The National Center for Engineering and Technology Education

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Abstract

The National Center for Engineering and Technology Education (NCETE) is a recently funded National Science Foundation Center for Learning and Teaching. This paper provides a broad overview of NCETE activities that will span the five years of the program, consistent with the goals of ASEE's Emerging Trends in Engineering Education session. The long-term goal of NCETE is to understand how to infuse engineering design into technology education in grades 9-12. The paper describes the relationship between engineering and technology education and why NCETE focuses on 9-12 grade technology education as the provider of engineering design concepts. The nine institutions associated with NCETE, the school district partners, and the professional society partners are described. The paper also presents a broad overview of research themes with a description of how these themes will be more sharply focused over the next five years. The paper briefly outlines the doctoral program and the technology teacher program. It concludes by describing some first year goals.

Introduction

Professional communities across the country are concerned with the future of the science and engineering (S&E) workforce. A report by the National Science Board of the National Science Foundation (NSF) highlights two important trends that imperil the workforce: 1) global competition for S&E talent is intensifying, and the United States may not be able to rely on the international S&E labor market to fill unmet skill needs; 2) the number of native-born S&E graduates entering the workforce is likely to decline unless the Nation intervenes in educating S&E students from all demographic groups.[1]

One NSF program that addresses the national workforce need is the Centers for Learning and Teaching (CLT) program. The CLT program has three goals. First, Centers are expected to renew and diversify the cadre of national leaders in science, technology, engineering and mathematics (STEM) education. Second, Centers will increase significantly the number of highly qualified K-12 STEM educators. Third, Centers will conduct research on the nature of learning, teaching, educational policy reform, and outcomes of standards-based reform.

The NSF 04-501 program solicitation focused on areas that represented gaps in the existing CLT portfolio. One identified gap was a Center focused on engineering and technology education with a requirement that a Center guide the expansion of engineering and technology education in the schools. In 2003, a team of faculty members from nine universities met to develop a proposal in response to the program solicitation, NSF 04-501. The goal of this team was to develop a proposal for a Center that would link engineering and technology education faculty in a partnership to build capacity and benefit the profession. The result was the formation of the

National Center for Engineering and Technology Education (NCETE). On September 15, 2004, NCETE received funding from the NSF as one of the 17 CLTs in the country and the only CLT addressing *engineering and technology education*. This paper describes the major goals of NCETE and highlights what we hope to accomplish during the next five years.

The Relationship Between Engineering and Technology Education

Introducing K-12 students to engineering concepts occurs formally in mathematics classes, science classes and technology classes, and informally through experiences in places such as science museums and discovery centers. NCETE emphasizes introducing engineering design and analysis formally through standards-based instruction in technology classes. One question that should be addressed is: Why did NCETE choose to introduce engineering concepts in technology classes? Why not work with K-12 science or mathematics teachers? The answer most simply stated is that design taught in technology education in K-12 is most closely related to engineering design. NCETE investigators feel exposing K-12 students to engineering design will excite young people about the engineering profession. Furthermore, technology education exposes students to open-ended problem solving, a skill required of future engineers.

Technology education is often misunderstood – it has undergone a significant transformation since the mid-1980's. At the core of this transformation is a transition from education associated with the industrial arts to education associated with technological literacy and engineering education in K-12 schools. This transformation is hardly complete, in part, because of stereotypical attitudes held by many. Greg Pearson, a Program Officer with the National Academy of Engineering, candidly points to some of the problem, "Let's face it, engineering is filled with elitists and technology education is for blue-collar academic washouts."[2] In the same article, he recommends, "Leaders and influential thinkers in both professions have to decide that the benefits of collaboration outweigh the risks."

