Engineering Equity Extension Service (EEES)

Proposal Writing and Project Management Guide

for

NSF Engineering Education Grant Proposals

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About the Authors

Tammy Bosler, Ph.D.

As a Christine Mirzayan Science & Technology Policy Graduate Fellow at NAE/CASEE, Tammy Bosler developed this "Guide to Proposing and Managing NSF Engineering Education Projects." Her impressive credentials include being awarded a Ph.D. in physics from the University of California-Irvine (UCI) in October 2004, where she also earned an M.S.; she received a B.A. in physics from Temple University in Philadelphia. Her research specialty was observational astrophysics in the context of stellar spectroscopy, stellar evolution, and galaxy formation.

Along with her Ph.D. research, she acted as an outreach coordinator to develop an astronomy and astrophysics outreach program at UCI where she created basic astronomy curricula and demonstrations for students from 3rd grade to high school. The outreach program targeted local schools that scored particularly low in math and science standardized testing in order to help develop educational resources for educators and to initiate sparks of interest for the students. She also taught physics and astronomy classes at UCI where she won a departmental teaching award and recently taught thermodynamics at the University of Regensburg, Germany.

Her latest endeavor in public education was the development of a two day astronomy workshop designed for the general public entitled "Astronomy: Understanding Our Place in the Universe." In an age of misinformation and misunderstanding about science, one of Tammy's passions is to help clarify modern science for the public. Her long-term goal is to contribute to the development and establishment of sound national and international scientific policy.

Lynette Osborne, Ph.D.

As an NAE/CASEE ExxonMobil postdoctoral Scholar-in-Residence, Lynette Osborne contributed her knowledge of gender in engineering education to the development of this "Guide to Proposing and Managing NSF Engineering Education Projects." In August 2006, Lynette was awarded a Ph.D. in sociology with a minor in Women's Studies from Purdue University, where she studied the classroom climate in engineering education. Lynette also earned an M.A. in sociology and criminal justice from Old Dominion University, and a B.A. in psychology with a minor in sociology from California State University, Chico. Her research expertise includes gender inequality and the use of learning-centered pedagogy in engineering.

Lynette has a long history of teaching sociology. Her initial interest in teaching about social inequality led to her dissertation project focusing on gender inequality in engineering education after several engineering students enrolled in her sociology courses and related their education experiences during class discussions. Her commitment to innovative, learning-centered teaching has been recognized by departmental, college, and university teaching awards including being inducted into Purdue's Teaching Academy in 2005. Lynette is active in the American Sociological Association's Teaching and Learning section and presents papers on teaching/learning and regularly at national and regional conferences.

Her research and teaching interests are particularly germane to her current assignments at NAE/CASEE where she will be working on projects related to diffusion of pedagogical innovations in engineering education.

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Tammy L. Bosler, Ph.D.
Lynette Osborne, Ph.D.

Summary

This *EEES Proposal Writing and Management Guide* is intended to be a resource for scholars who are writing National Science Foundation (NSF) grants focused on engineering education. The *Guide* explains basic requirements, offers tips, and provides references to help build and effectively communicate a great project idea in the area of engineering education. It also offers advice on project management for funded proposals.

The goal of this *Guide* is to condense the voluminous amount of NSF proposal writing and project management literature into one succinct, easy to navigate, advice document geared at assisting applicants through the engineering education grant writing process and beyond. In addition to synthesizing existing literature, this guide also draws on conversations with NSF program directors that have provided invaluable information including tips germane to producing a proposal that is strong yet easy to read and understand. This resource also provides references to more detailed guidance from the literature.

Once you have a funded project, the *Guide* can help you to effectively manage it. Basic management advice is provided on budgeting, staffing, recruitment of students, and the importance of diversifying the field of engineering, is provided to help assure long and short term success of the project.

Turning a great idea into a competitive proposal takes a clear vision and a lot of research, resources, and collaboration. The review process can appear nebulous and be difficult to navigate without a clear sense of who reads the proposals, what they consider important, and how they decide if your idea is worth funding. These guidelines provide a useful map through the process of engineering education proposal writing and project management.

Introduction[1]

It is the responsibility of engineering educators to make sure that students, particularly women and racial/ethnic minority students, who have strong academic backgrounds understand the promise and possibility of a career in engineering. In order to do this, engineers must develop an educational system that is more inclusive than the current system. It is only through redesigning our engineering education system that we can hope to include even higher numbers of students into engineering fields to help create innovation that will take our country into the next century as engineering leaders. With that goal in mind, this guide is designed to help you navigate proposal writing to assist in making your engineering education project become a funded project. Additionally, the guide provides advice on how to proceed once your project is funded.

The National Science Foundation (NSF) provides numerous sources of formal and informal guidance for grant applicants. The following proposal guidelines are the essence of the advice often given to inquirers. Most NSF engineering education proposals are peer-reviewed in panels consisting of colleagues in science, technology, engineering, and mathematics disciplines, education, learning sciences, or related fields, and the success in obtaining funding depends in great measure on reviewer's judgments and written reviews. Other proposals are subjected to *ad hoc* or mail review by individual reviewers who do not gather together as a panel.

While following the guidance provided here certainly does not guarantee funding, it is designed to help applicants write better, more competitive proposals.

"What makes an outstanding engineering education proposal?"

The most important factor is to create a project that will benefit engineering education, contribute to equity, and directly improve student opportunities to learn. However, you must convince the reviewers not only that you have an outstanding project idea, but that you are capable of actually performing the research. Reviewers need to balance an ambitious project proposal with researcher experience level to decide if it is within your capabilities. Make it clear that you and your co-PIs are the ***best*** people to be developing the proposed project. Of course, the proposal must also be written in sufficient detail to allow reviewers to understand:

- what is the specific research question or management objective and how does the project plan tie into it;
- the procedure, methods, evaluation and dissemination plans;
- if the project personnel have the necessary expertise to accomplish the goals and objectives;
- the potential of the project to improve engineering education;
- the potential for the project to improve the position of women, racial/ethnic minorities, and persons with disabilities in engineering;
- the national impact and cost effectiveness of the project.

[1] Adapted from the NSF's *A Guide for Proposal Writing* at http://www.nsf.gov/pubs/2004/nsf04016/print_toc.htm and *Grant Proposal Guide* at http://www.nsf.gov/pubs/gpg/nsf04_23/index.jsp

1.1 Program Announcements vs. Program Solicitations

Carefully read the ***program announcement or solicitation*** (both defined below). The Program Solicitation or Announcement gives the most current information available regarding the proposal requirements and provides (a) a rationale, (b) an overview, (c) detailed program information, (d) instructions for preparing and submitting proposals, and (e) special review criteria, if any. This is the best guide for preparing a proposal for an engineering education program - it should be read carefully and followed precisely.

"Program announcements" are formal NSF publications that announce NSF programs. Program announcements utilize the generic eligibility and proposal preparation guidelines specified in the Grant Proposal Guide and incorporate the National Science Board (NSB) approved merit review criteria (intellectual merit and broader impacts).

“Program solicitations” are used to encourage the submission of proposals in specific program areas of interest to NSF. They are generally more focused than program announcements, normally apply for a limited period of time, and include specific proposal due dates. Competition among proposals is more precisely defined than with program announcements. When a program solicitation is used, the proposals received compete directly with each other. Accordingly, programs using solicitations will be responsible for systematic evaluation, including comparative analysis of scientific, educational, and/or technical aspects, cost, and other significant factors within all proposals in accordance with the criteria specified in the program solicitation.

1.2 Review Process

Some important **practical aspects of the panel review process** that need to be taken into account are that reviewers have

- a number of proposals to read – often ten or more;
- a limited amount of time in which to read your proposal – approximately 20 minutes for the first read;
- different experiences in the review process – veterans to novice;
- different levels of knowledge in proposal area – expert to outsiders;
- limited time for discussions of proposal’s merits at panel meeting.

The majority of proposals submitted to NSF are evaluated by panels of peer reviewers. The purpose of the review is to provide NSF with a written critique and an individual rating from each reviewer as well as a summary analysis by the panel. Each panelist writes his or her own review for all proposals assigned to the panel. Reviewers are asked to provide a detailed evaluation of both the merits and the shortcomings of each proposal and to provide a rating. The rating criteria are defined as follows:

Excellent	Outstanding proposal in all respects; deserves highest priority for support.
Very Good	High quality proposal in nearly all respects; should be supported if at all possible.
Good	A quality proposal, worthy of support.
Fair	Proposal lacking in one or more critical aspects; key issues need to be addressed.
Poor	Proposal has serious deficiencies

The panel then convenes as a group to discuss the proposals. Following these discussions, panelists complete their individual reviews and one panel member writes a summary of the discussion for each proposal. Reviews are used by NSF program directors to inform funding decisions; and anonymous copies are made available to all applicants. See Appendix B for samples of two proposals in engineering education along with the reviewer's comments.

1.3 Criteria for Evaluation

Proposals to NSF are evaluated for merit on the basis of two general criteria: intellectual merit and broader impacts. These criteria, as they relate to engineering education, are defined below.

1.3.1 Intellectual Merit

What is the intellectual merit of the proposed activity? How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the applicant (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of the prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources? Typical questions raised in the review process of engineering education proposals submitted to NSF inlcude:

- Will the project continue efforts to serve underrepresented populations in STEM (women, racial/ethnic minorities, persons with disabilities)?
- Does the project address a major challenge facing engineering education?
- Is the design solid and attainable with a clearly defined methodology?
- Are the goals and objectives, and the plans and procedures for achieving them, innovative, well-developed, worthwhile, and realistic?
- Is the project sustainable? Is there a broad-based implementation plan?
- Does the project have potential for improving student learning of engineering principles?
- Is the project informed by relevant literature in teaching and learning?
- Does the project provide for effective assessment of student learning, which reflects the proposed educational objectives and practices?
- Does the project design consider the background, preparation, and experience of the target audience?
- Does the project have the potential to provide fundamental improvements in teaching and learning through effective uses of technology?
- Is the project led and supported by the involvement of capable faculty (and where appropriate, engineers, technicians, teachers, and student assistants), who have recent and relevant experience in education, in research, or in the workplace?
- Is the project supported by adequate facilities and resources, and by an institutional and departmental commitment?

1.3.2 Broader Impacts

What are the broader impacts of the proposed activity? It is important that you select a broader impact area that you have a particular passion for or interest in and that would be possible to fulfill at your home institution. Simply listing a general, popular broader impact issue is not enough to demonstrate a vested interest in that aspect of the project. Applicants should have a true plan for broader impact and not just provide lip service to the ideal.

For example, if you are concerned about the retention of women students in STEM (science, technology, engineering and mathematics) fields, you may be interested in broadening retention of all underrepresented students (e.g., gender, ethnicity, disability, geographic, etc.) to help make up this deficit. What techniques/teaching modalities will you use to accomplish these broader impact objectives? Be as specific as possible about the steps that will be taken to accomplish your broader impact objectives. Typical questions raised in the review process of proposals submitted to NSF education programs include:

- Will the proposed project have a positive impact on both female and male students, including underrepresented populations?
- Does the evaluation plan measure differential effects by gender and race/ethnicity?
- To what extent will the results of the project contribute to the knowledge base of activities that enhance student learning?
- Are the proposed courses, curriculum, faculty or teacher professional development, experiential learning, or laboratory activities integrated into the institution's academic program? What kind of broader impact projects is the institution currently supporting?
- Are plans for evaluation of the project appropriate for the project's size and scope?
- Are the results of the project likely to be transferable to similar institutions?
- What is the potential for the project to produce widely used products that can be disseminated through commercial or other channels? Are plans for producing, marketing and distributing these products and communication of results appropriate and adequate?
- Does the project address the current and future needs of industry?
- Will the project result in solid content and pedagogical preparation of faculty and teachers of science, technology, engineering, and mathematics? Will it
    - Ensure highest quality education for students planning to pursue STEM careers?
    - Increase participation of women, racial/ethnic minorities, and persons with disabilities?
    - Provide a foundation for scientific, technological, and workplace?
    - Develop multi- and interdisciplinary courses and curricula that are aligned with national standards, as appropriate?

Note that your proposed broader impact must be relevant to your institutional setting. If you are a faculty member at a university or institution that is comprised of mainly minority students, simple proposing to 'increase the number of minority participants' is not a feasible goal for your broader impact. More in-depth questions you might need to ask yourself are, what issues are faced by this group of students, and how can this project help to effect change? For example, if you have a class that exceeds the national average of percent of female students, you might propose to 'increase leadership skills among women students in a laboratory setting' rather than simply 'increase the number of women students.'

2 Advice to Proposal Writers[2]

This section is provided to emphasize the necessity for a focus on equity in engineering education and to help the proposal writer understand the steps that go into preparing a proposal.

2.1 The Importance of Attracting Underrepresented Students to Engineering

The number of American students interested in engineering is declining. According to a report by the National Academies (2005) the U.S. ranked 20th out of all nations for 24-year-olds who earned a degree in the natural sciences or engineering. Only 30% of American students entering college are interested in science or engineering (National Academies, 2005). According to data by the Engineering Workforce Commission, the total number of Ph.D.s in engineering has dropped from 6,986 in 1997 to 6,504 in 2004, which is a 7% decrease. Meanwhile, the global market continues to become increasingly technological and other developed countries continue to increase the numbers of engineers produced each year. A 2005 National Research Council report gives an ominous look at the trends in STEM in the US compared to other developed nations and concludes that unless we are able to make dramatic changes in our STEM educational system, the United States will fall behind as the technological leader.

There is a great reservoir of untapped, high-quality talent in this country in our well-prepared female students. Approximately 70% of America's high school valedictorians are women (Sullivan, 2005); however, traditional engineering education has been shown to effectively filter out and discourage women from pursuing engineering career paths, which means that engineers are not recruiting many of the best and brightest young minds.

Part of the problem with attracting young women to engineering, is that the image of engineering as a profession directly conflicts with many of the goals and aspirations of these talented high school students (see *Extraordinary Women Engineers, 2005*). In many cases, talented young women are discouraged from entering the sciences before they graduate from high school by the perceptions that fields like engineering are only for men.

What do women in high school think about engineering? Less than 10%[3] are interested in becoming engineers (Sullivan, 2005). They perceive engineering as a cold, purely technical field that has no relevance in society, and anyone who wants to be an engineer *must love* (obsess about) both science and mathematics. As many as 10% of the young women in the survey disliked science, and 10% disliked mathematics, so they believed that they could not be engineers. Surprisingly, 25% of these women did not know enough about engineering to know if they would be interested or not. Engineers have an image problem when it comes to recruiting our nation's youth in general and young women, specifically.

