Panel - Emerging Results: Were the Engineering Education Coalitions an Effective Intervention?

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Abstract - At the time the decision was made to discontinue funding to the NSF Engineering Education Coalitions, data in support of the impact of the coalitions were unavailable. Since then, whether an institution was a member of a coalition has been an important variable in many engineering education studies. In this panel session and paper, we present the results of three such studies and invite the audience to assess the strength of the evidence. Guided audience discussion will focus on whether the results can be used to evaluate the coalitions intervention, related research directions, and implications for future funding.

Index Terms – assessment, coalitions, funding policy, impact

INTRODUCTION

Funded by the National Science Foundation from 1990-2005, eight Engineering Education Coalitions, which included over 40 universities [1], represented a major source of funding for engineering education reform over the past twenty years. While many publications describe the Coalition activities and results while they were funded, the decision to discontinue Coalition funding and the Coalitions’ lasting impact are part of the folklore of engineering education. Many individuals have formed opinions as a result of their own experience within a Coalition or observing as an outsider. Few, if any, publications have attempted to capture the controversy about the lasting influences of the Coalitions or the events surrounding the end of the Coalition funding. One of few publications written after Coalition funding [1] discusses the types of innovations made in engineering classrooms with little mention of how and why funding ended.

The funding model at the time was to award multimillion-dollar contracts to coalitions, i.e., small groups of less than 10 institutions. As a result, about 40 of the approximately 350 institutions with ABET-accredited programs received Coalition funding. For Coalition personnel, institutionalizing reforms at their own institutions was an unexpectedly long and arduous process [2, 3]. By many accounts, the Coalitions were effective in diffusing curricular reforms from one Coalition institution to another. However, bringing the changes to non-coalition institutions proved far more challenging. According to some Coalition personnel interviewed [4], faculty and administrators from non-coalition schools complained that huge amounts of money were going to a handful of institutions and that the investment wasn’t impacting the larger community. NSF-contracted independent assessment of the Coalitions program provided evidence that few faculty and students were directly involved in Coalition efforts, and that diffusion beyond the Coalitions was not occurring as hoped [5]. Since discontinuing Coalition funding, NSF has moved to an engineering education funding model of awarding much smaller, shorter-term awards to a larger number and broader diversity of institutions and investigators.

While former Coalition personnel and centers have continued to track various indicators, larger multi-institution and multi-coalition studies have also included Coalition membership as an independent variable. In this panel session and paper, we present the results of three such studies and invite readers and participants to assess the strength of the evidence as to the impact, if any, of the Engineering Education Coalitions.

The first research to be presented is Robin Adams’ study of career trajectories in engineering education [6]. In investigating the risks of pursuing a career in engineering education, Adams and research assistant Cummings-Bond systematically identified a sample of faculty and future faculty pursuing engineering education careers. At much higher rates than might be expected, these people had completed their PhD at a Coalition school, were currently employed at a Coalition school, or both. The impact of various factors including the Coalitions on engineering education career trajectories is currently being investigated further through an extensive interview study with Cheryl Allendoerfer [7].

Similarly, the Engineering Change [8] dataset currently being analyzed by Lisa Lattuca, Patrick Terenzini, and Betty Harper, includes both Coalition and non-coalition institutions in its sample. Administrators, department heads, faculty, students and alumni from 39 institutions including 14 Coalition institutions were surveyed on faculty activities, administrative policies, and student experiences and outcomes. Faculty and administrators reported on their perceived impact of a wide variety of factors on engineering education reform,
including specific categories of Coalition activities. While faculty and administrators felt certain that the Coalitions had a strong impact, statistical analysis of the results indicates that multiple factors, including but not limited to the Coalitions, contributed to engineering education change during the 1990s. For example, the effect of new accreditation criteria which drove assessment efforts during this time is difficult to separate from the Coalitions, which often developed or tested assessment tools.

The third study to be discussed is more directly focused on the activity, evolution, and potential impact of the Coalitions. Maura Borrego categorized and analyzed the conference and journal publications of four Coalitions by topic areas, coalition, and year [4]. Using theory for the development of academic disciplines, she was able to show that while the Coalitions initially focused on reform, their efforts shifted over time to include assessment and some research. The argument was made that the Coalitions were a necessary learning experience for engineering education to evolve to its current state of debating rigorous research.