With the publication of the Standards for Technological Literacy in 2000, reshaping the technology education curriculum provides an important opportunity for engineering and technology education collaboration. The standards prescribe design concepts be introduced throughout the K-12 curriculum. Four of the 20 standards for technological literacy specifically address design: standard 8 deals with the "attributes of design," standard 9 with "engineering design," standard 10 with "troubleshooting, research and development, invention and innovation, and experimentation in problem solving," and standard 11 with "applying the design process."[3] In the forward to the standards, William Wulf, President of the National Academy of Engineering, noted, "It is not enough that the standards are published. To have an impact, they must influence what happens in every K-12 classroom in America."

Technology education shares engineering educations desire to emphasize open-ended problem solving and the design process. For example, Standard 8 delineates design steps very similar to those introduced to engineering students:

> "In order to recognize the attributes of design, students in grades 9-12 should learn that the design process includes
> - defining a problem,

- brainstorming, researching and generating ideas,
- identifying criteria and specifying constraints,
- exploring possibilities,
- selecting an approach,
- developing a design proposal,
- making a model or prototype,
- testing and evaluating the design using specifications,
- refining the design,
- creating or making it,
- and communicating processes and results."

The design process described by Standard 8 is iterative in nature so that students may make a number of models or prototypes that are tested and refined until the final solution is achieved. One difference between the design process prescribed by Standard 8 and engineering design is the role of engineering analysis in achieving the optimum solution. One goal of NCETE is to find ways to teach engineering analysis as part of the K-12 design experience.

NCETE Partners

NCETE comprises a strong team of partners to achieve Center goals. Each university partner brings strengths in engineering and in technology education. Four categories of partners have been identified: 1) doctoral-granting university partners, 2) technology teacher education partners, 3) K-12 school district partners, and 4) professional society partners.

Doctoral Partners

The four doctoral partners are land-grant research universities that offer the PhD degree in technology education and in various engineering disciplines, and have established links between the engineering and education colleges. These partners have an established record of producing PhD's and faculty expertise in conducting research on how students learn technological ideas and skills, and how we can better teach technological concepts as well as creative thinking and problem solving. NCETE doctoral partners are:

- Utah State University (USU): Department of Engineering and Technology Education, College of Engineering. USU offers the PhD degree in Technology Education. The Technology Education program at USU is administratively located within the College of Engineering and the new dean of Engineering has encouraged the department to focus on Engineering Education. USU is the site of the Program Director and support staff of NCETE.
- University of Illinois (UIUC): Department of Human Resource Education (HRE), College of Education. Both the College of Education and the HRE are consistently ranked among the top programs in the nation. The HRE and the College of Engineering have a long-standing relationship through the Academy of Excellence in Engineering Education. Through this academy, education and engineering professors have worked together to infuse sound educational theory and practice into the College's instructional program.

• University of Minnesota (UMN). Technology Education, Department of Work, Community and Family Education (WCFE), College of Education and Human Development (EHD). The EHD recently ranked fifth in a national poll on overall academic productivity. The WCFE is the home of technology education and has been ranked second in the US News and World Report survey of graduate schools in technical and vocational education. Doctoral enrollment in the department has typically exceeded 100 students.

• University of Georgia (UGA): Program of Technological Studies, College of Education. The Department of Occupational Studies houses the Technology Studies program and was ranked fourth in the nation in the area of technical and vocational education in a recent US News and World Report survey. The University of Georgia has successfully completed an NSF-sponsored Bridges to Engineering project that has fostered collaboration between engineering and technology education faculty.

Technology Teacher Education (TTE) Partners

The five TTE partners have successful programs to prepare technology teachers. Three of the partners' TTE programs were identified by Iley as growth programs with successful recruitment strategies (ISU, BYU, UW-Stout).[4] The two additional TTE partners include successful TTE programs at a historically black university (NCA&T) and a Hispanic serving university (CSULA). NCETE TTE partners are:

• Brigham Young University (BYU): Technology Teacher Education Program, School of Technology, College of Engineering and Technology. BYU's TTE program has more than 77 majors and graduates an average of 17 technology teachers per year. A significant percentage (26%) of BYU's TTE students are female, the highest percentage of female TTE enrollments in the US.