When young women do explore engineering, a "chilly" interpersonal environment exists that can discourage them from continuing further (CIRTL, 2005; Hall & Sandler, 1982). This "chilly

[2] Adapted from the NSF's A *Guide for Proposal Writing* at http://www.nsf.gov/pubs/2004/nsf04016/print_toc.htm and the *Grant Proposal Guide* at http://www.nsf.gov/pubs/gpg/nsf04_23/index.jsp

[3] 165 students were sampled in the Extraordinary Women Engineers 2005 report

climate" helps to explain why women are still seriously underrepresented in engineering (see Table 2-1).

Table 2-1. Percentage of degrees earned by women in engineering in 2001[4]

Education Level	Percent Women
Undergraduate	20.1%
Masters	21.2%
Doctoral	16.5%

It is the responsibility of the engineering educators to make sure that young women who have a strong academic background understand the promise and possibility of a career in engineering. In order to do this, engineers must develop an educational system that is more inclusive than the current system. It is only through redesigning our engineering education system that we can hope to include even higher numbers of students into engineering fields to help create innovation that will take our country into the next century as engineering leaders.

2.1.1 Talented Women are Opting out of Engineering

Women and students from other underrepresented groups are critical for diversifying and improving the engineering field. Not only do they offer a new perspective, but they also can help to make up for the decreasing numbers of engineers in the U.S. However, the engineering field will only be able to attract women and minorities if they are able to see themselves as engineers from a very young age and are comfortable in the engineering environment.

There is near parity in the percentages of girls and boys in America's high school science and mathematics classes (see Table 2-2).

Table 2-2. Percentages of Boys and Girls Enrolled in High School Science & Mathematics Courses[5]

Science Class	Girls	Boys
Biology	94%	91%
Chemistry	64%	57%
Physics	26%	32%
Algebra II	64%	60%

Higher numbers of women than men are enrolling in colleges, but the number of female students enrolled in engineering has declined from 1996 to 2003 from 20% to 17% (CPST). Once students leave high school, significantly lower percentages of women earn higher degrees in STEM fields.

Talented young women are being lost along the pathway to engineering. The numbers of young women in high school science and mathematics courses are approximately equal to the numbers of young men. However, as the level of engineering education increases, the number of women earning degrees decreases dramatically.

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[4] NSF (2004)
[5] Huang, Taddese & Walter (2000)

Valuable engineering talent is being lost at all levels of engineering education from high school to post-doctoral levels. If engineering is to truly grow in this country, we must understand *how* to attract women engineering careers in the first place and *why* they are leaving the field in much larger numbers than men.

In order to attract substantially larger numbers of women to engineering and retain them in the field, it is essential to *create a model for building diversity* rather than seeing it as an ad-hoc addition that is disposable to the overall program. Only with a systematic approach to diversity and equity can we achieve it and start to add to the pool of highly qualified engineers. Program proposals should reflect the need to understand gender issues in engineering to contribute to a stronger, more diverse workforce.

2.1.2 Factors Associated with Recruiting and Retaining Women[6]

Several important factors associated with effective recruitment and retaining of women and other underrepresented minorities include: positive elementary, high school, and college experiences with mathematics and science, positive mentoring, instructor teaching style (female-friendly, inclusive, learning-centered).

Minority students benefit greatly from programs in early education and high school. Educating students about what engineering actually is and what one can do with a degree in engineering is critical for dispelling myths associated with the field (e.g.: it is only for men, only for those who are obsessed with mathematics and science, is cold and does not focus on contributions to society, etc).

Once women enter college engineering, mentoring and teaching style are of paramount concern to reducing attrition. Effective mentoring is vital to all people seeking an advanced degree in engineering because mentors can open doors for students by direct action or merely by association. "This is especially true in academia, where an applicant's graduate institution and adviser are often enough to secure serious consideration by a hiring committee." (Riskin, et al, 2004). Additionally, programs designed to focus on empirical testing of innovative pedagogic contributions or dissemination of existing pedagogic ideals are necessary to improve the retention of women in engineering education.

Several references are provided in Appendix D to facilitate familiarity with previous projects that have dealt with gender equity in engineering education.

2.2 Education Components of Engineering Research Projects

There are certain characteristics common to successful NSF large engineering research projects that are expected to have a substantive educational component. They include:

- A cross-disciplinary commitment;
- An emphasis on the involvement of industry;
- Innovative use of educational technology;

[6] Drawn heavily from Riskin, et al. (2004)

- A dedication to reaching far beyond the host universities to include a diverse group of students of all ages who might be inspired to become engineers or scientists;
- Awareness of current issues in engineering education.

Embracing an interdisciplinary approach allows for more complete participation of women, underrepresented racial/ethnic minorities, and disabled persons, whose contributions have yet to be completely integrated into engineering education and projects. The NSF views such outreach as *essential* if the nation is to tap into a broader pool of potential engineering talent that traditionally has been underutilized. Additionally, direct interaction with industrial researchers, both on campus and at industrial sites, is a vital feature of successful programs. As students will be expected to actively contribute to work groups in industry, they must learn appreciation for an interdisciplinary approach to problem solving. It is also important to emphasize engineering design and synthesis, with a strong coupling between research and education programs. Because of this approach to education, employers in industry often note that graduates who have been trained in such programs (see the ERC "Best-Practices" manual, for example) are more effective and productive than their traditionally trained counterparts.

The primary role of successful projects is the education and training of students, fostering their professional growth in a multidisciplinary environment with team research, industrial interaction, and an integrated engineering systems approach. The education project should include practical approaches to engineering as well as theory in order to better serve the needs of industry and society. Strategies should include the active involvement of a diverse group of undergraduate and graduate students in all facets of the programs, particularly the team-related research activities. Participation in university-industry collaborative research teams, industrial internships, and participation in research seminars are all mechanisms that help students develop a deeper understanding of real-world engineering practices and requirements.

The goal of these projects is for students to develop and cultivate the following characteristics:

- have wide-ranging, cross-disciplinary education and awareness
- have an appreciation for the contributions of diverse populations (women, racial/ethnic minorities, disabled persons)
- treat diverse groups of people equitably
- have a broader outlook, integrate knowledge more readily
- work better in a collaborative mode and pursue active involvement in team activities
- have a global perspective
- have more effective communication skills, both oral and written
- benefit from professional conferences and participation in the NSF review process
- have training in systems-level engineering research
- are more flexible in resolving research problems by using other disciplines to help resolve problems
- have experience in interactions with industry
- tend to seek more research-oriented jobs
- have hands-on experience and are willing to apply this to their work
- develop a passion for conducting research, which may lead to continued graduate study in engineering

- with them to the work force
- are more sought after by industry, need less on-the-job training and contribute to real work earlier, take responsibility and contribute earlier in their careers, and rise to positions of leadership more often.

2.3 Before You Write

It is important to develop a clear vision of the project. Consider the following questions to guide you:

Is the project attainable and sustainable, while at the same time is exceptional and unique?
What about this project is a significant improvement over current practice?
What improvements will your project will make?
What activities and course(s) must be developed, what instruments will be needed, or what coalitions must be formed to make the desired improvements?

Clearly develop the *goals* and *objectives* of the project, where *goals* are the broad, overarching statement of intention and *objectives* are the specific statement of intention (is measurable, more focused than the goal, and there are typically more than one objective for a goal).

As an example of a goal with two corresponding objectives, consider the following:

- The goal is to create a course or curriculum to help retain women engineering students.
    - An objective is to design a new first-year student survey course to spark student interest in possible future endeavors and occupations in which students with engineering degrees may participate.
    - An objective is to develop a class for seniors that will pull together all of their engineering course work in their last semester and allows students to showcase their research accomplishments.

After the goals and associated objectives are well defined, consider what resources (e.g., people, time, equipment, technical support) will be necessary as part of the request to NSF. A better proposal is likely to result if the goals and activities are clear before resources are considered.

Projects should explore teaching and learning methods that use equipment, scientific knowledge, or teaching techniques in effective ways. In addition, more extensive projects, such as Engineering Research Centers (ERCs) must show clearly that they can initiate important changes in the teaching of technology or engineering for a significant segment of the community.

Describe specific attempts that have been made to try the proposed improvement for engineering education on a small scale. Evidence of preliminary work demonstrates planning and commitment to the project and often indicates the project's potential for success.

When the proposal requests significant funds for equipment, it is helpful to consider alternatives and explain why the instruments chosen are particularly suitable for the project and why others, especially less expensive ones, are less suitable.

2.3.1 Gathering Background Information

When writing an engineering education proposal, look for previously funded projects (both NSF and other sources). Become familiar with work in the area of your idea to help guide your project and to ensure that you are not proposing a project that has already been covered. The proposal should be an original idea or serve to fill important ***gaps*** in existing work. It must demonstrate awareness of current literature including techniques, equipment, teaching modalities, etc. that are associated with the field.

Examples of proposals and proposal abstracts are available for reference from the following:
Appendix B of this document contains two samples of two proposals along with reviewer comments; one proposal was funded and the other was not.
Project Information Resource System (PIRS) provides a gateway to award abstracts and other information about projects supported by the DUE. The PIRS database is searchable by PI name, awardee organization, DUE program, project discipline, abstract keywords, and other criteria. (https://www.ehr.nsf.gov/pirs_prs_web/search/).
Sample abstracts of funded EEC proposals are also available through a searchable NSF web page. Search awards for 'EEC,' and you will be given a list of proposals awarded through the EEC program. (http://www.nsf.gov/awardsearch/)

2.3.2 Looking at the Program Solicitation or Announcement

Identify the program or programs that best fit what you hope to accomplish.

Read the program solicitation or announcement guidelines carefully and consider what is requested. Each solicitation provides content and formatting requirements specific to that program. Each proposal should conform to the requirements, (i.e., target dates, text restrictions, font size, page limits, program objectives, budget limits, cost sharing, etc).

The review criteria are particularly important to consider in writing the proposal. Keep in mind that different programs may have special emphases for review. These will be mentioned in the program solicitation. You should consider, if appropriate, how your project might address these areas.

In some cases, programs have specific requirements that differ from the general requirements. When there are differences, the guidelines closest to the program should be followed (i.e., follow the program guidelines provided in the program solicitation). For example, if it calls for double line spacing while the NSF Grant Proposal Guide leaves line spacing to the discretion of the applicant, double line spacing should be used.

2.4 Education Research vs. Educational Development

The emphasis being placed on education research is apparent in recent changes to the funding priorities for engineering projects in two NSF programs. First, the Division of Engineering Education and Centers (EEC) of the Directorate for Engineering will *only* support education research after FY-06. The EEC division encourages partnerships that advance both research and education by creating new knowledge from multiple disciplines, taking advantage of new understanding of how students learn, and by focusing on engineered systems. The objective is to graduate engineering leaders with a global outlook and the ability to adapt to the rapidly evolving technical environment. Second, the Course, Curriculum, and Laboratory Improvement (CCLI) program is also expanding its support for education research in order to improve the quality of STEM education for all undergraduate students. CCLI supports efforts that conduct research on STEM teaching and learning, create new learning materials and teaching strategies, develop faculty expertise, implement educational innovations, assess learning, and evaluate innovations. The program supports three types of projects representing three different phases of development, ranging from small exploratory investigations to comprehensive projects.

For educational programs, be certain to read the program announcement carefully to determine what is being requested. There is a difference between educational research projects and educational development projects.

Educational development includes curriculum, course, laboratory, and faculty development. It can also include human resources development. Many educators begin education development projects which can eventually develop into a research project. These types of proposals will be judged based upon the importance of the proposed development idea, the anticipated impact and outcomes of the work, and how they will be disseminated and utilized.

Educational research is concerned with more fundamental information about education. A principal expectation for research is to provide a stronger evidentiary base to support sustained improvement in STEM educational practice both in formal classroom settings and in informal learning sites (including the home). “We must underpin our program development and adaptation efforts with learning research in order to enhance diversity, encourage equity, and develop a long-term and successful recruiting pipeline. We can no longer afford, as British philosopher Bertrand Russell said, ‘an enterprise of methodical guessing’ when it comes to educating our future engineers.”(Haghighi, 2005) Proposals in educational research will be judged upon the importance of the research question, the innovativeness of the research and methodological fit. For an example of methodology for an educational research project, see Olds, Moskal and Miller (2005).

2.4.1 Thinking About the Target Audience

The target audience of your engineering education project should be clearly explained in terms of demographic characteristics, size, and special characteristics or problems/challenges faced by the group. If you are uncertain about your target audience, use the background search to make yourself an expert.

The project design should be developed in a manner that will effectively assist the target group in addressing those special problems or challenges. The applicant must clearly understand the depth of the problem and the previous research in the area, and they should be able to clearly fill in the gaps in the existing work.

How effective is the project at including and encouraging students from underrepresented populations to participate in engineering? In a recent report entitled "Rising Above the Gathering Storm," a panel of the National Academies warned that America is falling behind internationally because we are not producing enough scientists and engineers. Not only are the numbers of engineers decreasing, but the population of engineers is incredibly homogeneous in culture and background. As engineering is a profoundly creative field faced with creating solutions for humanity, a lack of diversity leads to limited ingenuity. The 2004 YCC concept car and the 1999 Ford Windstar were both designed by teams of female engineers and aimed at female motorists. Both the cars not only utilized existing technologies but also contained unique innovations that had not been addressed in traditional automotive design. The Windstar has been a successful family vehicle for Ford, and many of the YCC ideas are now being incorporated into Volvo's standard designs to serve all of their consumers in new ways thanks to their creative design approach. Not only can projects like this serve as inspiration for young female engineering students, but they also serve to uniquely further the engineering field. According to Anne Asensio, Nissan's executive director of design quality and brand character, "We are a diverse society made up of many kinds of people. The best way to design for diversity is to make sure you hire the people you want to reach."

2.4.2 Building Coalitions

When several departments, several institutions, or constituencies outside the academic community are involved in the project, it is important to involve these groups in the project planning and to obtain letters of endorsement for the project. This demonstrates the sustainability, organization, and depth of the project. Consider using an advisory board to help to provide additional levels of expertise and experience and to disseminate project results.

Build consensus on your idea within your own department and institution. For example, if the courses to be developed are to be taught by different faculty members, reviewers may be more receptive if the proposal is submitted jointly by several members of the department or institution rather than by a single faculty member. It is often valuable to include a letter of endorsement from the department chair, dean or other individuals to establish institutional support. Include information about where the project fits in the context of the institution's academic program. As appropriate, show how your project is part of an overall plan to improve education by your institution and other institutions.

2.4.3 Proof of Concept and Sustainability

The basic sustainability question that must be answered is "after the funding: what now?" How can the research performed be leveraged into new and continuing programs, courses, activities, or initiatives? Most often, research projects begin with intricate designs and end with sustainable pieces. There are issues of sustainability that can be addressed in the grant proposal in terms o f anticipated potential outcomes. Consider various sources of sustainability such as policy changes (both internal to the institution and through external agencies), external funding sources, internal funding sources, various methods of obtaining equipment and even perhaps the ultimate dream of new facilities. In addressing the sustainability issue both in writing the proposal and in completing the grant, flexible, open-minded thinking and ideas pay off. The sustainable pieces do not always have to look exactly like the envisioned results. Applying the research results is paramount. Obtaining key stakeholder buy-in will also contribute greatly to sustainability. Always be on the lookout for new and novel approaches to sustaining research projects and applying research results.

