The Current State of Engineering, Science and Mathematics Education Centers in the United States

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ABSTRACT: *The objective of this work is to contribute to the understanding of current practices of engineering, science and mathematics education centers in the United States through an extensively distributed survey of center directors. The survey assessed (1) sources of funding, (2) types of pre-college outreach activities, (3) activities related to improvement of teaching in higher education, and (4) methods of promoting collaboration between faculty. Also collected were recommendations, based on the experience of the survey respondent, which would help others develop a successful center. This study was initiated to assist the University of South Carolina in the development of its own Center for Engineering and Computing Education; the results may help others with similar aspirations.*

1   INTRODUCTION

There is a growing trend for universities in the United States to develop so-called "Centers for Engineering (or Science or Mathematics) Education." Such centers may focus on outreach to primary and secondary school systems, on preparing future faculty, on improving teaching in higher education or other areas not historically addressed by the university's teaching, research or service mission. A survey of such centers throughout the United States was recently conducted in order to understand current practices. This paper describes the survey administration, analyzes the responses, and makes recommendations for future directions.

2   METHODOLOGY

The survey was sent to 271 centers. Many of these were identified with the internet search engine Google ™ by using key words and phrases like "center for engineering education." Also, all universities in the United States that have engineering programs were identified from the list maintained by the Accreditation Board for Engineering and Technology (www.abet.org). Then the web sites of those engineering colleges and departments were browsed in search of programs for improving college teaching or for K-12 outreach. In addition, some centers located by these two methods had links to other centers in the target demographic; the latter were also added to the center contact list. It should be noted that the process to survey the centers involves a non-probability method of sampling. The degree to which the sample differs from the total population of science, technology, engineering and mathematics (STEM) education centers is unknown. In fact, the total number of STEM education centers in the United States is also unknown. Nevertheless, the large number of centers identified through this process is considered sufficient for identifying trends and themes currently being explored.

The survey instrument was designed to be short, easy to complete, and not ambiguous. The survey consisted of the following questions.

1.   Do you want a copy of the survey summary report?
2.   Does your center involve faculty from multiple colleges/departments? If yes, which colleges / departments are involved?
3.   How is your center primarily funded?
4.   Is your center involved in K-12 programs? If yes, which programs?

5. Does your center have activities related to improvement of teaching in higher education? If yes, which programs?
6. Does your center promote collaborations between faculty in Education and faculty in Science, Mathematics and/or Engineering?
7. Please, give us one recommendation, based on your experience, that would help us develop a successful center.
8. Please, give us the following: center name, your name, position, address, e-mail.

Questions 3, 4, 5 and 6 also included multiple choices that could be selected in response, e.g. "by NSF" for question 3. The questions also included spaces for written responses.

The survey was administered by sending a personal email to the director of each center. The email included the survey as a Microsoft ® Word attachment that could be filled out electronically or by hand and returned by email, fax or mail. The email also included a link to an HTML version of the survey that was located on the website of USC's Center for Engineering and Computing Education (http://cece.engr.sc.edu/SMETsurvey.html). Thus, the center contacts were given four methods to choose to complete the survey; most chose the web-accessible version of the survey to complete.

3 RESULTS

The survey methodology resulted in the return of 173 completed surveys. The remarkable response rate of 73% is attributed to the process of survey administration, the short length of the survey, and the enthusiasm of the center directors for improving STEM education. The responding centers can be classified into eight demographic categories to facilitate data interpretation. The categories are described in Table 1. They were developed based on the centers' responses to Question 2 on the survey and on information posted on their websites.

Approximately 11% of the centers that responded focus explicitly on engineering education at the pre-college or college level and are associated with one or more universities. Such centers are categorized as "engineering education centers" in this research. Engineering faculty and departments are also involved with some of the centers in other categories. These include the "education and science/engineering" centers that focus on science or mathematics education and the "university wide" centers that support all colleges including the STEM disciplines. Centers in the demographic category "university consortia" involve multiple schools and have a science

Table 1. Demographics of Centers Responding

Type of Center	Description	Number of Centers	Percent of Total
Education and Science/ Engineering	Collaborative center involving Education and Science or Math; may also involve Engineering.	46	27%
University Wide	Associated with university administration and engages all colleges.	40	23%
Research Center	Primary mission is STEM research.	27	16%
Engineering	Situated in a College of Engineering and focused on engineering and/or computer science education; May collaborate with other colleges.	19	11%
University Consortia	Involves multiple universities in STEM education programs.	16	9%
Education	Situated in a College of Education; No explicit STEM collaborators	9	5%
Science	Situated in a College of Science and Math or Arts and Sciences; No explicit Education collaborations.	8	5%
Nonprofit	Non-profit organization engaged in STEM education.	8	5%
Total		**173**	**100%**

or mathematics, but not engineering, focus (see Table 1). An interesting finding was that the responses of 27 research centers included educational programs, for example the Materials Research Science and Engineering Centers (www.mrsec.org).