The goals of discussing these studies in one session are to (1) synthesize findings and methods across a broad range of studies, (2) actively engage the audience to critically evaluate the results in light of Coalition goals, and (3) generate ideas for future funding policy and research directions. The expected outcome is new insights into (a) the impact of the Coalitions if any, (b) evaluation of large-scale interventions, and (c) funding policy in engineering education. Evaluation of the Coalitions intervention is a complex problem, requiring critical assessment of the evidence and synthesis across multiple studies. This can only be achieved through active participation from an audience with varying perspectives and experience with the Coalitions.

**CAREER TRAJECTORIES: ADAMS**

During the period of the Engineering Education Coalitions, conversations often focused on the perils of pursuing an engineering education career in academia, particularly for junior faculty and graduate students. As national attentions turned towards building capacity in scientific research in education, new programs emerged that focused on developing engineering education researchers. This has prompted new concerns over the risks associated with pursuing an engineering education career in academia and questions over the impact of programs that sought to influence the culture of engineering education. Many of these risks involved finding academic positions and successfully navigating the academic reward structure. Questions about career paths persist: are engineering educators finding academic positions and successfully navigating the academic reward structure? What kinds of positions at what kinds of higher education institutions? Similarly, are engineering educators advancing to positions of higher rank? What kinds of factors influence engineering education career trajectories?

To answer these questions, we conducted a comparative study across three groups over a period of approximately ten years using publicly available data [6]. The timeline allowed opportunities to see noticeable changes in career patterns and to compare across perceived risks associated with different kinds of academic career decisions. The first group, hypothesized to be the most risky group, included recipients of doctoral degrees who completed a thesis topic in engineering education during the period of 1990 to 2003 (N=109). As an interdisciplinary topic, degrees were granted in a variety of programs (e.g., colleges of engineering, education, public policy, and psychology). The second group included recipients of the Apprentice Faculty Grant (AFG) (N=19) from 1997 to 2002. The AFG is awarded to graduate students and non-tenure track professionals who have been recognized for their present and future potential contributions to engineering education. The third group includes recipients of National Science Foundation CAREER grants, a grant program that seeks to help young faculty obtain tenure and develop an area of research, from 1995 to 2003 (N=474). One aspect of the grant is preparing a plan for integrating research and education activities. By using the internet and multiple sources to check accuracy, information was gathered that provided insights into (1) the nature of current employment (e.g., assistant professor, associate professor, instructor, professional staff, or industry), (2) the nature of current institution (e.g., Carnegie classification, accreditation region, participation in Coalitions program, or having an engineering related teaching and learning center), and (3) the nature of PhD granting institution.

A summary of results for the variables associated with Coalition schools suggests that the Coalitions may have had an impact on the culture of engineering programs in terms of granting engineering education related doctorates, employing individuals who have a career emphasis on engineering education, and receiving faculty CAREER grants. In particular:

- Subjects who pursued engineering education careers were almost twice as likely to have earned their PhD from a Coalition school than they were to work at one.
- AFG recipients are substantially more likely to be employed at a Coalition school (63.2%) or a school with an engineering education related teaching and learning center.
- More than half of the AFG recipients were educated at Coalition schools, and of those who are employed in tenure or tenure-track positions one-third were educated at Coalition schools.
- One-third of the CAREER recipients group are currently employed at Coalitions schools – which represent less than 15% of all possible engineering programs.

For this panel discussion, results of this study will be presented to encourage conversations around ways for articulating the impact of the Coalitions.

**ENGINEERING CHANGE STUDY: LATTUCA, TERENZINI AND HARPER**

In 2003-04, a research team from the Center for the Study of Higher Education at Penn State collected data from engineering deans, program chairs, faculty, graduating seniors from the class of 2004, alumni from the class of 1994, and...
These analyses indicate that program chairs and faculty view influences (including the NSF Coalitions in the aggregate, chairs and faculty members attributed to each of 12 separate Multivariate analyses isolated the unique contribution that what extent the Coalitions influenced these changes. course they teach regularly. Next the researchers asked to given to engineering design (56%) and teamwork (52%) in a reported "some" or a "significant increase" in the attention design (75%). More than half of the faculty respondents curricular emphases in teamwork (85%) and engineering more of responding program chairs reported increased and those that did not participate. Space limitations prevent a full reporting of these results here.