It is important to specify the scope of the project in terms of proposed development and growth over time. Include information on institutional support, noting that multi-institutional support has an even stronger potential for development and sustainability of the project.

2.4.4 Other Considerations

Organize a good working team. Distribute duties and develop a firm schedule of activities needed to prepare the proposal in time to meet the proposal deadline.

Schedule proposal writing and information gathering activities over a reasonable time and carefully manage the schedule. Consider scheduling the writing in small, regular amounts of time. Allow time to have the proposal reviewed by a third party if needed and to obtain all the necessary internal and external letters of endorsement and permissions. With several people working on parts of the proposal, the PI may serve as both contributor to and integrator of the parts. You may find it beneficial to have the final draft of the proposal, after all contributors parts are integrated by the PI, professionally edited to ensure consistency of tone and language in addition to editing for grammar, spelling, and sentence structure.

Invest time running a pilot program and preparing preliminary versions of curricular materials prior to the actual writing of the proposal. The proposal should be written so that, if funded, it can serve as a blueprint for executing the plan.

2.4.5 Outlining the Proposal

Consider using a collaborative proposal writing approach for the main body of the project description with the following outcomes agreed upon by the members: 1) headers and sub-headers to provide organization and context of the proposal; 2) main points to be included in each section; 3) page length of each section; 4) primary authors for each section. Deciding assignments at the outset of the planning allows all parties to contribute meaningfully and in a way that is agreed upon by the whole group. This planning meeting allows proposal members time to get everyone on the same page in terms of scope and direction and to include each member in the planning and engagement of the proposal process.

Generally, successful proposals contain several components which are clearly laid out (not necessarily in the order illustrated below). Steps one through three set up the broad vision of the project within the context of the field. Steps four through seven identify specifics of the project idea and a clear demonstration that the applicant understands the complexity and details of the project and how to make it successful.

1. **Proposal Strategy:** What is your strategy for making this project work?
2. **Goals, Objectives, Outcomes:**
    - *Goals* – Broad, overreaching statement of intention or ambition.
    - *Objectives* – Specific statement of intention. It is measurable, more focused than the goal and there is typically more than one objective for a goal.
    - *Outcomes* – Statement of expected results, which is measurable with criteria for success. One objective may lead to one or more outcomes.
3. **Project Rationale:** This is the narrative that provides the *context* for the project. It connects the ‘Project Outcomes’ to the ‘Project Plan.’ Consider questions like

- *What* does the knowledge base (i.e. literature) say about the approach?
- *What* is the evidence that the approach will solve the problem?
- *Why* is the problem important?
- *Have* you done prior work on the approach? *What* were the results? *Is* there a gap in that work that needs to be filed by the current project?

4. **Project Plan:** Explain your great new idea and be specific.
5. **Evaluation:** Include formative assessment so that you are getting feedback from the design phase to the implementation phase. Consider an outside evaluator to help provide unbiased, measurable feedback throughout the project so that it can be adapted to give the maximum impact. Provide a specific description of the evaluation tools that will be used.
6. **Dissemination:** Demonstrate how you will contribute to the knowledge base and how it will be used to build a community.
   - Demonstrate a proactive method of dissemination and be specific in publication efforts (list journal names, conference titles, dates, etc.)
   - Explore creative, non-traditional venues to increase the diversity of the target audience.
   - If a product will come out of the project, consider commercialization.
7. **Budget rationale:** Demonstrate the costs for each component of the project and justify how the benefits of the project justify the costs.

2.5 Writing the Proposal

The most important tip that NSF program directors give to applicants is to ***carefully read the Program Solicitation or Announcement***. Reviewers read the announcement before reading your proposal. If your idea does not match the criteria laid out by the announcement, it will not be considered. The solicitation or announcement criteria should be considered at every level of the proposal writing process.

2.5.1 Writing the Proposal Narrative

A good engineering education proposal

- is readable, well-organized, grammatically correct, and understandable;
- is specific about the proposed activities (details on organization, course content, laboratory and other inquiry-based experiments, participant activities must be included)
- follows a logical format with section headings and subheadings as outlined by the request for the proposal;
- is explicit about how the program will make an improvement;
- contains specifics including details of experiments and/or applications, both to show that planning has been done and to help reviewers understand why the particular application you propose is better than other ideas;.
- explains how you will implement *every* step of your plan using examples to illustrate, for example, innovative activities or exercises that students will be doing.

It is helpful for reviewers to see that you have devised a project time frame including long and short term goals which demonstrates that you have done adequate planning and are realistic about the program's implementation. It is also important to describe the sustainability of the project and the institutionalization of courses and curriculum beyond the funding period. You will also need to demonstrate good assessment of the results to determine the efficacy of the program. In general, consider answering questions like these in your project description.

- How will your project contribute to a gender-aware learning environment at your institution?
- How will the project improve engineering education for women, racial/ethnic minorities, and/or students with disabilities at your institution and how might it be emulated at other similar institutions?
- How will your plan ultimately improve students' understanding of concepts in science, technology, engineering, or mathematics?
- How will you know it has been done? How will you determine success? What are your evaluation criteria?
- Once successful, how will you assure that the program continues to grow?

You must demonstrate in the narrative that you have a broad knowledge of current scholarship and activities in your field and how this is relevant to your project's design. This knowledge should include current research in teaching and learning practices. However, do not focus entirely on this aspect and fail to adequately describe the components of your project.

The project description/narrative should be written by the person or persons in the science, engineering, or mathematics departments who will be the PI(s). The submitting institution's sponsored research office or grant administration expert can assist in some areas of the proposal writing, e.g., with budgets or grammar, but usually do not have the scientific qualifications or classroom experience to describe the project in an appropriately technical or pedagogical manner. For greater input on the technical and pedagogical details of the proposal, it is important to have the proposal reviewed by another specialist in the field and/or someone from the education department in the institution.

2.5.2 Project Summary

Given the time constraints on reviewers, it is invaluable that you make the project summary as clear and as readable as possible. Pay particular attention to the project summary (abstract) as it is the first thing that reviewers and NSF staff read. In the space allotted, it should outline the problem, the objectives and the expected outcomes, project activities, and the audience to be addressed. ***The project summary must also clearly address, in separate statements, the intellectual merit of the proposed activity and the broader impacts resulting from the proposed activity.*** Proposals that do not separately address both merit review criteria within the project summary will be returned without review. *Program directors use the summary to choose reviewers for the proposal*. It is also the reviewers' introduction to the project. NSF publishes an abstract of the project should it be funded. Considerable effort and thought should be spent in preparing a well-written summary.

2.5.3 A Clear, Concise Project Description

Points to remember:

- proposals must be clear and concise;
- use headings and sub-headings to help reviewers navigate the proposal;
- explain technical details clearly;

- use graphs and tables when possible.

For a larger scale project, you must also include a management plan. Make it clear that you have a defined strategy for implementing and maintaining the project including not only a timeline but such details as staffing decisions.

2.5.4 Including Budget Information

Funding for engineering education should be consistent with its high priority among NSF program goals. The initial budget should include sufficient funds to cover undergraduate research, graduate student support, and editorial and production help for dissemination efforts, but expect the budgetary needs to change as the program progresses. The reviewers are looking for budgets that appropriately cover project costs; proposals with higher budgets must justify the expense through the size and scope of the project. Make sure that your budget narrative reflects both your official NSF budget pages and the needs of the project.

Budget information should be complete, unambiguous, and realistic. Carefully review your budget to ensure that ineligible items are not included. Consult the program solicitation for eligible and ineligible items, and look at the program solicitation or announcement for average size of awards and the award range. Most reviewers and all program directors look carefully at the proposed budgets to find evidence of careful reflection and realistic project planning. Budgets are often negotiated as a proposal is being considered; but a clear, realistic budget request strengthens a proposal.

If you have had prior funding, you are required to describe it. Emphasize the results and successes of the earlier work to demonstrate that your project ideas have measurable returns. Use this as a means to promote your past experience and qualifications to accomplish more results with the proposed project. Do not be afraid of self promotion; past achievements with projects are a strong indication for future success.

As the program matures, the education budget should include increasing contributions from sources outside of NSF such as fellowships and scholarships from the university or industrial sector. Consider taking advantage of awards geared toward under-represented populations such as women, racial/ethnic minorities, and persons with disabilities.

2.5.5 Writing the Credentials of the PI and Other Staff

When writing the credentials of faculty for the grant proposal, each biographical sketch should be written with the proposal in mind and should display the unique background of the principal investigator(s) that will be valuable in working on the proposed project. Be sure that the roles of all personnel, especially the principal investigators, are described in the proposal itself. Having the roles of the principal investigators and other personnel discussed within the narrative is important so that reviewers can understand their involvement in the project. If your project involves industry, consider having a co-principal investigator representing industry.

Carefully follow program guidelines about format and length of biographical sketches. Make certain to keep the biographical sketches within the required 2-page maximum and to follow the requested formatting requirements.

2.5.6 Including Evaluation and Dissemination Information

An effective evaluation plan appropriate to the scale of the project will provide information as the project is developing and will determine how effectively the project has achieved its goals.

- Discuss how you plan to collect and analyze data on the project's impact (i.e., number of students or faculty affected).
- Describe why the proposed project is a good way to improve education at your institution and how it might be emulated at other similar institutions. Also explain how it will build the STEM knowledge base and contribute to the STEM education community.
- When extensive utilization of educational technology is expected, how will student learning outcomes be evaluated? What are the plans to ensure that electronic dissemination will lead to broad implementation of material provided, and that such material will be subjected to continued scrutiny for quality and currency of content?

Consider creating a table (see Table 2-3) with Goals, Objectives, Evaluation Techniques, and Anticipated Outcomes may help researchers to think through the evaluation process to ensure that goals and objectives are realistic in terms of being empirically evaluated.

Table 2-3 Evaluation Table

Goal	Objective	Evaluation Technique	Anticipated Outcome
Increased retention of women students in engineering	Develop courses with interdisciplinary focus to connect eng with societal concern	Retention data after each semester & for cohorts after 4 and 5 years	Increased percent of women remaining in any engineering major

Explain your dissemination plan. Be specific in explaining the methods of dissemination by stating the name(s) of conferences or journals you plan to submit papers. If you develop a web site, explain how people will benefit from this site and who the target audience of the site is and how the site will be publicized. For projects that are creating instructional materials, include information on potential commercial publication. What products (text, software, CD ROMS, manuals, or other publications) might result, and what plans are in place to distribute them effectively? Projects that include plans for commercial publication are encouraged by NSF. Authors who submit such proposals should demonstrate that NSF funding is necessary to create the work, make the product available earlier, or better serve the community.

2.5.7 Letters of Endorsement

Include letters of endorsement from your department chair and other appropriate administrators.
If your project involves people or groups not on your campus (e.g., K-12 teachers, consultants, other colleges or industry), include letters of endorsement from appropriate individuals, organizations, or consortiums. The letters should include indications of specific contributions from the participants' supporting institutions. These should make specific commitments and not just be generic support of good will. Uniquely phrased letters of endorsement from different institutions are better than nearly identical letters from the institutions to be served.

2.5.8 Getting the Details Right - Formatting and Appendices

Prior to electronic submission, it is strongly recommended that applicants conduct an administrative review to ensure that proposals comply with the proposal preparation guidelines established in the *Grant Proposal Guide*. Appendix A contains a proposal preparation checklist that may be used to assist in this review. This checklist is not intended to be an all-inclusive repetition of the required proposal contents and associated proposal preparation guidelines. It is, however, meant to highlight certain critical items so they will not be overlooked when the proposal is prepared.

- **Proposal Pagination Instructions**
  - Applicants are advised that FastLane does not automatically paginate proposals. Each section of the proposal that is uploaded as a file must be individually paginated before upload.

- **Proposal Margin and Spacing Requirements**
  - The proposal must be clear, readily legible, and conform to the following four requirements:
  - The **minimum font** size allowed is 10 point, unless otherwise specified in the program solicitation. However, proposal writers are advised that ***readability is of paramount importance*** and should take priority in selection of an appropriate font for use in the proposal.
  - **Type density**, including characters and spaces, must be no more than 15 characters per 2.5 cm. For proportional spacing, the average for any representative section of text must not exceed 15 characters per 2.5 cm
  - **No more than 6 lines** of type within a vertical space of 2.5 cm.
  - **Margins,** in all directions, must be at least 2.5 cm.

While line spacing (single-spaced, double-spaced, etc.) is at your discretion, established page limits must be followed. (Individual program solicitations, however, may eliminate this option by requiring other type size, margin or line spacing requirements.)

Appendices are strongly discouraged by program directors. Everything the reviewer needs to know should be included in the project description. However, if you must use an appendix, be sure to summarize its contents in the program description section so the reviewer understands what kind of information can be found there.

2.6 Before Sending Your Proposal to NSF

2.6.1 Getting Advice

Consider asking someone who has served on an NSF program review panel to assess your proposal. In general, contact as many people as you can who are familiar with the process. If possible, have someone not connected with the proposal read and comment on a draft of your proposal—with sufficient time allowed for changes prior to the submission of your proposal.
Some programs require a preliminary proposal. Check the Program Solicitation and with NSF staff.

It is ***important*** to establish a relationship with the program officer if possible. Having a good relationship established makes it easier to contact him/her when you have questions or concerns about the proposal writing. They can offer advice and help you sort out misunderstandings about the process. It also gives them a personality to put with the proposal once it is submitted.

2.6.2 Checking over the Proposal

When a checklist is provided in the program solicitation or announcement, use it to ensure that all needed information and/or administrative details are included:

- Are goals and objectives and written plans and procedures for achieving the goals clear?
- Are goals well-developed and realistic, innovative and appropriate?
- Consider using graphics to make your point stronger and clearer.
- Add a timeline to show when different components of your project are to be implemented. For large scale projects, make sure you have included a management guideline to demonstrate how the project will be implemented.

2.6.3 Little Things That Can Make a Difference

- Be sure to *follow the directions* given in the program solicitation or announcement.
- In general *avoid abbreviations*. For example, use mathematics, not math.
- *Write out the meaning of an acronym*. For example, write "Electrical and Computer Engineering Department Heads Association (ECEDHA)" the first time you use the name, and after that use the acronym.
- *Do not overuse acronyms*. Excessive use of acronyms and jargon can make your proposal unreadable to a reviewer not in your specific subfield.
- *Proofread* carefully before submitting the proposal. Do not rely on spell/grammar checker to catch all errors. Consider having the proposal edited by a professional editor.
- Make sure all *your references and page numbers are correct*.
- *Print a copy* of your proposal from FastLane to ensure that all sections are readable.
- The program 5:00 PM submission deadline is a *'hard' deadline*. Only in exceptional circumstances will a late submission be accepted.