• Illinois State University (ISU): Department of Technology, College of Applied Sciences and Technology, established as the Technology Education Learning Laboratory in 1999 to serve as a model TTE training and research facility. ISU currently operates an NSF-funded Project ProBase, a pre-engineering curriculum development project.

• University of Wisconsin-Stout (UW-Stout): Technology Teacher Education Program, School of Education. UW-Stout, a 2001 Baldrige Award recipient, has the largest TTE program in the nation with more than 350 undergraduates preparing to become technology teachers, in addition to more than 60 students pursuing technology education teacher certification through a master's program.

• North Carolina A & T State University (NCA&T): Department of Graphic Communications and Technological Studies, School of Technology. NCA&T graduates more African-American engineers than any other institution in the nation. Likewise, NC A&T graduates a significant number of engineering technologists and technology education teachers.

• California State University at Los Angeles (CSULA): Department of Technology, College of Engineering, Computer Science and Technology. CSULA is a member of the Hispanic Association of Colleges and Universities.

K-12 School District Partners

Each of the TTE partners is linked with one or more K-12 school districts, including rural, urban, and suburban schools that serve diverse student populations. Each K-12 school partner is committed to testing engineering content in technology education in collaboration with the TTE and doctoral partners. The school district partners include collaborations with the state education agencies.

Professional Society Partners (PSP)

NCETE has established partnerships with key professional societies to assist with its goals. Of particular importance, the PSPs have agreed to assist with dissemination of materials and provide an important mechanism for sustaining the NCETE mission. The PSP's include the following societies:

- International Technology Education Association (ITEA)
- Council on Technology Teacher Education (CTTE)
- American Society for Engineering Education (ASEE)

Collaboration Potential

NCETE provides synergistic regional collaborations, spanning the educational levels from K-PhD in regional teams, as illustrated in Figure 1. The regional teams are located in the West, the Upper Midwest, the Central Midwest, and the Southeast. The geographic locations of the regional teams will facilitate collaborative research, professional development, capacity building, and dissemination of research findings and model practices. NCETE is also organized for horizontal collaboration among the various levels of partners. The four doctoral university partners will link and collaborate in strengthening PhD programs, developing four common core courses for PhD programs, developing effective recruitment strategies to ensure that a high quality, diverse cohort of PhD students is admitted to NCETE sponsored PhD programs, and developing a community of scholars among faculty and PhD students. The five teacher education partners will collaborate by refocusing TTE programs, sharing effective recruitment strategies to attract a diverse student body, and sharing effective strategies to infuse engineering into technology education programs. The K-12 partners will link and collaborate by sharing best practices in terms of infusing engineering into the K-12 schools.

NCETE Research Themes and RFP Process

The proposal to the National Science Foundation outlined three broadly stated research themes. The NCETE research agenda would focus on learning and teaching engineering content and analytical methods in K-12 technology education classrooms and laboratories, and in TTE programs. The long-term outcome of this program of research is to develop approaches to instruction that are based on principles of learning and information processing gained from cognitive science and to provide evidence of their usefulness in education settings. To achieve this outcome, NCETE addresses three overarching research themes.

Research Theme 1 – How and What Students Learn in Technology Education

In order to develop developmentally appropriate learning sequences and effective engineering design challenges for K-12 settings, we need to know more about how students learn technological concepts and how best to foster critical thinking and creative problem solving. Thus, the first NCETE research theme is to conduct research about how students learn in technology education. This research is grounded in the cognitive sciences and considers research questions such as: How do students learn technological and engineering concepts? How do students learn creative problem solving? How do students learn to visualize while engaging in engineering design activities? To what extent do engineering activities enhance learning in mathematics and science?