Lattuca, Terenzin, and Harper also examined the influence of the Coalitions on curricular change nationwide. In these analyses, the researchers control for Coalition participation status in order to provide an overall estimate of the role of the Coalitions in promoting curricular reform.

A number of the NSF Coalitions promoted instruction in design and teamwork [9], so the researchers were particularly interested curricular changes in these areas. Three-quarters of more of responding program chairs reported increased curricular emphases in teamwork (85%) and engineering design (75%). More than half of the faculty respondents reported “some” or a “significant increase” in the attention given to engineering design (56%) and teamwork (52%) in a course they teach regularly. Next the researchers asked to what extent the Coalitions influenced these changes. Multivariate analyses isolated the unique contribution that chairs and faculty members attributed to each of 12 separate influences (including the NSF Coalitions in the aggregate, industry feedback, ABET accreditation, and faculty initiative). These analyses indicate that program chairs and faculty view the Coalitions as a significant influence (net of all other influences) on a number of curricular changes at the course and program levels. Program chairs viewed the Coalitions as influencing changes in emphases on technical writing, experimental methods, foundational math, project management, and the use of modern engineering tools. Reporting on a course they regularly teach, faculty respondents indicated that the NSF Coalitions were a significant and independent influence on the changes they made in their emphasis on verbal communication and modern engineering tools, and (marginally) on teamwork. None of the significant beta weights for the different sources of influence is very large, suggesting that that a number of factors, rather than one or two primary ones, are driving program and course changes in engineering programs. Engineering programs appear to be responding to a number of convergent forces, rather than simply to the Coalitions, ABET, or industry.

**COALITION PUBLICATION ANALYSIS: BORREGO**

Recent calls for increased rigor in engineering education research have included harsh criticism of prior reform-based approaches such as those of the Coalitions. Guided by a framework of criteria for a research discipline [10], publications of four Coalitions with active web sites were analyzed to quantify the extent to which engineering education work from 1990-2005 can be considered research. Overall, the results were indicative of a reform-based approach to engineering education work. The overwhelming majority of publications were conference papers, most often describing a classroom “experience” with or without assessment data to evaluate the intervention.

When the results were plotted over time, however, a progression toward more rigorous work could be observed over the 15-year funding period. The population of focus shifted gradually from students (principally freshmen) to faculty. Methodology shifted away from classroom-based activities in favor of faculty development and assessment. The contribution format remained dominated by reports of experiences, but included increasing research-type studies featuring theory, controlled experiments, or quantitative results. Using models of engineering education reform and inquiry, the conclusion was drawn that the learning experience of the Coalitions and Coalition personnel, from reform work to assessment and finally research, was a necessary experience for the field to be at its current state of debating and defining rigor.

Citation analysis revealed more opportunities for engineering education to progress by building upon prior work. This analysis focused on the 74 journal articles generated by the four Coalitions over 15 years (under 10% of all publications). Many were not in journals tracked by Web of Science, which calculates the impact factors engineers use to rank journals. Only 29 of these articles were cited by other works for a total of 92 citations, with over one-third of the citations occurring since 2005. Many articles were cited only once; the maximum was 9 times. These low numbers point to both a non-research focus during the Coalition time period and the need for current engineering education researchers to situate their work with respect to prior efforts.

A second data source for this study was interviews with Coalition leaders and prolific authors to react to the initial results of the publication analysis and answer questions of their motivations and perceptions during that time. Many raised the issue that engineering education work was not valued as research by promotion and tenure committees. Some viewed the work as research, which should first be presented at a conference for feedback and then refined for journal publication. Nearly all participants cited difficulties with uninformed reviewers and phenomenally high rejection rates.
for engineering education journals as opposed to conferences, which accounts for the disproportionate numbers listed above.