2.7 Awards and Declinations

2.7.1 If the Grant is Awarded

If the proposal is successful, make the best possible use of the funds awarded. Situations may arise that require changes in your plans to accomplish the goals of the project. Within broad limits described in the grant conditions (reference GC-1, FDP, and NSF's *Grant Policy Manual*) and within the overall budget, such changes may be possible. Consult your institution's sponsored research office or grant administration office for guidance.

In addition, let others know about your project. This may include providing advice or assistance to faculty developing similar projects. Take advantage of university publications or public relations offices that can offer you publicity on multiple levels. Make sure that other scientists and educators learn about your activities through correspondence, telephone conversations, presentations, and publications. Finally, reference the National Science Foundation as well as the sponsoring Division and/or program in all presentations and publications.

2.7.2 If Your Proposal is Not Funded

If you proposal is not funded, step back and take a few days to recover first. Though negative reviews and a rejection can feel very personal, a rejection of the proposal is not necessarily a reflection of the quality of the idea presented but merely a reflection of the number of high quality proposals received for review.

There are more good proposals submitted than can be funded in any given year, and many good proposals are not funded only because of limited funds. If the proposal is not funded, consider the reviews of the panel and the comments from NSF staff objectively and seriously. Consult NSF staff if necessary and, unless the feedback indicates otherwise, submit a revised or new proposal the following year. Many awards made in the programs have been for proposals that were revised thoughtfully and resubmitted after having been declined initially.

Should your project not receive funding, your institution may have a strong enough commitment to the project to provide funding; consider your department, school or university visiting advisory boards. You may be able to develop a lower cost pilot of your project that can allow you to continue developing the idea that can become a test case for next year's proposal. Also take this opportunity to make your literature review richer to support the foundation of your idea.

You may also discover other funding avenues open to you. If you have contacts with business and industry in your community, a company in the private sector may be interested in helping fund your project. Often, institution grant officers have directories that include the names of other foundations and their funding priorities.

3 Project Management[7]

3.1 Introduction/Overview

Successful project management begins with clear definitions of what constitutes success and the careful alignment of resources. The goal of engineering education programs is to develop a team-based and research-inspired culture for the education of undergraduate and graduate students that will produce engineering leaders for the future. Graduates make up a new generation of engineers who are adept at the cross-disciplinary team approach to problem solving and who are well-prepared to contribute readily and productively to the field of engineering.

An important feature of all successful project management is active outreach to involve administrators, faculty and students in research and education programs. It is also vital to increase the involvement of underrepresented populations in engineering, including minorities, women, and persons with disabilities. Finally, as the project manager, you are charged with enriching engineering education at all levels by integrating their research findings into new curricula for students and practitioners.

This chapter reviews some project management best practices in engineering education. It describes how to manage a budget, staffing and how to develop a sustainable project that has real impact on engineering education. The ideal project, no matter how precisely proposed, will face unforeseen problems, but with a clear plan and strategy, a successful manager can keep a project moving. One project manager for an NSF funded education project advises that most problems that come up have already been solved. Your job as a project manager is to find the existing solutions and leverage them.

For a more extensive explanation of some best-practices in the context of project management for a large-scale project, visit the Engineering Research Centers (ERC) Association's *Best Practice Manual* at http://www.erc-assoc.org/manual/bp_index.htm.

3.2 Tips for Sustaining Human Resource Development Projects

Successful, sustainable human resource development projects have innovative educational benefits for the students to be identified, engaged, recruited, and sustained within the project. Students should have exposure to a cross-disciplinary systems view, teamwork, communications training, and mentoring opportunities. They should also have exposure to the latest developments not only in technology but also in pedagogy, including gender equity pedagogical innovations.

[7] Some sections were adapted from Engineering Research Centers (ERC) Association's "Best Practice Manual" at http://www.erc-assoc.org/manual/bp_index.htm

3.2.1 Recruiting and Retaining Students

To attract students to these programs, the faculty, department, and college need to cooperate in recruiting undergraduate and graduate students as broadly as possible. Some methods for recruiting and retaining students include:

- Attracting undergraduate or graduate students (general strategies)
  - Attend and recruit at professional meetings.
  - Advertise your program and actively recruit via the Internet. Many online resources exist through the universities and professional societies that can bring your ideas to students around the world.
  - If you are in a large department or school, build a network of contacts in the department or college recruiting offices (particularly special offices for women or minorities) who have regular interaction with students.

- Attracting and retaining undergraduate students
  - Introduce the 'Big Picture' to first-year engineering students. Studies have shown that remain motivated to learn when they understand the larger context of the information. Traditional engineering education tends to work from the details up to the big picture, and along the way, universities lose passionate students who become uninterested because they don't understand the meaning behind the details.
  - Develop learning communities for incoming students to help them become a part of the engineering community at your institution within their first year.
  - Develop mentoring programs with advanced engineering students and faculty to help students build a network of resources (Rhoads, et al. 2005).

- Attracting and retaining graduate students
  - Be involved in department/college programs (such as the admissions committees) to be aware of newly available students, and follow up with these students personally.
  - Target historically black, Hispanic, Tribal, and women's colleges and institutions.. Contacting administrators or faculty from these institutions will help establish ties for graduate student recruitment and possibly lead to future collaborations.
  - Be aware of alternative sources of financial support for graduate students. Some of the alternative funding sources are particularly helpful in attracting underrepresented populations. The National Consortium of Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM) is a one example of fellowships for graduate students. Funding can be obtained from a wide variety of sources, including grants from NSF, industry, private foundations, and federal and state agencies.
  - Develop graduate mentoring programs that give graduate students the opportunity to work with a mentor and be a mentor to younger students.

Mentoring is associated with student retention (Rhoads, et al. 2005). Since most faculty members have not had experience with mentoring, it may be useful to set up mentor training to inform them how to become a proactive mentor for their students. (See the full workshop proceedings for best practices advice and more details).

Riskin, et al (2004) also note that two special issues arise when mentoring women, some of which pertain more generally to other under-represented groups. Since the number of women faculty members in engineering is still relatively small, women tend to be asked to take on a greater service burden than are men faculty. Although this is driven by the admirable goal of providing diverse opinions on key committees, it can adversely affect the progress of junior faculty members in establishing successful research programs. Women faculty need to be especially careful in not becoming too immersed in such matters before tenure. A mentor can be very useful here in helping junior women faculty members navigate these waters.

3.2.2 Curriculum Development

Establishing a new curriculum is a challenging and complex task, involving coordinating many faculty members in an interdisciplinary research area. Use the curriculum development as a means to establish departmental and interdepartmental ties for future collaborations. Any new degree or minor degree program must be especially well coordinated with the existing academic standards and structures of the university. Involving high level administrators such a departmental dean can be very affective in building a new curriculum.

The key to successful curriculum development is to build on student interest and enthusiasm. Involve students (undergraduate or graduate) in evaluating plans and implementing the new project. This gives a student's perspective to the curriculum development and is a great tool for providing the students with experience. As the project is implemented, it is also important to evaluate the students' progress at points along the curriculum in order to track efficacy and success; evaluations also provide information about what is working and what needs to be redesigned.

Another vital component of building a sustainable new curriculum is to get the word out and make the information easily available to students and educators; find a vehicle, such as CD, web, or book, for wider distribution of course materials. Additionally, training teachers in the new curriculum or methodology assures that the new information is passed on effectively. In distributing the new curriculum ideas, you can gain valuable feedback not only from students but from colleagues who are also looking to improve the pedagogy of engineering.

3.2.3 Outreach to Schools – Engaging Pre-college Populations

Each PI should determine what pre-college offerings make sense in the context of her/his project's strategic plan, resources, and community relationships. NSF sponsored educators are in pivotal positions to work with local communities to foster innovation in pre-college science and math education (and education more broadly); improve the diversity of the population drawn into science and engineering research; and enrich the general scientific literacy. In fact, some of the larger NSF Centers and CAREER grants require this kind of outreach. Developing outreach to K-12 teachers and students (through means such as summer camps, workshops, competitions, lab tours, and school visits) is an important contribution to reforming science and math education at the pre-college level.

You can change the perceptions of engineering by connecting with K-12 students and educators. In the final report of the "Extraordinary Women Engineers Project" in 2005, which looked at why academically prepared young women are not choosing engineering career pathways, it was recommended that to recruit young women to engineering, we must fundamentally shift the way engineering is portrayed. Engineering is not understood by many K-12 educators, counselors and students and is perceived as a cold, purely technical career with no social relevance.

Increasing the numbers of women interested in engineering means employing many novel recruiting and retention strategies, including tapping into the mostly unmined source of bright and prepared high school women. Increasingly, the vast majority of high school valedictorians are women (Sullivan 2005). The lack of interest among high school girls in engineering is now well documented and is apparent long before high school graduation. According to the 2002 College Board data, only 2% of high school women taking the fall 2002 PSAT (mostly juniors) expressed an interest in engineering as a career (compared to 11% for men). This lack of interest in engineering comes from a fundamental misunderstanding about engineering and its role in society: in short, young women perceive engineering as a predominantly technical career with little impact on the greater societal good. Engineering educators have the opportunity to *communicate and model* that engineering goes well beyond building bridges and engines – engineers *create what has never existed before for the service of humanity*. As such, engineering is an incredibly creative and most human endeavor.

The NSF makes special efforts to reach certain groups (including women, racial/ethnic minorities, persons with disabilities, unemployed or dislocated workers, and at-risk youth). In this role, the NSF seeks to improve public awareness of technology, improve the skills and knowledge of potential science and engineering students, increase the diversity of the engineering student pool, and recruit those students to the engineering education. Creating connections between the university and high schools helps inspire some of the schools' best students. Targeting local schools that are under-funded or have performed poorly on math and science standardized testing is also important for tapping into a student base that is often overlooked. You may provide inspiration and opportunities schools that are under-funded and unprepared to provide students with the information needed to consider engineering careers.

3.2.4 Outreach to Industry

For large-scale educational projects such as the ERCs, it is important to reach out to industry as they will benefit directly from the project. Educational links to industry involve mutual learning, in which knowledge flows both ways. Students and the companies benefit greatly from the interaction.

If you will be establishing ties to industry as part of your program, establish contacts/partners as early as possible, to help ensure industrially relevant education and industrial support in the later years of the program. Industrial internships are one of the most valuable mechanisms for industry-educational interaction. They provide vital technology transfer and educational experience for both undergraduate and graduate students, while giving the industry partners a thorough look at students as potential employees.

3.2.5 Educational Collaborations and Partnerships

Collaborations both within and beyond the department and universities are *essential* for sustaining a project. One critical component to a lasting project is the involvement of at least one high level administrator in your institution. Some of the most successful programs have been strongly supported and publicized by departmental deans or other high level administrators.

Collaborations with existing programs within your department can also be extremely beneficial in sustaining and building your own program. If other programs already exist in your department, look into collaborating and building upon their success.

For projects that incorporate industrial partnerships, programs can propagate their successes through first-hand human contact – the most effective channel for transferring educational know-how or technology. Collaboration with *local* industry and universities should have a high priority, since it is generally cheaper and easier than working with partners who are farther afield. It also builds relationships with local partners that are potential sources of support for the education programs.

Aside from the collaborations with administrators, industry and other faculty members within your institution, forming long-lived collaborations with the faculty and staff of other institutions is also important. This can help establish outreach programs for graduate students, which will help disseminate your ideas to a larger audience and promote the project. Educational partnerships with community colleges and technical institutes have great potential, as well.

3.2.6 Dissemination

In the project proposal, you defined a program of dissemination for the project; build on that framework as you see more possibilities for publicizing the project. The best way to get your information out is to be proactive in promoting websites and materials. Integrate community building with your dissemination plan and be creative. Take every opportunity to talk about your research. The networking aspect of research cannot be over emphasized. The following is a list of some ideas suggested by NSF program directors for disseminating educational projects.

Target and involve a specific subpopulation

- Ask faculty who teach similar courses at other locations to review various products, data and experimental approaches to evaluate there effectiveness and consistency with other programs..
- Work with them to organize events:
  - E-mail exchange and listserves
  - Faculty development workshops (at your institution, off-campus at their institution and at conferences)
- Explore test sites
- Be specific in publication efforts - Target the most relevant conferences and journals.
- Explore non-traditional venues:
  - Council on Undergraduate Research (CUR - http://www.cur.org/), Project Kaleidoscope (PKAL – http://www.pkal.org), State Academy of Science meetings, American Education Research Association (AERA), etc.
  - Science news publications and popular press
  - Professional societies and specialty listserves
- Explore commercialization. Contact software and textbook publishers.
- Put materials in a form suitable for the National Science Digital Library (NSDL).

3.3 Managing a Long Term Budget

Most universities have an office and staff responsible for helping with this aspect of project management. See if your institution has an 'after the funding' workshop to guide you through the process. The NSF Grant Policy Manual contains one sentence about standards for financial management: "NSF grantees are required to have financial management systems that meet the requirements of Section .21 of OMB Circular A-110." (For the OMB Circular A-110, see http://www.whitehouse.gov/omb/circulars/a110/a110.html#21).

Every new NSF project manager faces a few challenges within the context of the NSF definition for financial management. First, the changing nature of a project directly affects the budgeting and management strategies. You evaluated options and projected them into the future when you wrote the project proposal. Unfortunately, reality does not usually match these projections as some things will cost more than anticipated and others less, and your strategy will need to adjust accordingly. Another challenge is that all NSF projects must be managed, painstakingly, down to "net zero." Every allocated dollar available must be used productively, and at the same time, one needs to avoid returning unused funds or risk running over budget.

A vital component to financial management is *regular finance review*. This ensures that performance and results are compared to the budget and actual expenditures on a regular basis. An example is provided in Table 3-1.

Table 3-1 Financial Review Schedule (Large-Scale Project)

Frequency	**Purpose**	**Participants**
Monthly	Review budget	Project Director & Financial Manager
Quarterly	Compare budget to outcomes	Financial Management Team
Quarterly	Review deliverables status (Highlights)	Project Team
Annually	Review performance against budget	National Visiting Committee, External Evaluator & Project Team
Annually	Financial audits	Financial Manager

This schedule is designed for a larger-scale project with many administrative components, but the model of financial review can be applied to a project of any size. Notice that they lay out regular meetings scheduled at different points in the fiscal cycle in order to track the budget as the year progresses. This assures that there are no financial surprises at the end of the year.

Another simple but important detail in planning your financial management strategy is to be **aware of the different fiscal cycles**. Choosing and committing to the right budget cycle can be a critical decision. Three factors must be taken into account when developing the financial management strategy and the fiscal cycle for your project.

