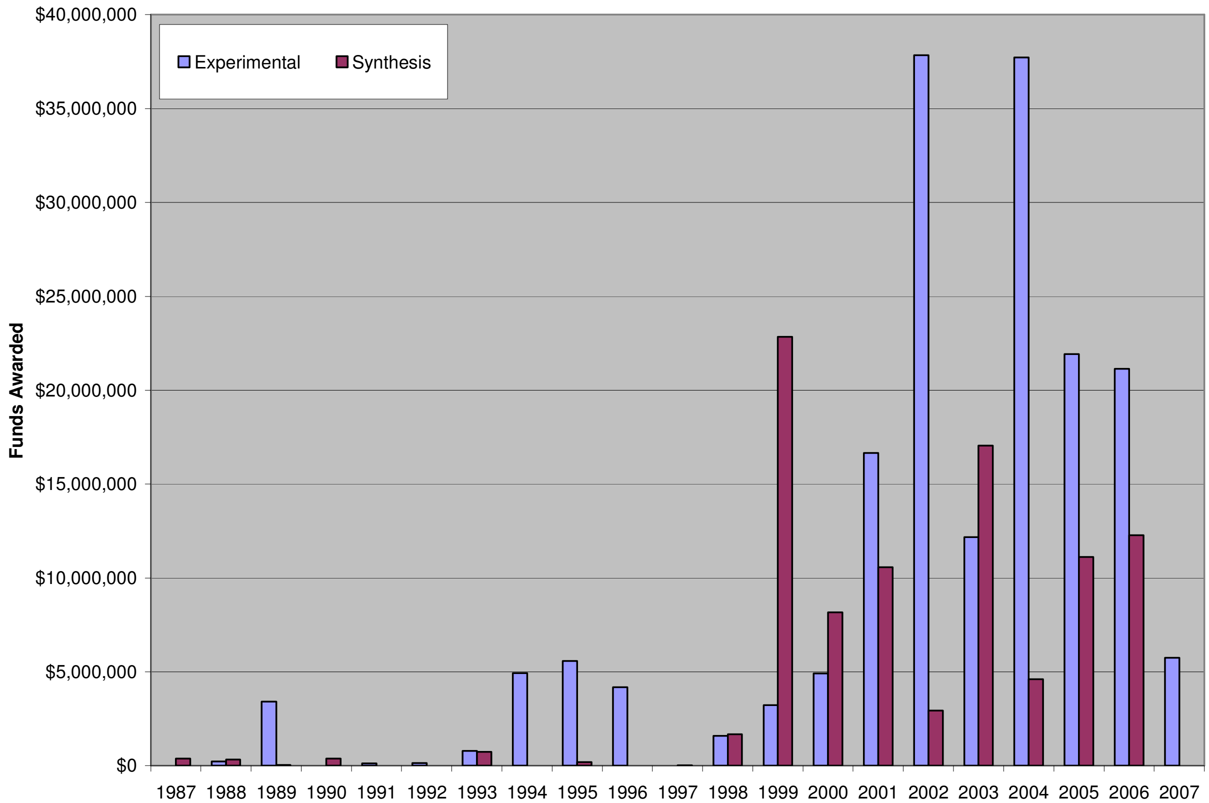
Figure 9. Synthesis research topics, 1987-2006.



Funds Awarded

Although Experimental awards constituted more than twice the number of grants analyzed than Synthesis research Synthesis awards received slightly more average funds. Overall, Experimental awards received $182,299,165, or an average of $635,189 per award. Synthesis awards received a total of $93,363,880, an average of $696,745 per grant. Awards for Experimental research ranged from $9,000 to $22,327,498, while those for Synthesis research ranged from $5,900 to $21,052,138. It is important to note that the present analysis examined funds awarded only and did not distinguish between single-year and multi-year grants. Figure 10 presents the funds for both types of research according to the year the project began.

Figure 10. Funds awarded for experimental and synthesis research, 1987-2007.



Discussion

The present analysis shows two periods of increased funding for engineering education research, a small increase between 1993 and 1996 followed by a much larger increase after 2000. Although causality cannot be determined, several events both internal and external to the NSF may have contributed to this pattern in their funding history. The first funding increase occurred soon after the Office of Engineering Infrastructure Development and the Division of Engineering Centers combined to form the Division of Engineering Education and Centers (EEC) in 1992 [10]. This new division funded a variety of projects, although most of the funding awarded between 1992 and 2001 went to Engineering Research Centers [10]. In 2000, the NSF began to decrease funding awarded to the Engineering Education Coalitions program. This may have contributed to the increase in the variety of engineering education projects funded after 2000. In addition, 2001 marked the start of NSF funding for two multi-institutional engineering and technology education-focused Centers for Learning and Teaching [1], which were headquartered in the engineering colleges at the University of Washington and Utah State University. Not only did the centers themselves receive funding, but as affiliated faculty and graduate students left the institution some may have earned funding for their own projects in their new institutions, which may have contributed to the increase in the number of grants after 2001. Finally, the Engineering Education Program (EEP) at the NSF was revamped in 2006 to have an enhanced emphasis on engineering education research [10], possibly contributing to the large number of funded projects in that year.