Where leaders and authors differed was in the impact of the Coalitions on where engineering education is today. Authors who only worked with the Coalitions on their own campuses believed that Coalition efforts and programs would have happened anyway but that having the money available at the time was helpful. Coalition leaders (not necessarily university administrators) were far more adamant that the Coalitions drove engineering education and made it what it is today. Many of these participants expressed frustration that little evidence is available to prove to others what they firmly believe was the true contribution of the Coalitions. These two types of insider perceptions raise important questions as to the isolated impact of the Coalitions, separate from faculty initiative and other efforts of the time.

DISCUSSION QUESTIONS

Proposed questions for discussion at the session are:
• Were the Coalitions an effective intervention?
• Are the results conclusive and convincing to skeptics?
• What questions remain to be answered, and what is needed to answer them? Should more studies focus on the Coalitions and/or should they remain a variable in comparisons across institutions?
• What are implications for future funding in engineering education and their connections to prospects for systemic reform?

In the following sections, Jeff Froyd, former Foundation Coalition director, addresses two of these.

WERE THE COALITIONS AN EFFECTIVE INTERVENTION? (FROYD)

The SRI progress report on the engineering education coalitions states that the “Engineering Education Coalitions Program was established to create broad-based institutional collaborations aimed at establishing ‘bold, innovative, comprehensive, and systemic new models for undergraduate engineering education’” [5]. If this was the goal, and impartial observers examined engineering curricula both in 1990 and 2007, they would be hard-pressed to conclude that engineering curricula in 2007 represent bold, innovative, comprehensive transformations of the engineering curricula of 1990. The change model underlying the Coalitions Program was that if a group of institutions developed, implemented, assessed, and institutionalized a set of innovations with extensive funding, then these innovations would be rapidly adapted and adopted across a broad spectrum of institutions without significant funding. As a result, one of the research questions implicitly, if not explicitly, addressed through the Coalitions programs was the degree to which the proposed change model was valid. Evidence from the Coalitions Program, as presented in the studies cited in this paper and elsewhere [11–14] has raised serious questions about the validity of the change model. Also, it appears that NSF thought that revisions to the change model might be required as it created the Action Agenda for Systemic Engineering Education Reform program in 1998 [15]. The Action Agenda program provided funding for institutions to adapt and adopt curricular innovations that had shown positive results elsewhere, including the Coalitions program. However, the Action Agenda program lasted only two years (NSF 98-27, NSF 99-169). Based on these results, it appears that the Coalitions Program as an intervention to achieve the stated goals was less than completely effective.

In addition to the question of whether the Coalitions Program accomplished its stated goal, other questions about the degree to which it influenced engineering curricula can and should be raised. The Coalitions Program covered 15 years and in that period of time may have had substantial influence on the development of engineering curricula. One research question that might be studied is a cost-benefit analysis. Since it might be difficult to quantify the benefits of the Coalitions Program, one way to address this question would be to compare the influence of the Coalitions Program with another large program that is intended to have systemic influence, the Engineering Research Centers (ERCs). The following analysis and computations will show that the cost of the educational initiatives in the ERC program is about 65% of the cost of the Coalitions Program. Eight engineering education programs were funded at an approximate total cost of $200 million. Six of the Coalitions were funded for ten years at approximately $30 million apiece. The other two Coalitions were funded for three years each from a technology reinvestment initiative, so $200 million is a conservative estimate. To date, 43 Engineering Research Centers have been funded. If each ERC is funded for ten years at $3 million per year, the total amount committed to the ERC program to date has been approximately $1.290 billion. Each ERC must have an educational component, although the main emphasis of an ERC is not education. As a conservative estimate, approximately ten percent of each the total ERC commitment might be assigned to education. Using this estimate, then approximately $129 million have been invested in ERC educational initiatives, which is about 65% of the amount that was invested over the course of the Coalitions Program. Has the influence of the ERC program on engineering education been about 65% of the influence of the Coalitions Program? This author has not found a published analysis that suggests that the influence of the ERC program on engineering education has been even close to half of the influence of the Coalitions program. The study by Lattuca et al. shows no influence of the ERC program. The above cost-benefit analysis of the Coalitions Program, coupled with positive results from Adams [6] and others, indicates a positive return on investment. Finally, this author has been unable to find much evidence that educational innovations developed at one or more ERC institutions (especially if the VaNTH ERC [16] is excluded) have been transferred to other institutions.