- Make sure you know the relevant dates in your institution's defined fiscal year.
- The NSF grant year begins August 1.
- Understand when you will *actually* receive the NSF funds.

Funds distributed to the host institution, and all ongoing financial issues (payroll, purchase orders, invoices, etc.) are managed with the assistance of and in compliance with the host institution's policies and procedures. One recommended strategy is to synchronize the budgetary timelines with the timelines for the project results so they coincide with the budget cycle of your institution. This will tie together all of the annual reporting to one short period in the year. This organization may take a lot of time in the early stages of your project, but having an organized and efficient budgetary strategy will save you endless hours of going back through unaccounted for financial records.

In short, a budget is a financial plan of action that details the allocation of project funding to particular project activities. Develop an accounting strategy that offers you transparency to your budget and that allows you to track expenses and costs against the planned allocation. Measure success by creating the desired output and remaining within the budgeted allocation. For more details on budget management, see the NSF *Grant Policy Manual* at http://www.nsf.gov/pubs/manuals/gpm05_131/index.jsp.

3.4 Building and Maintaining an Effective Staff

For larger educational projects, staffing is incredibly important to the success of a program. Settle on an administrative structure before defining positions. Then carefully lay out the job descriptions because taking time now will prevent problems later. You might consider filling immediate needs with temporary personnel so you have time to consider staffing that meets the needs of the project.

3.4.1 Hiring Staff

Extra effort is required the first time you do anything new; thus, demand for staff support may be especially high during start-up and during key times of transition. Determine how large your program will be over a period of time, based on your strategic plan, and consider how the staff can be used to extend faculty expertise and time.

In drafting employment agreements, be poised to balance the pressures of the program's growth and new program development against a simultaneous need for reorganizing due to program shifts and funding changes over time. Traditional human resource practices and layoff policies may not accommodate simultaneous retrenchment and reallocation within one administrative unit. Anticipating problems in this area can positively influence your early personnel choices, and may prevent grievances, conflict with unions, and/or future litigation. Plan early for the phase-down of NSF support.

In many larger scale educational programs, the PI takes responsibility for the many aspects of the project that could be handled by trained staff members. This is not the most effective structure in the long run. Appointing separate individuals with responsibility for administrative tasks is a more effective and sustainable way to run a larger project. You need to consider the necessity of each of the following:

- Administrative Assistant
- Accounting personnel
- Information Systems personnel
- Communications personnel

3.4.2 Position Titles

Your university has central personnel who can provide help you ensure that your position titles are congruent with university guidelines. They can guide you in the use of employment categories/titles, and can help to ensure that the university complies with laws and regulations regarding recruiting, hiring, conditions of employment, and termination. The university's personnel policies also address regulatory issues such as equal employment opportunity, nondiscrimination, sexual harassment, and drug and alcohol abuse.

3.4.3 Before You Hire

You may want to consider alternative appointment strategies. For instance, under what circumstances should tenured instructors be funded by your program? Some programs do not pay participating faculty salaries; rather, continued department support of faculty lines is viewed as the appropriate "contribution" in return for student support and other benefits that come with project involvement.

You may have the option to appoint non-faculty staff directly within the program, or else to process appointment documents through participating academic departments. This issue also calls for an evaluation of several operational and resource concerns.

You should recognize the important role you can play, through hiring decisions, in supporting the careers of women, minorities, and the disabled. NSF encourages diversity in the administrative staff as well as the faculty. On many campuses, your program can serve as role models for how to do this well.

3.4.4 Personnel Records and Reports

It is essential that an accurate and up-to-date record of all personnel be maintained. Reporting agencies set guidelines on the type of personnel reports required (e.g., federal grants require effort reports on the number of hours devoted to the project). Check the requirements for the tables in the NSF Annual Report and the NSF Indicators Report carefully. Consistency in how the information is gathered and managed is imperative. It is recommended that only one or two people be allowed to change data. Some information will be confidential, so file sharing must be carefully considered.

Sponsors require a wide variety of personnel statistics. It will be important for you to distinguish/track the following in your records:

- headcount (the number of individuals) vs. full time equivalent (FTE) counts;
- paid (salaried) vs. otherwise supported personnel;
- directly supported students vs. those indirectly involved (as in taking program-influenced courses) to provide the total number of students "impacted" by the program;
- historical information (e.g., personnel over time);
- student details (e.g. major, year, academic status);
- faculty detail (e.g., core faculty vs. participating faculty; visiting faculty);
- gender/racial/ethnic classifications and other demographic data;

- program affiliations and program changes over time;
- time and effort reporting, for any personnel paid on federal funds;
- alumni information, including address after leaving the program.

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Appendix A

Proposal Preparation Checklist[8]

This checklist is not intended to be an all-inclusive repetition of the required proposal contents and associated proposal preparation guidelines. It is, however, meant to highlight certain critical items so they will not be overlooked when the proposal is prepared.

[ ] **Proposal is responsive to the program announcement/solicitation** or to the grant proposal guide. If previously declined, proposal has been revised to take into account the major comments from the prior NSF review.
[ ] **Proposed work is appropriate** for funding by NSF, and is not a duplicate of, or substantially similar to, a proposal already under consideration by NSF from the same submitter.
[ ] **Proposal Format** (ensure compliance with font, margin and spacing requirements, bearing in mind that proposal readability is of utmost importance)
[ ] **Information about Principal Investigators/Project Directors** (except for the required information regarding current or previous Federal research support and the name(s) of the PI/co-PI, submission of the information is voluntary)
[ ] List of suggested reviewers, or reviewers not to include (optional)
[ ] Deviation Authorization (if applicable)
[ ] Proprietary or Privileged Information Statement (if applicable)
[ ] SF LLL, Disclosure of Lobbying Activities (if applicable) (one copy only, scanned as a single copy document)
[ ] **Cover Sheet**
 [ ] Program Announcement/Solicitation No./Closing Date (If the proposal is not submitted in response to a specific program announcement/solicitation, proposers must enter NSF 04-23)
 [ ] Specific NSF program(s) identified (if known)
 [ ] For renewal proposal, previous award number entered
 [ ] Related preliminary proposal number entered (if applicable)
 [ ] Appropriate boxes on Cover Sheet checked
[ ] **Project Summary** (one page only with both merit review criteria separately addressed within the body of the Summary)
 [ ] Contains specific sections on the *Intellectual Merit* and *Broader Impact* of the project.
[ ] **Project Description** (15 page limitation)
 [ ] Results from Prior NSF Support (required only for PIs and Co-PIs who have received NSF support within last 5 years)
 [ ] Merit Review Criteria (ensure both merit review criteria are described as an integral part of the narrative). Numerous examples illustrating activities likely to demonstrate broader impacts are available electronically on the NSF Website at http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf)
 [ ] Human-resource information (required for renewal proposals from academic institutions only)

[8] From the NSF's "Grant Proposal Guide" http://www.nsf.gov/pubs/gpg/nsf04_23/index.jsp

[ ] **References Cited** (No page limitation, however, this section must include bibliographic citations only and must not be used to provide parenthetical information outside of the 15-page Project Description. Each reference must be in the specified format.)
[ ] **Biographical Sketch(es)** (2-page limitation, required for all senior project personnel. The required information must be provided in the order and format specified.)
[ ] **Proposal Budget** (cumulative and annual)
[ ] Budget Justification (3 page limitation per proposal)
[ ] Cost Sharing (if applicable)
[ ] For proposals submitted in response to the grant proposal guide or an NSF program announcement, only the statutory cost sharing amount (1%) is required. In such cases, proposers are advised **NOT** to identify cost sharing amounts on Line M of the proposal budget.
[ ] For proposals submitted in response to solicitations that require cost sharing, proposers are advised not to exceed the cost sharing level or amount specified in the solicitation.
[ ] **Current and Pending Support** (required for all senior project personnel including PIs)
[ ] **Facilities, Equipment and Other Resources**
[ ] **Special Information and Supplementary Documentation**
[ ] **Any additional items** specified in a relevant program solicitation
[ ] **Proposal Certifications** (submitted by the Authorized Organizational Representative within 5 working days following the electronic submission of the proposal.)
[ ] **Submit before the 5:00 PM deadline!**

Appendix B

Examples of Proposals

In order to assist those preparing and submitting proposals for engineering education projects to the NSF, two examples of research proposals are provided. There are three parts listed for each proposal below: (1) the summary (2) the proposal and (3) the reviewers' comments and funding recommendations. Please note that your research proposal and topic may differ substantially from the examples provided. The examples are offered to provide greater awareness of what constitutes a successful proposal and to illuminate various aspects of the review and award decision.

Example of a Funded Proposal

This section includes a proposal summary, project description, and reviews for a proposal that was granted NSF funding. The reviews include a panel summary review and individual reviewer comments.

PGE/RES Why Does It Work? A Study of Successful Gender Equity in Industrial Engineering at the University of Oklahoma

Summary:

As of Fall 2001, 58% of the undergraduate majors in Industrial Engineering (IE) at the University of Oklahoma (OU) are women. This proportion is strikingly higher than both the nationwide proportion in IE and the proportion in other STEM degree programs at OU. Furthermore, the proportion has more than doubled in the space of five years, having steadily increased from 27% in 1996. This phenomenon is especially puzzling because IE at OU did not set out specifically to accomplish gender parity among its undergraduate majors. It should be noted that IE at OU also has a high proportion of women faculty (4 of 10 faculty, 40%), which is one of the factors identified by Seymour and Hewitt (1997) as having an impact on retention of women majors. This phenomenon alone is unlikely to account for the present gender parity, as evidenced by nationwide trends in other disciplines (e.g., chemical engineering and computer science). We propose to investigate this phenomenon in order to contribute to the knowledge about increasing the representation of women in STEM undergraduate majors and to make recommendations both for systemic efforts and for future research directions. We consider it particularly critical to investigate *combinations of factors* that affect students' choices.

Our primary source of data will be interviews with students. For each of the three project years, we will interview students at multiple levels – from sophomore to senior, as well as alumni – thus gathering information about experiences not only from across cohorts but longitudinally following cohorts as they progress through degree programs. As part of our design, we will probe systemic factors that help/hinder departments in their efforts to achieve gender equity goals, an undertaking that will involve additional departments at OU as well as departments at other institutions. This design will enable us to identify *combinations of factors* by targeting departments that vary in the extent to which such factors are present (e.g., departments that have a relatively high proportion of women faculty and those that have lower proportions). To assure triangulation, other sources of data will include student transcript records, the Pittsburgh

Engineering Attitudes Toward Engineering Survey©, and interviews with faculty, program directors, advisors, and graduate students, all of whom affect student experiences in college.

We will conduct 600 interviews of students. Each interview will last 60-90 minutes, with questions related to each of six factor categories, which are based on a review of the literature and a small pilot study. During the first year, we will interview only IE majors at OU. From this data, we will develop both knowledge about the factors at play and an efficient analysis system for compiling the results. In the second and third years, we will interview students at OU majoring in Aerospace & Mechanical Engineering, Chemical Engineering, Computer Science, Mathematics, and Physics, in addition to students majoring in Industrial Engineering. Finally, during the third year, we will include additional interviews of IE majors at Arizona State University, the University of Nebraska at Lincoln, and the University of Pittsburgh.

The substantial data that we intend to collect and analyze will require a relatively large team of researchers with a diversity of skills. Thus, we have a fifteen-person research team consisting of: two anthropologists, two educational researchers, two faculty in IE at OU (one with expertise in engineering education research), one faculty liaison for each of the other participating departments at OU (one with expertise in undergraduate mathematics education research), one faculty liaison with each of the participating institutions, and an experienced project director.

Project Description:

1. Purpose

For decades, there have been efforts within the science, technology, engineering, and mathematics (STEM) communities to address the under-participation of women in these fields. Most studies and projects related to gender equity seek insight about why women are *under*-represented in STEM fields. In contrast, for reasons that are not yet clear, the School of Industrial Engineering (IE) at the University of Oklahoma (OU) has achieved what other STEM programs consider a goal: gender parity. Therefore, our approach is to start with a program that is working and investigate why it is working.

As of Fall 2001, 58% of the undergraduate majors in IE at OU are women. This proportion is strikingly higher than both the nationwide proportion in IE and the proportion in other STEM degree programs at OU. Furthermore, the proportion has more than doubled in the space of five years, having steadily increased from 27% in 1996. This phenomenon is especially puzzling because IE at OU did not set out specifically to accomplish gender parity among its undergraduate majors. We propose to investigate this phenomenon in order to contribute to the knowledge about increasing the representation of women in STEM undergraduate majors and to make recommendations both for systemic efforts and for future research directions.

Although progress has been made over the past two decades, there are still concerns about the under-participation of women in STEM professions [3]. Qualified, talented women continue to reject or abandon careers in STEM fields [4]. Furthermore, some fields have made less progress than others (Table 1). Statistical studies of large data sets have identified variables related to entry and persistence rates, but have failed to explain sufficiently the remaining gender gap [5].

Now that statistical data has identified some key facets, what is needed is rich, qualitative data to get at the heart of the issues. Thus, we will adopt a longitudinal, ethnographic research design.

Our primary source of data will be interviews with students. This ethnographic research design has as precedents works such as Seymour and Hewitt [1] and Margolis and Fisher [2]. Seymour and Hewitt [1] interviewed hundreds of undergraduates at colleges across the country to identify factors that contributed to the students' decisions about completing or switching out of a degree in science, mathematics, or engineering. Margolis and Fisher [2] focused on women students majoring in computer science. We will extend and refine this prior work by investigating what characteristics of IE at OU, as compared to less successful STEM fields/departments, attract and retain female (and male) students.

2. Research Base for Need and Design

In Spring 2002, we conducted a very small pilot study to explore the logistics and issues of the large-scale study. We interviewed twelve students (eight women, four men) majoring in IE at OU. We used an interview protocol initially based on the work of Seymour and Hewitt [1], Margolis and Fisher [2], and the conjectures and experiences of the research team. Based on our review of the literature and our experiences with the pilot interviews, we will target the following six factor categories in the study:

<u>I Student's Background</u>: Many studies have documented the role of quality pre-college experiences in science and mathematics in a student's choice to pursue a STEM major [1, 2, 4-9]. Such experiences come from formal school activities, informal or extracurricular activities, and family setting. Most of the students who participated in the pilot interviews had a strong STEM background in one form or another. Our focus will be on why students select a particular field (e.g., IE) within STEM and why they persevere in that field, as opposed to rejecting or abandoning such a pursuit.

<u>II Attributes of the Institution</u>: Factors in this category relate to student retention in general [10, 11], which in turn affects retention within specific majors. We expect that retention rate is an important factor that enables IE to sustain both an increasing number of students attracted to the major and the high proportion of women majors. For example, several of the students who participated in the pilot study mentioned scholarships, student organizations, and proactive recruiting activities as important factors in their choice of a major within the College of Engineering (CoE) at OU.