3.1 Funding Sources

The survey asked centers how they were funded. Over 80% of the centers indicated State or university support. Slightly over 44% reported funding from the National Science Foundation, 42% from private sources, and 17% from other federal agencies. Other sources of support include user fees and tuition. Table 2 shows a breakdown of funding sources for the different center demographic categories. The engineering education centers are slightly more likely to be funded by the State or university, by NSF, and by other sources than is the total population of centers. The most striking contrast is that about 80% of the engineering education centers receive support from private sources and donations, which is almost twice the value of the population. The results of this survey question suggest that centers for engineering education are more likely to have the financial support of multiple and more varied sources than other centers.

3.2 K-12 Education Programs

Approximately 70% of all centers reported an involvement in K-12 education. Centers reported programs involving on-campus programs for in-service teachers and K-12 students, outreach programs where university students, staff and faculty go into K-12 classes, and on-campus programs for pre-service teachers. About 56% of the centers bring in-service teachers on campus for various programs and activities. A significant number of centers also send university personnel into the K-12 schools: 41% send students, 40% send staff, and 35% send faculty. Other frequently reported activities include on-campus programs for K-12 students and for pre-service teachers. Table 3 shows a breakdown of K-12 education activities for the different center demographic categories.   The university-wide centers were least likely to be involved in K-12 education; only 30% reported programs or activities in this area. The education and science/engineering centers are most heavily involved in K-12 education and the focus appears to be on the teachers; 98% of these centers had on-campus programs for in-service teachers and 70% of these centers had on-campus programs for pre-service teachers. About 58% of the engineering education centers had K-12 programs, and a significant number of these were involved in many types of K-12 outreach. The most frequently reported activities for engineering-focused centers involve college students going into K-12 classes (58% of centers) and in-service teachers coming on-campus (42% of centers).

Table 2. Sources of Funding

	State or University	NSF	Private Sources	Other Federal Agencies	Other
Education and Science/Engr	41	23	18	12	3
University Wide	39	3	11	4	1
Research Centers	19	23	10	5	1
Engineering	18	10	15	2	2
University Consortia	10	11	6	1	1
Education	6	0	3	1	2
Science	6	2	4	1	0
Nonprofit	3	4	5	3	0
All Centers	142	76	72	29	10

Table 3. Programs for Enhancing STEM Education in K-12

	In-Service Teachers On Campus	Students go into K-12 Classes	Staff go into K-12 classes	Faculty go into K-12 classes	K-12 Students On Campus	Pre-Service Teacher Programs
Education and Science/Engr	45	27	30	30	22	32
University Wide	8	5	6	2	2	4
Research Centers	9	8	11	10	18	1
Engineering	8	11	6	6	7	4
University Consortia	11	12	7	6	4	10
Education	6	6	4	3	4	4
Science	5	1	2	3	3	0
Nonprofit	5	1	3	1	0	2
All Centers	97	71	69	61	60	57

3.3   Higher Education Improvement Programs

The survey asked if the centers were involved in activities related to improvement of teaching in higher education. Approximately 71% of all the centers reported one or more program related to college teaching. It is interesting to note that over half of these also reported K-12 education programs. Considering all centers together, the most common approaches used to improve college teaching were workshops and seminars for faculty (57%), coaching and mentoring activities (35%) and grant and fellowship programs (34%). Other programs cited by the survey respondents include programs for graduate students, course and curriculum development projects, and assessment activities. Table 4 shows a breakdown of higher education-related activities for the different center demographic categories.