External to the NSF, in 1993 former American Society for Engineering Education president Lawrence P. Grayson published *The Making of an Engineer: An Illustrated History of Engineering Education in the United States and Canada* [11]. The book discusses engineering education from prior to 1862 through 1990, and includes over 300 pictures of engineering students and faculty as well as institutions and documents important in the history of the field. Although a single publication is unlikely to have encouraged an increase in research funding, the book may have triggered interest in conducting engineering education research in engineering faculty, and that interest combined with the knowledge of a new NSF Division focused on engineering education may have convinced faculty to apply for funding to develop their own engineering education research projects.

Another external influence on engineering education research could be the EC 2000 criteria adopted by ABET, Inc. (www.abet.org). The new criteria added a focus on defining and measuring learning outcomes and program objectives, and also included a call to use evaluation of these outcomes and objectives to improve the programs [12].

Future Directions

This analysis presents a preliminary examination of trends in NSF funding for engineering education research over the past 20 years. More research is needed to examine further the money awarded according to directorate, division, and research topic. Examining this database according to projected length of the research project would also provide information relevant to future researchers as they plan their work. For example, knowing that multi-year projects dominate certain topics and divisions might help a new faculty member form a research plan that coincides with the trends in the field. In addition, future analysis could examine funds awarded to single-institution projects compared to those awarded to multi-institution collaborations. Other possible future research directions include linking past funding and results to arguments for providing the requisite human, financial, and intellectual resources need for engineering education research to reach its potential as a field of scholarly endeavor with practical applications to the enhancement of engineering learning. Finally, it would be useful to examine this set of funded projects in terms of research taxonomies such as the Engineering Education Research Colloquies report [13] or the research areas offered by the Center for the Advancement of Scholarship on Engineering Education (CASEE)[14]. This could lead to a portfolio analysis that could indicate which areas need further support in terms of either financial help or encouragement of further research.

Caveats

This final database of abstracts included in this analysis may contain some omissions. First, the grants excluded on based on the above criteria may have supported engineering education research but described activities not considered to be research or did not include the research aspect of the project in the abstract. Second, although there were many abstracts that described implementing an innovation in a classroom, relatively few of them also described how the effects of that innovation would be assessed. Abstracts that did not mention any type of assessment (whether of learning or opinions) were not included as research. It is probable that some of the omitted projects did include learning assessment but did not include a description of it in the abstract. It is also likely that many of the projects that introduced an innovation assessed student opinions but did not explain the research design in the abstract. In addition, a very small minority of the awards listed contained no abstract and were thus excluded. Finally, although the search terms were highly inclusive, it is possible that they did not match descriptions of research described in different terms, and thus research studies may have been excluded if the abstracts did not contain the search terms. Although relying only on abstracts to determine patterns of funding for research is problematic, for an analysis of past grants through NSF it is the most reasonable.

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Appendix

Partial List of NSF Directorates, Division, and Acronyms

BIO	Directorate for Biological Sciences	
	DBI	Division of Biological Infrastructure
	MCB	Division of Molecular and Cellular Biosciences
CISE	Directorate for Computer and Information Science and Engineering	
	CNS	Division of Computer and Network Systems
	EIA*	Division of Experimental and Integrative Activities
	IIS	Division of Information and Intelligent Systems
EHR	Directorate for Education and Human Resources	
	DGE	Division of Graduate Education
	DUE	Division of Undergraduate Education
	ESI**	Division of Elementary, Secondary, and Informal Education
	HRD	Division of Human Resource Development
	REC**	Division of Research, Evaluation, and Communication
ENG	Directorate for Engineering	
	CBET	Division of Chemical, Bioengineering, Environmental, and Transport Systems
	CMMI	Division of Civil, Mechanical, and Manufacturing Innovation
	ECCS	Division of Electrical, Communications and Cyber Systems
	EEC	Division of Engineering Education and Centers
	IIP	Division of Industrial Innovation and Partnerships
MPS	Directorate for Mathematical and Physical Sciences	
	DMR	Division of Materials Research
SBE	Directorate for Social, Behavioral, and Economic Sciences	
	BCS	Division of Behavioral and Cognitive Sciences
	SES	Division of Social and Economic Sciences

OCI	Office of Cyberinfrastructure
OD	Office of the Director
OISE	Office of International Science and Engineering

* No longer a division
** Have been combined into DRL (Division of Learning in Formal and Informal Settings)