<u>III Attributes of the Field</u>: Recent studies indicate that women are especially attracted to fields that focus on people, community, and society [1, 8, 12]. This factor is used to account for the higher participation of women in social and life sciences (including medicine). We suspect that this will also be a critical factor in our study, based on how students described IE as a field during the pilot interviews. Also based on the pilot interviews, we expect that other attributes of the field of IE, compared to other STEM disciplines, will turn out to be attractive to women as well: big-picture/systems focus, variety of choice for area of concentration (human factors vs. operations research vs. manufacturing, etc.). However, given that the proportion of women

majors in IE at OU is more than twice the nationwide proportion of women in IE (Table 1), we believe that attributes of IE as a field are not sufficient to account for the phenomenon.

Table 1: Proportion of Women in Selected STEM Fields

Participating Departments	OU students[b]		students nationwide[d]	OU faculty[e]		faculty nationwide
IE	47/84	55%	25%	4/10	40%	10% [f]
Chem E[a]	126/325[c]	39%	33%	1/15	6%	8% [f]
Mathematics	24/75	32%	46%	3/29	10%	19% [13]
Physics	16/75	21%	20%	4/28	14%	8% [g]
CS[a]	46/312	15%	24%	2/12	17%	11% [h]
AME[a]	45/338	13%	12%	1/15	6%	6% [f]

TABLE NOTES: (a) "Chem E" is Chemical Engineering; "CS" is Computer Science; "AME" is Aerospace & Mechanical Engineering; (b) [14], *Table 46: Norman Campus Students By College, Major And Level Unduplicated Headcount: Fall 2000*, left column is women/total; (c) Chem E at OU includes material science; (d) [15] *Table 257.--Bachelor's, master's, and doctor's degrees conferred by degree-granting institutions, by sex of student and field of study: 1997-98*; (e) Obtained by consulting department personnel; left column is women/total; includes tenured and tenure-track only; (f) [16] *Appendix D: Data on Faculty Rank Comparing Georgia Tech to Benchmark Schools, 1998*; (g) [17] *Table 4. Percent of Faculty Positions in Physics That Were Held by Women, 1998* (includes Full, Associate, Assistant Professor, and other ranks); (h) [18] *Table 21. Gender of Current Faculty* (includes Full, Associate, and Assistant Professors in CS and computer engineering departments that grant Ph.D.'s)

IV Pedagogies/Curricula: All students benefit from quality teaching, but women tend to be more disappointed and put off by poor teaching than are men [1, 8]. As part of "quality" teaching, women students tend to want positive feedback from instructors (external validation, as opposed to no feedback or non-negative feedback), beyond grades [1]. Furthermore, women students benefit from pedagogy that includes cooperative learning and curriculum that includes hands-on, practical problem-solving [8]. During the pilot interviews, several students talked at length and with enthusiasm about their experiences with projects, supporting our expectation that this factor category plays a substantial role.

V Department Culture: IE at OU has a high proportion of women faculty (Table 1), which is one of the factors identified as having an impact on retention of women majors [1]. One might suggest that this attribute explains the high proportion of women majors (and that the corresponding solution for other departments is simply to hire more women faculty). While we are convinced that the high proportion of women faculty is a critical factor, we do not believe that it alone accounts for the phenomenon. We take as one counterexample the situation in chemical engineering. Nationally, women comprise only 8% of chemical engineering faculty but 33% of bachelor's recipients are women [3, 16]. A different counterexample can be found in computer science. The proportion of women faculty has remained relatively stable, even comparable to that in chemical engineering (9% in 1993, 11% in 2002), but the proportion of bachelor's recipients who are women has decreased considerably (37% in 1985, 28% in 1994, 24% in 2001) [15, 18, 19]. Thus, we do not believe that the high proportion of women faculty in IE at OU sufficiently accounts for the gender parity among majors in IE at OU. An alternate possibility is that the department culture is attractive to women – both at the undergraduate level and at the faculty level [20, 21]. For example, according to the pilot interviewees, the IE faculty are unusually collegial. This observation was made also by a faculty member outside of IE. It is possible that having more women in the department shaped the department culture; it is also possible that an existing department culture attracted women.

VI Student's Future: The literature raises such issues as work-life balance, the nature of the work, and the climate of the workplace as factors affecting women's choices [22]. As with factor category II (Attributes of the Institution), the foundation of this factor category is retention of students within a major. As students progress through a major, they gain a better sense of what the future might look like while simultaneously getting to know themselves and refining their own personal goals. Our pilot interviews indicated that students majoring in IE see a career path that is demanding and time-consuming but that is also flexible.

3. Research Design

In this study, we will probe systemic factors that affect departmental efforts to achieve gender equity goals, an undertaking that will involve additional departments at OU as well as departments at other institutions. This design will enable us to identify *combinations of factors* by targeting comparison/contrast departments that vary in the extent to which such factors are present. One such factor is the proportion of women faculty. IE at OU has both a high proportion of women faculty and a high proportion of women majors; CS, on the other hand, has a relatively high proportion of women faculty (the 11% national average leads to an expected proportion of 1/12 but CS at OU has twice this: 2/12) but a relatively low proportion of women majors. Thus, we consider CS to be a good comparison/contrast department. Similar arguments hold for including the other departments. Table 2 illustrates the relationship between proportion of women faculty and proportion of women majors for the departments at OU that will participate in this study relative to the national proportions reported in Table 1.

Table 2: Representation of Women in Departments at OU
Relative to Corresponding National Proportions

	high in students	average in students	low in students
high in faculty	IE at OU	Physics at OU	CS at OU
average in faculty		AME at OU	
low in faculty	Chem E at OU		Mathematics at OU

Student Informant Pool. We will obtain lists of current majors and recent alumni from the participating departments. To generate the initial pool of participants from each department, we will randomly select students within each cohort (using a random number generator). We will contact each student by phone and/or e-mail to invite him or her to participate in the study. The first students to agree to participate, up to the number listed in Table 3 (with 75-80% being women), will be the informant pool. Each participant will be randomly assigned to an interviewer and the interview scheduled at a time convenient for both the participant and the interviewer. This process of selecting participants, assigning them to interviewers, and scheduling the interview sessions worked well in our pilot study.

Table 3: Interview Schedule (shading is to illustrate longitudinal aspect)

<table>
<tr><td colspan="2">Interviews 2003</td><td colspan="2">Interviews 2004</td><td colspan="2">Interviews 2005</td></tr>
<tr><td>IE class of 05 (Sophs)</td><td>25</td><td>IE class of 06 (Sophs)</td><td>25</td><td>IE class of 07 (Sophs)</td><td>25</td></tr>
<tr><td>IE class of 04 (Juniors)</td><td>25</td><td>IE class of 05 (Juniors)</td><td>25</td><td>IE class of 06 (Juniors)</td><td>25</td></tr>
<tr><td>IE class of 03 (Seniors)</td><td>25</td><td>IE class of 04 (Seniors)</td><td>25</td><td>IE class of 05 (Seniors)</td><td>25</td></tr>
<tr><td>IE class of 01,02 (alum)</td><td>10</td><td>IE class of 03 (alum)</td><td>5</td><td>IE class of 04 (alum)</td><td>5</td></tr>
<tr><td colspan="2" rowspan="2">75-80% of those interviewed will be women</td><td>Chem E, AME, CS, across three cohorts</td><td>75</td><td>Chem E, AME, CS, across three cohorts</td><td>75</td></tr>
<tr><td>Mathematics, Physics across three cohorts</td><td>50</td><td>Mathematics, Physics across three cohorts</td><td>50</td></tr>
<tr><td colspan="4">IE at OU interviews: 245 total
(75 sophs + 75 juniors + 75 seniors + 20 alumni)</td><td>AZ State Univ, Univ of NE, Univ of Pittsburgh, across three cohorts</td><td>90</td></tr>
<tr><td>total interviews/year</td><td>85</td><td></td><td>205</td><td></td><td>295</td></tr>
<tr><td colspan="6">+ approximately 15 switchers from participating departments at OU = 600 total interviews</td></tr>
</table>

We will follow several cohorts of students for several years. In particular we will follow one cohort of sophomores through their senior year and one cohort of juniors into their first year after graduation. We will interview three cohorts of sophomores, three of juniors, three of seniors, and three of recent alumni. We will take the sophomore year rather than the freshman year as the initial interview year because students tend to change majors several times during their freshman year, which would confound data collection and analysis. Many students settle into a major around their sophomore year and have fresh memories of their decision-making process. We will include men in the sample to provide comparison/contrast perspectives as well as to explore the possibility that men who choose IE share common characteristics and the related impact this might have on the environment. It is important for us to include the initial group of alumni (classes of 2001 and 2002) because those people were students before gender parity was reached and before the fourth woman faculty member was hired. Subsequent alumni cohorts are included because they can reflect on the entire program.

After the first year, we will contact students who participated in the initial year (to get a longitudinal view), as well as add new cohorts to the pool. We expect attrition both in the sense of students changing majors and in the sense of informants withdrawing from participation. We will still want to interview the number of students indicated in Table 3. So, for example, if we lose 5 of 25 students in a cohort, but the other 20 agree to continue participation, we will interview those 20 and add in 5 replacements (using the random selection process described above). In addition, suppose that 3 of the "lost" students have switched majors. We will contact those students, and if they agree to continue participation, we will include them in the dataset as "switchers" [1]. Students who no longer want to continue participation will not be contacted further. Students will be assigned to the same interviewer as much as possible, accounting for attrition of interviewers and added scheduling problems.

<u>Data Collection</u>. For each of the three project years, we will interview students at multiple levels – from sophomore to senior, as well as alumni. Table 3 shows the interview schedule and Table 9 shows the timeline. This design will enable us to gather data about experiences not only across cohorts but longitudinally following cohorts as they progress through degree programs. The

interview protocol is provided below. To ensure triangulation, other sources of data will include student transcript records (to verify progress to degree), the Pittsburgh Engineering Attitudes Toward Engineering Surveys, and interviews with faculty, program directors, advisors, and graduate students, all of whom affect student experiences in college.

Co-PI Harris, who teaches a course titled, "The Anthropology of Communities" [23], will use materials from that course to train graduate and undergraduate research assistants, as well as senior personnel, in ethnographic research methods. Based on our pilot study, we anticipate that senior personnel will complete up to 1.5 interviews per week and that student assistants will complete up to 2 interviews per week. During Spring 2003, 7 senior personnel will be available to interview for at least 6 weeks early in the semester (Jan-Mar) and 4 student assistants for at least 6 weeks later in the semester (Mar-May). Thus, for example, we expect to complete approximately 55 interviews in the early part of the Spring 2003 and the remaining 30 in the latter part of the semester. Once we have refined the system, we expect interviews and analysis to be more efficient.

After completing each interview, the interviewer will review notes to look for remaining issues that need to be addressed before the participant leaves. Concurrently, participants will spend the last 10 minutes of each interview period completing the Pittsburgh Engineering Attitudes Surveys©. There is a survey for each of the sophomore, junior, and senior participants and each has been validated and found to be reliable for use with student attribute modeling. These instruments measure several facets of students' attitudes (e.g., their opinions about engineering as a profession, the reasons they chose to study engineering, and their perceived ability to succeed in engineering) and the questionnaire items have been statistically clustered into 13 attitude and self-assessment measures. These 13 measures will be added to the overall data analysis. In addition, the *Sophomore Engineering Learning and Curriculum Evaluation Instrument*© asks the student's self-assessed preparedness of their current level given their educational experiences during the previous year; the *Junior Engineering Learning and Curriculum Evaluation Instrument*© asks additional questions about a student's work experiences and how they relate to the outcomes; the *Senior Exit Survey*© asks supplementary questions about a student's future educational plans and employment information.

Faculty, program directors, advisors, and graduate students have a different kind of insight to department characteristics than that of undergraduates. For example, informal conversations have led us to believe that the department culture of IE at OU differs from the culture in other STEM departments. Thus, for each participating department, we will collect formal interview data from a sample of such personnel to help us identify characteristics particular to IE at OU that enabled it to achieve gender parity among its undergraduate majors. Each faculty member, program director, and advisor will be interviewed only once during the three-year duration of the project. A small sample of graduate students – especially those who come into contact with undergraduate majors (e.g., teaching assistants) – will be selected each year, with some being interviewed over multiple years. To ensure confidentiality, interviews will be conducted by the co-PIs who are the least closely associated with the participating STEM departments: Fleener (Associate Dean of the College of Education and Professor in Instructional Leadership and Academic Curriculum) and Harris (Director of Women's Studies and Associate Professor in Anthropology). Questions will be motivated by the interview protocol and factor categories used for students. For instance, we will ask "How do you think students might respond to the question 'Why did you choose <for each field in the study> as a major?' "

<u>Interview Protocol</u>

Each session will last up to 90 minutes, including time to complete the Pittsburgh Engineering Attitudes Toward Engineering Survey, and will be audiotaped for later completion of written field notes. Specific questions will likely be addressed in different orders and/or modified appropriately for different participants (e.g., sophomores vs. seniors).

Student's Background

Year in college, major, minor(s).

What year were you born? Did you come straight to college from high school?

High school background (classes, grades, interest in STEM). Compare high school courses in science and math with your current engineering-related courses (easier/more challenging, teaching styles, etc.).

In high school, what did you do when you weren't in class? Outside interests? Extracurricular activities? Sports? Did you have a job?

Parents' occupations? Siblings? Other family? Do they like their work? Do you identify with some of them?

What do you do when you are not in class or studying? Extracurricular activities? What did you do last Saturday? What would you do if you had time? Family and community responsibilities? Do you have a job?

Tell me the story about you and computers (when/how did you get interested)

Attributes of the Institution

What brought you to college? Why did you choose OU (or …) over other schools? What schools did you apply to? Do you have scholarships?

Are you involved in student organizations or student professional organizations? Sorority/fraternity? [Why not?] [if not addressed in extracurricular activities]

Attributes of the Field

Why did you choose IE (or …) as a major (especially vs. some other STEM field)?

How did you learn about IE as a major? What experience was most responsible for your decision? Was there anyone who especially encouraged you?

How would you describe IE? What are the qualities/skills that make a good industrial engineer (or …)?

How are those around you (family, friends) responding to your decision?

How is IE perceived by others in engineering? People not in engineering?

What interests you most about IE? Least? Interest in IE increased/decreased?

Do you feel that you and IE are a good fit? Are you happy with your decision? Would you make the same decision if you knew earlier what you know now?

What other majors have you considered/pursued? Why those? Why not choose one of those? In what other areas do you maintain an interest? Thoughts about switching out of IE? Why? Why not?

Pedagogy/Curriculum

Tell me about the classes you have taken.

Favorite undergrad class (in IE and other)? Why? Describe a typical class period.

Least favorite undergraduate class (in IE and other)? Why? Describe a typical class period.