Another research question raised in this paper is how much influence the Coalitions Program had on engineering education. The evidence presented in this paper suggests that the influence of the Coalitions Program was more extensive than concluded by either informal pundits or the SRI Progress
Report. Based on the study by Adams and Cummings-Bond, the Coalitions Program had a substantial influence on the numbers of people now doing engineering education research. In its stated goals, the focus of the Coalitions Program was curricular change. In the study by Adams and Cummings, the focus is on changes or additions to the capacity of people. In this study, it appears that the Coalitions Program has an influence on the number and perhaps the preparation of people conducting engineering education research which was larger than might be expected from the number of institutions participating in the Coalitions Program. Results from the study by Lattuca et al. show that faculty members and chairs acknowledge the influence of the Coalitions. Although the Coalitions Program did not appear to be a single, significant influence for comprehensive, systemic reform, given the pride of ownership that engineering faculty have for the curricula that they fashion, it is difficult to conceive that they would ever acknowledge a single, significant influence that drove them to reform their curricula. Finally, Borrego's extensive analysis of the publications from the Coalitions shows the influence of the Coalitions Program conceivably has had on the rise of research in engineering education and on the potential emergence of engineering education as a recognized discipline. Perhaps one conclusion that can be drawn from these studies is the need for broader definitions, descriptions, and considerations of impact; methodologies through which these definitions, descriptions, and considerations may be studied (in addition to the methodologies presented in this paper); and actual studies that explore influences of programs intended to achieve systemic reform.

**IMPLICATIONS FOR FUTURE FUNDING FOR SYSTEMIC REFORM: FROYD**

There have been at least two significant changes in how NSF funds work in engineering education. First, the structure and funding priorities for the Course, Curriculum, and Laboratory Improvement (CCLI) program were changed in 2005 to support a five-component “cyclic model of knowledge production and the improvement of practice” [17]. Second, the Division of Engineering Education and Centers (EEC) changed its program solicitation to emphasize research into how students learn engineering. These changes appear to respond to the perception of the need for more and more rigorous research in engineering.

However, to provide funding intended to catalyze systemic reform, greater clarity regarding the nature of systemic reform is necessary. Froyd and Watson described four criteria for recognizing system reform:

- Systemic reform increases the capacity of an institution to continuously create responsive curricula.
- Systemic reform is sustainable.
- Systemic reform is recognizable.
- Systemic reform is replicable [18].

These criteria may need revision, but efforts aimed at systemic reform should begin with criteria for recognizing the extent to which it has occurred. Also, Froyd, Penberthy, and Watson have argued for distinction between educational experiments, which may provide knowledge required for improving engineering education, and change efforts that are aimed at actually improving engineering education [19]. It is thought that these are distinct initiatives and should be funded and reviewed separately. Attention to change efforts might focus on faculty development [2] and decision processes that faculty members use to make choices about pedagogy, course design, and curriculum design. For example, for CCLI projects intended to move from classroom projects to dissemination and institutionalization projects (Phase II and III projects), fundamentally different expertise may be needed. Just as course and curriculum development projects need to be informed by research on student learning, projects for dissemination and institutionalization need to be informed by the growing bodies of knowledge on change and faculty development. These bodies of knowledge form part of the third area of research: Engineering Learning Systems, which was identified in the research agenda by the Engineering Education Research Colloquies [20]. Dissemination and institutionalization may need to be treated as distinct applications of this area of research.

**CONCLUSIONS**

Taken together, these studies suggest a need to redefine the goals, or at least the underlying assumptions, of the Coalitions and engineering education reform. While arguments for reform focus on maintaining national competitiveness via increasing numbers of well-trained engineers and research on student learning [21-23], there is another “people” aspect of engineering education becoming increasingly important to change: development of faculty, administrators, and other engineering education researchers. In each of the studies presented, the interests, activities, learning and perceptions of faculty and other personnel is highlighted as an outcome. As engineering education moves forward and considers research capacity (the personnel capable of conducting engineering education research) and results (how people learn engineering), success in innovation and systemic reform may depend as much on attention to faculty development and institutional change as on the results of rigorous engineering education research.

**REFERENCES**