Table 4. Programs for Improving Teaching in Higher Education

	Workshops & Seminars for Faculty	Coaching and Mentoring	Grants and Fellowships	Graduate Student Programs
Education and Science/Engr	24	12	15	3
University Wide	31	27	24	9
Research Centers	12	3	6	0
Engineering	13	10	5	2
University Consortia	9	5	5	5
Education	3	2	1	1
Nonprofit	2	1	1	0
Science	4	2	1	0
All Centers	98	62	58	20

Table 4 Continued. Programs for Improving Teaching in Higher Education

	Course/ Curriculum Development	Assessment	Other
Education and Science/Engr	4	0	4
University Wide	1	7	3
Research Centers	1	0	1
Engineering	1	1	2

University Consortia	1	0	1
Education	0	0	1
Nonprofit	0	0	2
Science	0	0	0
All Centers	8	8	14

The university-wide centers were most likely to be involved in higher education improvement; 90% of these centers reported involvement in this area. Centers that were least likely to be involved in this area are those situated in a college of education and without explicit STEM collaborators. Only 33% of these centers reported engagement in improving teaching in higher education. Ninety percent of the engineering education centers reported one or more program aimed at improving higher education. Engineering-focused centers more frequently engage in workshops and seminars for faculty and in coaching and mentoring activities than the total population of centers responding, but were less likely to provide grants and fellowships.

3.4   Promoting Collaboration

Centers were asked if they promote collaborations between faculty in education and faculty in science, mathematics and/or engineering. About 74% of the centers responded with one or more activities in this area. The most common activities involve joint workshops and seminars (47%) and proposal writing support (34%). Other activities include cross-college peer mentoring programs (18%), seed grants (18%) and course & curriculum development and delivery (14%). Only 14% of the centers responded that their sponsored programs and research promote collaborations across colleges. This percentage may be much higher, considering the variety of funding sources discussed above. Joint education programs, team teaching and assessment activities were also reported to promote collaboration. Table 5 shows a breakdown of the types of collaboration-promoting activities for the different center demographic categories.

Not surprisingly, 100% of the university consortia reported collaboration-building activities. The most frequent were joint workshops and seminars (75%) and course and curriculum development and delivery (44%). Least likely to promote collaborations were centers situated in a single college such as the education centers or science education centers. The engineering focused centers were similar to the total population in terms of how they promoted collaborations across colleges. Significant distinctions are that the engineering education centers are more likely to promote collaborations through proposal writing support and assessment activities.

4   RECOMMENDATIONS FOR SUCCESS

About 85% of the returned surveys included a response to the question "please, give us one recommendation, based on your experience that would help us develop a successful center." This is a good response rate, considering that the survey did not suggest a definition of success. Of the 147 responses that were provided, 33 included more than one recommendation and several included as many as four. A content analysis was performed to code the recommendations into fourteen themes, as discussed below.

4.1   Engage the Faculty.

Thirty centers made recommendations to engage the faculty in the activities of the center. Most of these suggestions were to listen to the faculty and respond to their needs or to develop solutions in collaboration with your constituency. It was also suggested to avoid the "build it and they will come" mentality. One respondent recommended reaching out to as many departments as possible, whereas another suggested the core faculty should be limited in number. Developing a culture of "faculty working with faculty" was also suggested.

Table 5. Activities for Promoting Cross-College Collaboration

	Joint Workshops and Seminars	Proposal Writing Support	Cross-College Peer Mentoring	Seed Grants & Funding	Courses & Curriculum
Education and Science/Engr	26	26	10	7	11
University Wide	19	8	11	7	1
Research Centers	9	7	4	7	1
Engineering	7	8	2	3	3
University Consortia	12	5	2	5	7
Education	3	0	2	1	1
Science	2	3	0	0	0
Nonprofit	3	1	1	1	0
All Centers	81	58	32	31	24

Table 5 Continued. Activities for Promoting Cross-College Collaboration

	Sponsored Programs & Research	Joint Education Programs or Team Teaching	Assessment	Other
Education and Science/Engr	11	5	0	4
University Wide	1	0	1	1
Research Centers	3	1	1	0
Engineering	3	2	2	1
University Consortia	4	3	0	1
Education	1	1	0	0
Science	0	0	0	0
Nonprofit	1	0	0	2
All Centers	24	12	4	9

4.2   *Interdisciplinary Collaboration*. Twenty-three centers suggested that collaboration and partnerships are keys to successes. Potential partners should be viewed as allies rather than as competitors. Partners that were suggested included faculty in the fields of education, science, mathematics, engineering and the business community. It was also suggested to develop strong collaborations between the domain experts in STEM disciplines and learning scientists in education. Monthly meetings to network and collaborate were suggested as a way to promote collaboration. It was cited as important that the participants respect and embrace the importance of interdisciplinary approaches in addressing the challenges of teaching in K-20 settings.