In general, do you prefer classes that have a lot of lecture, small group work, competition, use of computers, big projects?
What makes a class easy? Hard? Which do you prefer?
How do you learn best? What do you need for an optimum learning experience? Do your professors (in IE and other) provide that? What projects do you like best? Least?
Do your professors provide encouragement? What does that look like? Are there moments when you feel discouraged? Has your confidence in your ability to do well in the major/field increased or decreased?
Department Culture
What is your best experience with a faculty member? Worst? How often do you interact with faculty? Graduate students? Who are the people who are important to you (role models)/who do you identify with?
How often do you interact with other students (in IE and other)? When/where? What kinds of interactions to you have with fellow industrial engineering majors? What kinds of things do you do or talk about? How have these interactions changed over time? Who are the people who are important to you (role models)/who do you identify with?
What advice would you give to new students (and/or high school seniors considering engineering at OU)? Is your advice different for women than for men?
What advice would you give to faculty? What advice would you give to the decision-makers (about curriculum, policies)?
Ideas of why so few women in field at large? Why different at OU? Ideas on what would have to be different to attract/excite more women? What is at OU that "works"?
Student's Future
When do you think you will complete the degree?
What are your plans for after graduation (career, family, other interests, where to live, financial security)? Where do you see yourself in five years? What do you want a typical day to look like? How will your degree in IE fit into your goals?
Experiences with job market/internships, job recruiters, finding employment.

<u>Data Analysis</u> [23-26]. We will complete approximately 600 interviews, with a 225 students potentially being interviewed at least twice. After each interview session, the interviewer will complete field notes, which will be the primary data archive. Interviewers will meet as a group several times each month to discuss findings, identify factors, and develop themes. We will employ software designed for qualitative data analysis (NUD*IST, NVivo, and The Ethnograph). We expect to complete at least two kinds of analyses:

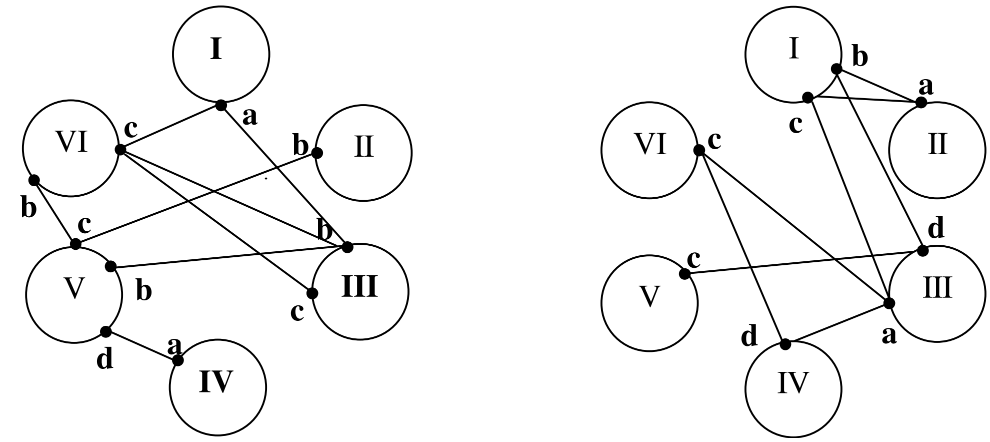
(1) Pattern Analysis: Field notes will be coded – that is, pieces of dissected interviews will be labeled with key words to identify factors. From the coded field notes, we will be able to identify themes and patterns that are representative of what students tell us. We will search for themes that have been identified in previous literature (e.g., [1, 2]) as well as additional themes that emerge from our study. As an example theme, during the pilot study, a number of students mentioned "IE is people-oriented" (Table 4) as a reason they opted to major in IE at OU. This analysis will help us to establish the relative importance of each identified factor.
(2) Multi-Factor Analysis: Choosing a major is a complex process, affected by many interrelated factors. Themes reach across factor categories to affect the choices that students make. When we

analyzed the pilot data, we attempted to create a matrix for doing a two-way comparison (a cross-tab). In doing this, we discovered that the relationships really are more complex than a two-way comparison permits. What we wanted was a multi-dimensional strategy for analysis. This led us to construct diagrams like those in Figure 1. From such diagrams, we will be able to group students based on the similarity of factor relationships that contributed most to their choices. For example, we might be able to create a group of students who are "people oriented."

Anticipated Results. We will compile a profile for a department that has succeeded in establishing gender parity. From this profile, we will contribute to the knowledge about attracting and retaining women in STEM fields and we will make recommendations to STEM departments to help focus their efforts to achieve gender equity. Table 4 and Figure 1 give sample results from the pilot interviews. To conserve space, and because we had such a small sample for the pilot study (twelve interviews), the table and figure include only a few factors, aggregated across participants to protect confidentiality. For example, the pilot study brought to our attention several possibly salient characteristics of IE at OU: (1) compared to other IE departments, IE at OU has a noticeable focus on human factors (e.g., as opposed to an overwhelming focus on manufacturing; Table 4 IIIc), (2) compared to other departments in CoE, IE has an especially collegial environment (Table 4 Va), (3) compared to other departments in CoE, IE faculty treat undergraduates as apprentices (Table 4 Vc).

Table 4: Sample Factors from Pilot Interviews

Factor Category	**sample factors identified in pilot study interviews with ten students majoring in Industrial Engineering at OU**			
I. Student's Background	a. strong desire for career with people orientation	b. strong interest in math and science	c. exposure to science and engineering via family	d. exposure to computers at home and in school
II. Attributes of the Institution	a. scholarship opportunities	b. student organizations and networking	c. OU is close to home	d. like OU
III. Attributes of the Field	a. switch from chemical or petroleum engr	b. people oriented	c. useful to public and human factors	d. challenges, opportunities, and flexibility
IV. Pedagogy/ Curriculum	a. interaction with faculty	b. interactive and group work	c. feedback from faculty	d. student work has relation to real life
V. Department Culture	a. interaction between faculty	b. women role models	c. faculty invite participation in projects	d. faculty are approachable
VI. Student's Future	a. graduate school	b. balance between family and work	c. seeks work for company w community involvement and flexibility	d. developing other interests, e.g., music



(A) factors related to people interests (B) factors related to STEM interests

Figure 1: Complex Interrelationships Among Factors, Based on Pilot Interviews

In addition to the list of factors that comprise the profile, we will develop a better understanding of the complex relationships among these factors that affect students' decisions. These relationships will be depicted graphically using node-arc networks. The pilot interviews verified the existence of such network webs. For example, some students expressed concern that many areas of engineering appear "too thing-oriented" rather than "people-oriented". These students wanted a people-oriented career (listed in Table 4, cell I.a, and shown in Figure 1-A by arc “a” emanating from node “I”). This factor is related to the perception that IE is a people-oriented field (Table 4, cell III.b, and Figure 1-A, arc ”b” from node “III”) and to a student’s desire to work for a company that is involved in the community (Table 4, cell VI.c, and Figure 1-A, arc “c” from node “VI”). Even though each of the factor categories - student's background, attributes of the field, and student's future - is clearly relevant, the actual choice of IE as a major depended on the relationships among these factors, depicted in Figure 1-A as a interconnected network of nodes and arc. The theme of a "people-oriented" degree and career path reached across factors to attract and retain those students in IE as a major.

The literature indicates that women are especially attracted to majors and professions that involve people, contribute to the community, and enable a balance between work and personal life [1, 8]. Most fields have such characteristics in some form, but most departments fail to advertise these aspects. Thus, one possible recommendation to departments would be to identify the aspects of the field that appeal to women and advertise these aspects more. Based on our work, we might, for example, recommend that departments (1) cultivate a spirit of community among faculty, (2) treat students (undergraduates as well as graduate students) as apprentices, and (3) advertise the "human aspects" of the field. The key is identifying *combinations of factors* that departments can implement to achieve their gender equity goals.

Our pilot sample was very small and it would be premature to draw general conclusions, or even to constrain our expectations, at this point. Nevertheless, we believe that our pilot study supports both our assertion that achieving gender equity involves complex relationships among factors and our design involving hundreds of interviews with student informants.

4. Descriptions of the Roles of Collaborating Partners

There are three phases to this study. One is the portion of the study that is relevant to the IE department at OU. The next phase is the addition of the other engineering schools, mathematics, and physics, each at OU. In order to reach beyond the OU environment, we will expand the third phase of the study to three institutions with IE programs similar, yet different from OU's. This will allow us to examine which phenomena transcend the institution and are generalized to the degree program. Table 5 is a summary of some basic demographic data from each institution.

Table 5: Demographics of Participating Institutions

	Undergraduate Student Population		Faculty (Tenure-track)		Tuition (Per semester)		National Merit Scholars
	Count	% Women	Count	% Women	In-State	Out-of-State	
Arizona State University (main)	35,191	52%	1,822	37%	$1,136 (12 hours)	$4,864 (12 hours)	~150
University of Nebraska (Lincoln)	18,455	47%	1,106	26%	$1,215 (12 hours)	$3,456 (12 hours)	39
University of Pittsburgh (main)	26,710	53%	3,253	---	$3,706 (Per term)	$8,302 (Per term)	---
University of Oklahoma (Norman)	25,559	50%	1,179	28%	$808 (Per term)	$2,561 (Per term)	110

Industrial Engineering at Arizona State University (PI: William Moor, Associate Professor and Director of Undergraduate Programs), the University of Nebraska (PI: Susan Hallbeck, Associate Professor), and the University of Pittsburgh (PI: Mary Besterfield-Sacre, Assistant Professor) will be the external participants. Table 6 is a summary of the departmental demographics from each of the participating departments. Organizational efforts will be achieved through a summer preparation meeting where all three subaward PI's will attend a meeting at OU to discuss OU results, definition of terms (such as time to graduation determination, etc), timing of interviews, interview protocols, IRB approvals and applications, and general logistics. In year 3, the OU Team will divide between the three universities for one week to conduct the interviews.

Table 6: Demographics of Participating Industrial Engineering Departments

	Undergraduate Student Population		Faculty (Tenure-track)		National Merit Scholars	
	Count	% Women	Count	% Women	Count	% Women
Arizona State University (main)	201	32%	20	20%	15	27%
University of Nebraska (Lincoln)	71	37%	10	20%	---	---
University of Pittsburgh (main)	140	41%	11.5	17%	5	40%
University of Oklahoma (Norman)	110	57%	10	40%	7	57%

Table 6 (cont.): Demographics of Participating Industrial Engineering Departments

	Program Areas	Women's Programs	Technical Societies
Arizona State University (main)	Industrial & Mgmt Systems Info & Telecomm Systems Global Ind Engr Leadership High-Tech Mfg Pre-Prof & Svc Systems	Women in Science & Engr Program Women's Studies (Univ) Feminist Majority Leadership Alliance (Univ) Women of Worth (Univ)	Society of Women Engr Minority Engr Program Ntl Society Black Engr Society Hispanic Prof Engr
University of Nebraska (Lincoln)	Operations Research Manufacturing Ergonomics Management	Women's Studies (Univ) Women's Center (Univ)	Society of Women Engr Ntl Society Black Engr
University of Pittsburgh (main)	Operations Research Mfg & New Product Research Information Systems Engineering Management	Women's Studies (Univ)	Society of Women Engr Ntl Society Black Engr Society Hispanic Prof Engr
University of Oklahoma (Norman)	Operations Research Manufacturing Human Factors Simulation Information Technology	Women's Studies (Univ)	Society of Women Engr Ntl Society Black Engr Society Hispanic Prof Engr American Indian Sci and Engr Society

The Department of Industrial Engineering at Arizona State University is widely considered to possess one of the best programs in the western United States. The program uses a system of career-focused study areas to help the students concentrate their interests. The University of Nebraska IE Department is home to two premiere research centers. The Center for Non-Traditional Manufacturing Research is the only facility in the U.S. dedicated solely to the examination of non-traditional manufacturing methods. The Center for Ergonomics and Safety Research was established in 1991 to study job performance and well being of people in relation to their job tasks, equipment, and environment. The Department of Industrial Engineering at Pitt is one of the five oldest in the world. The department is known throughout the academic IE community as offering an outstanding academic environment that values teaching and mentoring, both at the undergraduate and graduate levels. OU and UNL are both state schools located in suburb-type communities, while ASU and Pitt are metropolitan or urban schools. ASU is almost twice the size in students and faculty as OU. Pitt is a semi-private institution. These similarities and differences will strengthen the outcomes of the study.

5. Dissemination Plan

The target audience for our dissemination efforts will be STEM faculty, administrators, and policy makers, as well as STEM education research faculty. These populations are best reached through conferences and journals. Samples of appropriate conferences and journals are listed in Table 7. During the first semester of the project Spring 2003, we will collect a substantial amount of data. As is standard with qualitative research, we will begin analyzing the data as we collect it. Thus, we will have preliminary results as early as the Summer 2003. So, for example, we will submit a proposal to the Mathematical Association of America's MathFest (due May) for the conference in August 2003. We will also submit an abstract to the Annual Meeting of the

American Educational Research Association (due August) for a presentation at the conference the following April. During that first summer we will also begin to prepare articles for journals.

Table 7: Sample Conferences and Journals Targeting STEM and STEM Education Faculty

Target population	conferences	Journals
engineering and computer science	American Society for Engineering Education Annual Conference and Exposition, Frontiers in Education, Association for Computing Machinery Technical Symposium on Computer Science Education	*International Journal of Engineering Education, Journal of Engineering Education, Journal of Women and Minorities in Science and Engineering, IEEE Transactions on Education*
physics	National Meeting of the American Association of Physics Teachers	*Physics Teacher*
mathematics	Joint Meetings of the American Mathematical Society and the Mathematical Association of America (MAA), MAA MathFest	*Conference Board of the Mathematical Sciences: Issues in Mathematics Education, Journal for Research in Mathematics Education*
education	Annual Meeting of the American Educational Research Association	*American Educational Research Journal*

6. Qualifications of Team Members and Suitability for Their Role in the Project

The substantial data that we intend to collect and analyze will require a relatively large team of researchers with a diversity of skills. Tasks to be completed include: (1) administration; (2) interviewing students; (3) interviewing faculty, program directors, advisors, and graduate students; (4) organization and analysis of large data sets. Table 8 indicates the role(s) that each PI and Senior Personnel will assume, with the numbers in the right-most column referring to these tasks. Tasks are divided among the team members based on their positions at OU and their areas of expertise.