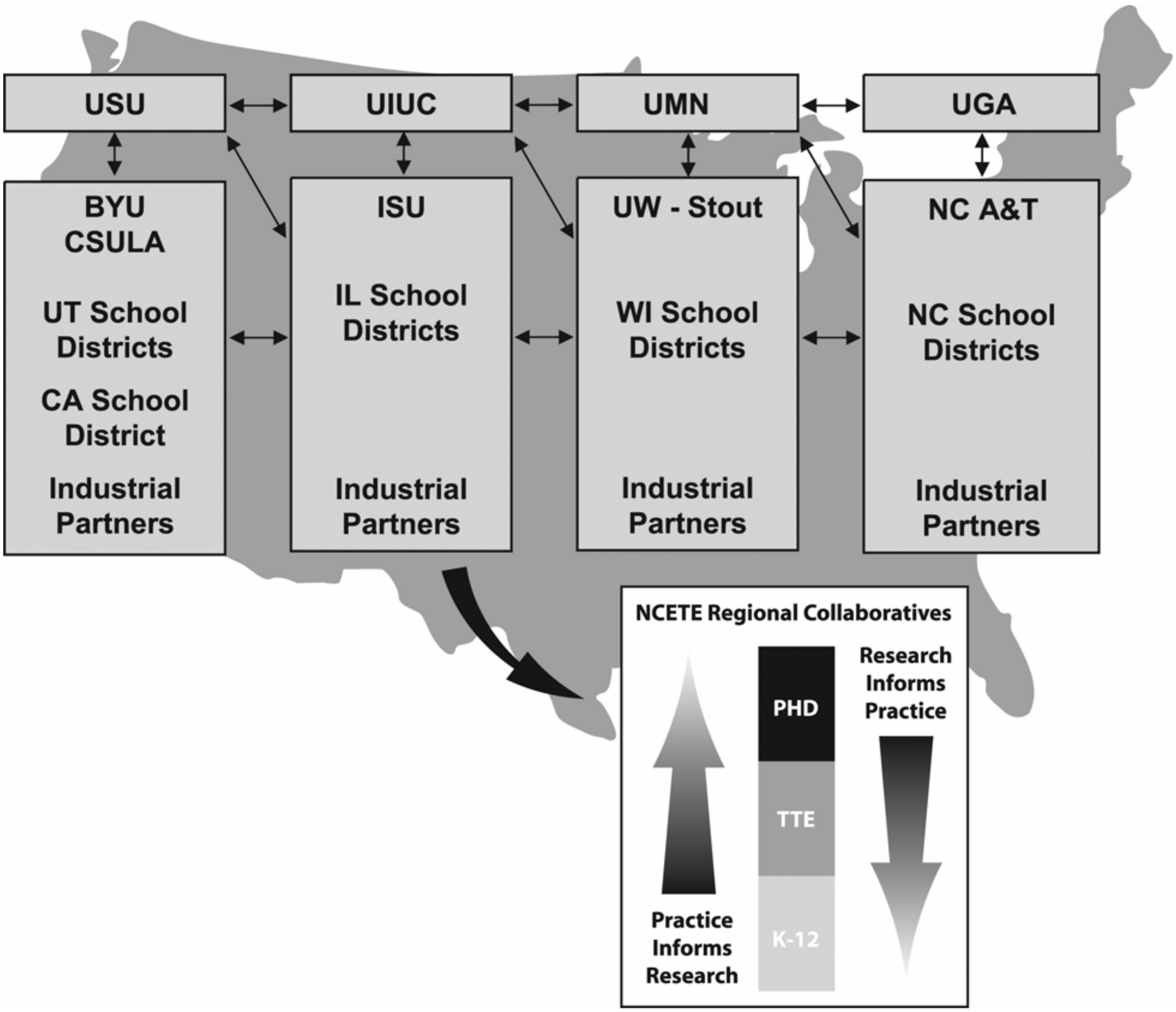

Figure One: Sketch Illustrating Collaboration Potential of NCETE Partnerships

Research on K-12 curriculum and instruction builds on the existing learning and cognition research base. The Center is interested in curriculum research questions such as: How do broader concepts associated with technological literacy relate to engineering concepts and analytical methods? Does infusing engineering content and design, problem solving and analytical skills into technology education increase the quality, quantity and diversity of engineering and technology education? What are the core-engineering concepts that are foundational to all branches of engineering and how are they best organized for learning? How should K-12 technology education programs be configured to serve as part of the pre-collegiate preparation for engineering (along with science and mathematics)? How should K-12 laboratories be equipped and configured for teaching engineering concepts? How can technology education effectively offer both general courses related to technological literacy and specialized courses in engineering?

Research Theme 2 – How Best to Prepare Technology Teachers

In order to prepare the next generation of technology teachers with the capabilities to design and deliver effective engineering and technology education programs, we need to know more about how to effectively prepare these teachers. Thus, the second NCETE research theme is to conduct research about technology teacher education. This research should be grounded in the cognitive sciences and may consider research questions such as: How can we better prepare technology and engineering teachers through cognitive science? How should TTE programs be configured to assure that new teachers acquire the requisite engineering design and analytical knowledge and skills? How are clinical experiences for technology teachers best configured? What are the effective means for delivering ongoing professional development for teachers?

Research Theme 3 – Assessment and Evaluation

In order to know what students have learned as a result of instruction, and to learn about program quality and effectiveness, we need to know more about assessment and evaluation. Thus, the third NCETE research theme is to conduct research regarding assessment and evaluation. This includes assessing and evaluating Center activities and will include research questions such as: What are the effective assessment and evaluation strategies of learning and teaching engineering concepts to K-12 students? How do we best measure engineering knowledge and skill acquisition? To what extent do the national curriculum standards in mathematics, science, and technological literacy guide program assessment?

Focusing the Research Agenda