4.3   *Leadership, Organization and Staffing*. Nineteen centers made recommendations about the importance of effective leadership, organization and staffing for the center. These included a leader passionate about teaching and learning and a team of persons with varied backgrounds and experiences. Several stated that an external advisory board can provide totally different perspectives on the issues as well as give more credibility (hence, buy-in) on the services of a center. One respondent noted the need to provide adequate time for administration, saying "it will take much more time than you anticipate." It is interesting that one recommended that the "home" of the Center be a college to reduce vulnerability to budget cuts, whereas another recommended to make the center independent of a college, so that the dean or faculty cannot attempt to control or siphon on the resources.

4.4   Alignment with Audience Interests. Eighteen centers stressed the need to make sure the participants in center activities take ownership of the projects. It was suggested to conduct a needs analysis of the target population. Those who will be involved in and use the center should carefully discuss their needs and what activities are going to take place. Design and organization of the facility should flow from that. One respondent cautioned to "be ready for implementation dips (i.e. don't give up)."

4.5   University Support and Culture. Seventeen recommendations were related to the support and culture of the university at which the center is located. The major theme was to be aware of what the institution or department values and to work from within. Active support (not just monetary) of chairs, deans and the central administration were cited as important by several.

4.6   Clear Mission. The recommendations of fifteen centers were related to having clearly stated goals and a focus for the activities. It was recommended that the mission statement should be achievable, yet broad enough to avoid limits. Staying true to the mission was also cited as important in three responses, including "don't get sidetracked on things that might be nice to do" and "avoid following the money trail."

4.7   Funding and Support. Fourteen of the respondents made recommendations specifically about monetary support. Many recommended that a solid base of institutional financial support is the key to long term successes. Encouragement to obtain external funding was also given, including endowments, federal funding and private sources. One proclaimed that "building a center using only soft money will not enable the center to be sustained!"

4.8   Treat People Well. Recommendations for treating the center's clientele as professionals were made by seven respondents. It was suggested to be aware of the demanding schedule of K-12 teachers and to include honoraria, meals, substitutes and other items in planning collaborative activities with/for them. One recommendation was to "make it exciting!"

4.9   Educational Research Base. Seven recommendations related specifically to educational research. It was suggested to be knowledgeable about important developments in education including research on teaching, to use the research literature to interest the faculty in learning about learning, and to convince faculty from the content areas to approach teaching and learning as a scholarly endeavor. A focus on research was suggested as a way to encourage faculty who face pressure to publish to collaborate on center activities.

4.10   External Networking. Seven center directors recommended networking with other center directors, professional organizations, and other state agencies. Active engagement in the Professional and Organizational Development Network (http://www.podnetwork.org/) was suggested by three respondents.

4.11   Communication and Visibility. Six recommendations focused on substantive communication between participants or on a high visibility of the center and its products. It was suggested to "talk and talk again" and to chronicle all activities. Having a talented webmaster that has a clear understanding of the project's goals was recommended.

4.12   Assess and Evaluate. Six respondents made recommendations relating to assessment and evaluation of the center's activities. It was suggested to assess new programs as they are implemented to make appropriate changes, to assess the learning that occurs in mature programs, and to evaluate the goals and effectiveness of the center yearly.

4.13   Summer Salary and Rewards. Eight recommendations indicated that incentives for faculty to participate are needed. These included finding a way to count their efforts towards promotion and/or tenure, providing summer salary, or providing computers or other technology.

4.14   Other Recommendations. Seven respondents made recommendations for a specific program to implement. These were varied and reflected the target audience of the individual centers. Nine other recommendations were received that did not fit the major categories. These included work hard on areas with potential impact, put teaching first in everything you do, encourage graduate students to be involved, and be entrepreneurial and think out of the box.

5   CONCLUSION

The results of the survey show that STEM-related education centers vary widely in their focus and activities.   Combined with personal experience in the establishment of the South Carolina Center for Engineering and Computing Education, the authors can postulate what the characteristics of a successful center should be. A successful engineering education center should be led by an individual passionate about teaching and learning. It should have a clearly-defined mission that is developed by a group of core faculty and that is guided by frequent input from the constituencies served by the center. It should be aligned with the values of its home (the institution or department) and should work from within that culture. The center should obtain funding from a variety of sources. However direct support from the university is critical. The center's outreach activities should send college students into K-12 and should bring K-12 teachers onto the university campus. Programs for improving higher education should include workshops for faculty as well as individual interactions. Collaborations between faculty in education and engineering should be promoted through sponsored programs and research that is mutually beneficial to the collaborators.   Organizing seminars and meetings can help these faculty members establish connections. Assessing the center's programs and communicating these to the faculty are important to interesting the faculty in learning about learning or in engaging in educational research. Finally, the successful center will find a niche, stay focused and treat people well.