Once NCETE was awarded funding from the National Science Foundation, a Research Committee was formed to more sharply focus the questions within each of the research themes. The Research Committee is currently interviewing current and future teachers to help understand what they see as research questions they would like addressed to help them become better classroom teachers. The Research Committee is also meeting with well-known researchers in the area of engineering design to find out what questions they consider important and reviewing important papers in engineering design by authors such as Dym, et al.[7-9] Atman and her colleagues,[10-12] and Koen.[13-14] The Research Committee will synthesize their findings and report back to NCETE during the summer of 2005.

NCETE RFP Process

NCETE has allocated research funds for competitive research proposals from the partner institutions, using a Request for Proposal (RFP) process similar to that of NSF. As part of their learning experience, graduate students associated with NCETE will write proposals in response to the RFP call. Research funds will be allocated using a center-wide review process to ensure the proposals are collaborative, research agenda focused, and adhere to the research themes of the Center. General criteria for the competitive research proposals include that they are aligned with NCETE research themes, involve collaboration of two or more researchers in engineering and technology education, utilize specific assessments aligned with national standards, investigate student learning in schools with diverse learner characteristics, and include mechanisms for communicating results to broader audiences.

Doctoral Program

Engineering and technology education faculty at the four doctoral partner institutions will work together to prepare doctoral students. NCETE's goal is to prepare the next generation of educational leaders, who will, in turn, educate and support the K-12 educators. We are developing a community of doctoral fellows that reside at the four doctoral partner institutions and that take core courses together (through distance delivery) at each of the four institutions. NCETE doctoral fellows will come together during summer workshops to share research results and strengthen their sense of community. The fellows, and associated faculty, experience the strengths of the four doctoral partners rather than that of a single partner. Each of the four doctoral partners will support five full-time doctoral fellowships. The fellows begin the program in stages: 12 fellows starting in Fall semester 2005 (three at each institution), four fellows beginning in Fall semester 2007 (one at each institution), and similarly, four fellows beginning in Fall semester 2008. The 12 fellows beginning in 2005 are expected to mentor students admitted in 2007 and 2008.

Doctoral fellows will be awarded based on the following criteria. First, each doctoral university will utilize their own admission standards for initial consideration as a doctoral fellow. Second, doctoral candidates will be asked to submit a 1-3 page statement of their career goals, why they desire to participate with the Center, and their level of commitment/availability to the Center. NCETE will consider the following qualifications when reviewing applications. Selection will be based on a total review of the candidate; no single criterion will prevent admission. Criteria include:

1. Technology education, engineering, mathematics, or physical science bachelors degrees
2. Master's degree in technology education, engineering, or related field.
3. Research experience at the master's degree level.
4. K-12 teaching experience
5. Work experience related to engineering or design.

NCETE research faculty will jointly develop four core courses taken by the doctoral fellows. Our goal is to strengthen the backgrounds of the doctoral fellows in cognitive science, engineering design, and problem solving. The first core course, taught in Fall 2005, will focus on cognitive science and its application to engineering and technology education. The second core course, taught in Spring 2006, will focus on engineering design and will build on ideas presented in the cognitive science course. The final two core courses will focus on engineering analysis, and the associated mathematics and science needed to teach engineering design problems in the 9-12 grade classroom.

Technology Teacher Education Program

Salinger noted that to implement curricular frameworks focusing on engineering at the K-12 levels, like those established in Massachusetts, will not be easily implemented unless there is a change in teacher preparation.[13] Thus, a major thrust of NCETE is to refocus TTE programs at the partner universities to prepare technology teachers who are capable of infusing engineering design and analytical methods into the K-12 schools. This will be accomplished by linking TTE faculty with engineering faculty to redesign and refocus TTE programs. The teacher education component includes redesigning and refocusing pre-service TTE preparation, simultaneously renewing K-12 schooling, and supporting teacher professional development.

Redesigning and Refocusing Pre-service TTE Preparation

NCETE is identifying and demonstrating best practices in standards-based TTE preparation, and developing and testing TTE program models that represent the array of administrative structures, including 1) preparing technology teachers in colleges of engineering, 2) preparing technology teachers at universities with engineering programs but not in the engineering college, and 3) preparing technology teachers at universities that do not have engineering programs. In all instances, the TTE programs and faculty are linked with engineering faculty at their university and/or another NCETE partner university. Furthermore, the model TTE programs also demonstrates the preparation of technology teachers at both the BS and master's degree levels, including master's certification for individuals who have the BS degree in engineering or closely related discipline.

Research is being conducted to substantiate effective TTE methods, curricula, and clinical experiences required to prepare technology teachers to infuse engineering into K-12 schools. An aspect of this research is to determine the analytical skill set requisite for technology teachers to effectively teach engineering at the high school level. Wicklein noted that the new skill set will require a much deeper grasp of mathematics and science principles for technology teachers.[14] Wicklein further noted that technology teachers would need skills for collaborating closely with mathematics and science teachers.

Simultaneously Renewing K-12 Schooling

Efforts to refocus TTE programs will have limited impact unless there are student teaching sites that are infusing engineering design into the curriculum. Therefore, another thrust for NCETE is to simultaneously refocus and redesign TTE programs and improve K-12 schooling by infusing engineering analysis and design into technology education classes. Simultaneous renewal requires effective partnerships between the NCETE university partners (both doctoral and TTE partners) with K-12 schools that have made a commitment to infuse engineering into the high school curriculum.

Supporting Teacher Professional Development

Each of the five TTE partners are delivering professional development for at least five technology teachers from the partner K-12 schools, beginning in Winter, 2005. Development of the in-service experience is guided by the works of a number of researchers, including Rhoton, Bybee, Loukes-Horsely and Stiles. For effective professional development, Rhoton noted that science teachers need to rethink their notions about the nature of science, develop views about how students learn, construct new classroom learning environments, and create new expectations about student outcomes.[15] It could also be concluded that technology teachers likewise will need to rethink their notions and views on how students learn, and the types of laboratory environments needed for effective learning of engineering content. National curriculum standards can guide teachers as they rethink the curriculum. Bybee noted that the power of standards lies in their capacity to catalyze change in fundamental components of the educational system.[16] Bybee further noted that teachers need more than content knowledge, they also need to know how students learn and what facilitates learning. Loukes-Horsely and Stiles found that one-time workshops rarely provided lasting professional development.[17] Studies are now showing that the most effective professional development projects were driven by active learning of content in the context of teaching, involved groups of teachers from the same school, and involved consistent, high-quality contact lasting months.[18-20]

Professional development in 2005 and 2006 involve 9-12 grade teachers from NCETE partner school districts providing a cadre of master teachers in five states (CA, UT, WI, IL, and NC). In 2007-2009, K-12 schools in adjacent states may be invited to participate in NCETE professional development. This has the potential to prepare a cadre of leader teachers in twenty states, expanding the impact of NCETE and enhancing the sustainability of the Center.

Model K-12 Engineering and Technology Education Programs

NCETE K-12 school partners are developing model technology education programs by infusing engineering design and content into the curriculum. NCETE is developing a database of engineering and engineering-related curriculum materials that will be made available to partner K-12 schools. In addition, each NCETE university partner is currently developing targeted engineering curriculum materials in the form of an engineering design challenge. The content areas for the engineering design challenges are guided by the TTE team to ensure non-duplication of effort. The development of each design challenge began with a review of existing engineering curricula in the content area that could be adapted for NCETE purposes. Each of the design challenges follow a template developed by Center personnel that are experts in design, development and the use of instructional technology. The design challenges include an interface matrix that identifies the national standards for science, mathematics, and technological literacy that are being addressed. A Center quality control team will review the design challenges before they are available for general use.

Summary: NCETE Goals and First Year Impacts

The vision of NCETE is to refocus technology education and prepare the next generation of educators with the necessary skills to teach engineering design as well as conduct important research that would improve our understanding of learning and teaching of engineering and technology. Efforts during the first five year will focus on grades 9-12. NCETE teams engineering faculty and technology educators in a systematic approach that involves:

1. Building a community of researchers and leaders to conduct research in emerging engineering and technology education areas.
2. Creating a body of research that improves our understanding of learning and teaching engineering and technology subjects.
3. Preparing technology education teachers at the BS and MS level who can infuse engineering design into the curriculum (current and future teachers).
4. Increasing the number and diversity in the pathway of students selecting engineering, science, mathematics and technology careers.

NCETE team members have been working hard to achieve Center goals for roughly three months. At the conclusion of our first year, we hope to have achieved the following goals:

1. Recruit 12 doctoral fellows and develop a recruiting and retention strategy to guide the Center.
2. Develop four Ph.D. core courses that will be taken together by the doctoral fellows using a combination of distance delivery and face-to-face delivery in the second year of the grant. Three core courses will introduce the doctoral students to engineering analysis and infusing engineering design into technology education. The fourth core course will focus on cognitive science in engineering and technology education. The core courses will be developed by engineering and technology education faculty.
3. Develop nine case studies to be used in teacher professional development. The case studies will be developed jointly with engineering and technology education faculty and will emphasize the role of analysis in engineering design.
4. Conduct the first teacher in-service experience that helps them rethink how to deliver instruction to infuse engineering content and design into their instruction.
5. Evaluate current pre-service programs and begin to refocus them to infuse engineering analysis and design content into the curriculum.
6. Focus the research agenda and develop an RFP process to solicit, review and award proposals for research.

Both an internal and an external evaluation team will review NCETE progress toward achieving the six stated goals. NSF will also conduct an 18-month reverse site visit to determine NCETE's progress and whether to continue funding the Center.

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