Table 8: Qualifications and Role(s) of Project Personnel

Personnel	Position at OU	Expertise	Role in Project Tasks (1)-(4)
Fleener	Assoc. Dean, CoEduc; Prof., ILAC	education research methods	(1) co-PI (3) all depts.
Furneaux	Prof., Physics & Astronomy	physics content and culture	(1) liaison with Physics & Astronomy
Harris	Assoc. Prof., Anthropology; Director, Women's Studies	anthropology research methods	(1) co-PI; train student assistants to conduct interviews (2) all depts. (3) all depts. (4) analyze interview data
Lobban	Director, Chem E	chemical engineering content and culture	(1) liaison with Chem E
Meissler		ethnography research methods	(1) research coordinator (2) all depts. (4) analyze interview data
Murphy	Asst. Prof., Math	undergraduate	(1) PI; provide liaison with Math

		mathematics education research	(2) non-Math majors (4) analyze interview data
Reynolds	Assoc. Prof., ILAC	education research methods	(2) all depts. (4) analyze interview data
Rhoads	Asst. Prof., IE	engineering education; statistics; IE content and culture	(1) co-PIs; liaison with IE at OU, ASU, UNL, Pitt (2) interview non-IE students (4) statistical analysis
Shehab	Asst. Prof., IE	human factors, design of experiments, IE content and culture	
Shirley	Asst. Dean, CoE; adjunct faculty, AME	mechanical engineering content and culture	(1) liaison with AME (2) non-AME majors
Trytten	Assoc. Prof, CS	computer science content and culture	(1) liaison with CS majors (2) non-CS majors
Walden	Lecturer, Chemistry & Biochemistry	project management and curriculum development	(1) project director (2) all depts.

7. Timeline and Management Plan

The timeline in Table 9 shows our primary administrative and research activities for the three project years. The investigator whose name appears in parentheses after the task has primary responsibility for assuring completion.

Table 9: Timeline and Responsibilities

Jan 03 – Dec 05	Administration	Data Collection & Analysis
prior to start	e student assts (Shehab) fine IE cohorts (Rhoads)	ot study (Spring 2002)
each year	ec) hire student assistants (Shehab) n) train student assistants (Harris) n) schedule interviews (Murphy)	going analysis (Murphy) erview faculty, program directors, advisors, duate students (Fleener) immer, Fall) complete interviews left-over m Spring (Murphy)
Spring 2003		interview IE at OU cohorts (Murphy)
Summer 2003	define cohorts in Chem E, AME, CS, Math, Physics (Rhoads)	refine/systematize analysis procedures (Murphy)
Fall 2003		begin to interview Chem E, AME, CS, Math, Physics cohorts (Murphy)
Spring 2004		add interviews at OU: Chem E, AME, CS, Math, Physics cohorts (Murphy)
Summer 2004	Representatives from ASU, UNL, Pitt meet at OU (e.g., define cohorts) (Shehab)	
Fall 2004	prepare visits to ASU, UNL, Pitt (Shehab)	continue to interview at OU: IE, Chem E, AME, CS, Math, Physics cohorts (Murphy)
Spring 2005		add interviews: IE at ASU, UNL, Pitt cohorts (Murphy)
Summer-Fall 2005		final data analysis (Murphy)

Throughout the project years we will also submit proposals and abstracts for conference presentations. Examples of such activities include:
Engineering community: Frontiers in Education Work in Progress session (abstract due January, conference in October), American Society for Engineering Education (abstract due November, conference in June)
Mathematics community: Mathematical Association of America MathFest (abstract due May, conference in August)
Education community: American Educational Research Association (abstract due August, Conference in April)
Although writing will happen year-round, the bulk of journal article writing will happen during the summers.

8. Results from Prior NSF Funding

Rhoads
Science and Technology Enhance Authentic Learning in the High Schools: Project STEALTH
PIs: Mark Nanny (PI); Teri Reed Rhoads (co-PI) and Mary John O'Hair (co-PI)
Grant No.: GK-12: DGE00-86457, Amount: $1,409,011, Period of support: 3/1/01-5/31/04

This research is in the early stages of implementation where the overall goal is to teach Fellows how to successfully integrate their technical background and expertise into secondary science and math classrooms. This will enable secondary students to directly experience the relevancy of their education to "real-world" problems and technology. The project involves thirteen graduate and twelve advanced undergraduate Fellows, twelve secondary science and mathematics teachers (from three high schools and three middle schools located in Oklahoma City and Del City), and seven OU faculty (from the School of Civil Engineering and Environmental Science, School of Industrial Engineering, and the Center for Educational and Community Renewal), who work together in teams developing, designing, implementing, and assessing authentic learning, inquiry-based activities for secondary science and mathematics students. The main components of this research project include Instructional Preparation, Technology Preparation, Technology Infrastructure, Secondary Teachers, Secondary Students, and University Faculty. These components are centered on the Fellows and intertwined through the inquiry-based activities and projects that the Fellows, teachers, and faculty will develop and implement together as a team. To date, there are two publications and an informational website located at www.coe.ou.edu/ata/.

Shehab
REU on Human Technology Interactions (REU Site 96-102)
Grant No.: SES-9820689, Amount: $157,428 Period of Support: 6/1/1999 – 5/31/2002

The University of Oklahoma's (OU) Human Technology Interaction Center's REU Site on Human Technology Interaction concluded this year after three-years of support. This REU site supported the undergraduate training mission of the HTI Center to involve and engage students in interdisciplinary research experiences focused on the interaction of humans with various forms of technology. The center has been successful in its mission by providing research experiences to a total of 42 undergraduate students representing 10 different majors from 31 institutions and 18 different states. The participants were typically from smaller institutions where the opportunities for research are limited. In addition, we were able to recruit 5 African American, 2 Hispanic, and 2 Native American participants and 45% of the participants were female. We believe that the students were able to gain an accurate perception of research and the issues involved with working on interdisciplinary teams. For the most part, student feedback was extremely positive regarding their experiences and most suggested that participating in the REU has furthered their desire to pursue an advanced degree. This demonstrates the enthusiasm with which students left the program. The success of the program has been demonstrated by the scholarly activities that the students have continued after returning to their home institution. Many students have continued the research with their faculty mentor, some long-distance and others at OU. In addition, many of the faculty have benefited by advancing their research program substantially through REU support.

Reviews:
Panel Summary:

The review panel was extremely enthusiastic about this proposal. The research plan is clear and reflects the thoughtful pilot work that the researchers have already carried out. The mixture of methods should allow them to get at an interesting and robust array of data. The findings from this study could push STEM departments to examine the humanistic aspects of their work and thus support women students better with what might even be minimal changes to their current way of doing business. Thus the impact from this study could be high and could begin early, as researchers begin disseminating findings while the study is ongoing. As will become evident below, the review panel had some concerns about managing this large, multi-institutional project and so is gratified to see that the researchers have constructed their budget to assure that each person gets some benefit that will increase the likelihood of continued cooperation. Additionally, in choosing the institutions to be involved, the researchers have apparently leveraged previous relationships, again increasing the likelihood of a successful collaboration.

The reviewers had two concerns. The first has to do with managing this highly ambitious project. The panel suggests that the researchers plan to include an active listserve and a password-protected intranet site for use by the researchers from the several institutions. Periodic formative evaluation of the collaborative process may also help to maintain a strong relationship among the researchers.

The panel's second concern is with the interview protocol and the number of protocols. The protocol is very dense and the panel wondered whether the interviewers will be able to complete it in 90 minutes. The panel also wants to be sure that the interview process leaves time for the students to tell their stories. If this is the same protocol that the researchers used in their pilot study, then the researchers will know if the panel's concerns are justified. If it is a new protocol, then the researchers may want to make adjustments. The panel wondered if the researchers need to conduct as many interviews as they have planned or if they would be better off with a smaller, well-chosen sample. Do the researchers need this number of interviews in order to reach data saturation? Perhaps they could anticipate stopping data collection when saturation is reached.

Panel Recommendation: Highly Competitive; fund it

REVIEW # 1 - Rating: Excellent

What is the intellectual merit of the proposed activity?
The idea of looking at a program that has been inadvertently successful is a novel one.

What are the broader impacts of the proposed activity?
The impact on our understanding is likely to be high as the researchers identify factors and combinations of factors that influence the recruitment and retention of women students. They note that some of these factors could be deliberately incorporated in other departments and suggest that some departments may not have to change much, just identify and advertise the factors that would attract and retain women students. The dissemination plan is clear, with journals and conferences named. The researchers will begin disseminating results early in the program.

Summary Statement
The research plans and objectives are laid out with extreme clarity. We know who is doing what at what point. We see the interview protocols and understand why they include the questions they do. We see some preliminary analysis of pilot data. We understand why they researchers want to extend their investigation to other departments and other institutions. The research methodology is credible and appropriate.

The understanding of gender equity issues is strong. Researchers seem well acquainted with past findings. The key personnel seem to combine appropriate skills and experience.

The organizational resources are adequate. The collaborating institutions seem committed to the project, with some money as well as facilities provided.
The budget is large but well justified.

REVIEW # 2 - Rating: Good
What is the intellectual merit of the proposed activity?
The proposed study plans to utilize multiple qualitative methods to investigate the characteristics of an IE program with exemplary female enrollment proportions and to compare the life experiences of its students with those of students from other institutions. I am heartened by the choice of qualitative methodology in that I believe women need an opportunity to talk about their life influences and career choices. Higher education could benefit from understanding trends in these phenomena that are freely revealed by students rather than constructed prior to survey administration. My concerns about this study are twofold. As a qualitative researcher myself I have doubts about the researchers' abilities to cover the interview protocol in 90 minutes. The protocol is extremely dense and leaves little room for participants to truly reveal their stories. In addition, I am unclear about the rationale behind the sampling of university programs. The authors state that the differences among the institutions will strengthen the outcomes of the study. I am unclear about how these particular choices would do that.

What are the broader impacts of the proposed activity?
Potential outcomes of the study would offer an intimate and elaborate view of women's choices about careers in engineering. Moreover, the qualitative thematic data would provide a rich source of constructs to inform future investigations about women in SMET studies and careers.

Summary Statement
This highly ambitious study proposes to gather a massive data set in hopes of providing deep understanding of women's experiences in engineering programs. The presence of a high proportion of women at OU presents a unique opportunity for ethnographic study of this phenomenon. I have some concerns about the sampling rationale and also about the restrictive nature of the interview protocol, which is too dense to allow for the elucidation of the students' stories.

REVIEW # 3 - Rating: Very Good
What is the intellectual merit of the proposed activity?
This proposals seeks to deconstruct (through a variety of disciplinary perspectives), "What constituted success?" for women in STEM communities given complex relationships that yielded

positive outcomes of persistence and retention. This grant proposal builds on the development of intended and unintended successful outcomes. This information will be useful to faculty in colleges and universities nationwide.

What are the broader impacts of the proposed activity?
The development of an understanding about what contributed to success for women in SMET is a sure way to plan for replication of good outcomes. The research plan includes an analysis of student attributes, attention to pedagogy, and discipline-specific attributes.

Summary Statement
Institutional collaborations and research consortiums are challenging to maintain. Periodic formative evaluation of the collaboration may not only yield insights into the "health" of the collaboration; but, most importantly, may identify potential concerns before they become problematic or establish new information related to best practices in the development of effective partnerships.

REVIEW # 4 – Rating: Excellent
What is the intellectual merit of the proposed activity?
The phenomena at Oklahoma University of gender parity in Industrial Engineering may be relevant for other engineering fields. Discovering why more female students have decided to major in IE is important, especially if the environmental factors can be replicated. One of the important aspects of this study is the collaboration of experts from many disciplines and the comparison between institutions.

The qualitative study is very well organized, although the repetitive nature of the questions over a period of years is of questionable value. (I understand that the researchers are looking for stability and change, but the students may treat it as an eye exam, decide how they want to respond rather than honestly responding.) The methods, however, are sound and based on accepted anthropological practices.

The PI is well qualified as are the Co-PIs. The other team members are not as well versed in gender educational issues as viewed through their publications. Professor Murphy"s work as seen through her publications is of high quality and reflects a focus on the area of undergraduate education in mathematics and gender issues. Betty Harris" work also focuses on the status of women (especially African women), although it does not involve science or mathematics.

The number of faculty participating at different institutions (especially those at Oklahoma University) gives the PI and Co-PIs access to engineering faculty and students on the different campuses involved.

What are the broader impacts of the proposed activity?
The broader impact of this study is significant because this study will advance the understanding of why female engineering students select IE at OU as a major. Although OU will have a pretty clear picture of why EI appeals to female engineering students, the other participating campuses may not understand as much about their programs because of the short duration of the information gathering on their campuses.

This study will also increase communication among the institutions involved without a doubt. Because of the diversity of these institutions (urban/suburban, public/private) other engineering programs may weigh the results of this research more heavily than a study of a single institution.

The dissemination plan is specific and well designed.

The obvious social benefit will be the increased number of female engineers. A secondary benefit may be a push by traditionally mechanical engineering disciplines to develop their humanistic attributes more. This kind of change might encourage more diversity in the students who select engineering as a major.

REVIEW # 5 – Rating: Excellent

What is the intellectual merit of the proposed activity?

This research is particularly meritorious in that it examines a successful program with a large ration of female to male faculty in IE. It is also significant in that it proposes to make recommendations fro systemic reform and set directions for future research rather than simply reporting on "best practices" at one institution. An additional merit of this proposal is that it relies on interview data rather than survey data as the primary data for analysis. In addition, the interviews are iterative and recursive, which enhances the level of internal validity of the study. By examining combinations of factors, the findings will provide a much richer set of data for analysis and interpretation. The research design is well-crafted and presented in sufficient detail. The informants will be selected randomly from the pool of students. this increases the power of the research design. The research team is diverse and well-qualified to conduct the research proposed. the inter-disciplinary approach is a significant strength.

What are the broader impacts of the proposed activity?

Because of its strong research design, this study will contribute significantly to the body of knowledge on how programs in IE can attract and maintain a high proportion of female students and faculty. There is a limited amount of rigorous research on successful IE programs in terms of gender equity. The data from this study can be used to inform policy as well as practice on a national level.

Summary Statement

This is a well-designed, artfully described proposal that should contribute significantly to the general body of knowledge on successful programs in IE. It has potential to provide important insight into reform efforts in engineering education at the national and international level.

Example of a Proposal not Funded

This section includes a proposal summary, project description (with the contents of Exhibits 1 – 7 removed for brevity), and reviews. Note that this proposal rated from 'poor' to 'excellent' depending upon the reviewer.

PROMOTING EFFECTIVE DIFFUSION OF STEM EDUCATIONAL INNOVATIONS

Summary:

This project will conduct a workshop that brings together innovators in undergraduate education from an array of science, technology, engineering, and mathematics (STEM) disciplines (e.g., biology, chemistry, computer science, civil engineering, electrical engineering, mechanical engineering, geosciences, mathematics, physics, sociology, psychology, etc.) with experts in the diffusion of innovation, social marketing, and the psychology of compliance in order to develop strategies for increasing awareness of and use of innovations in undergraduate STEM education.

Outcomes from the workshop will include the following:

A better understanding by STEM faculty of impediments to the diffusion of innovation in undergraduate STEM education,

Frameworks, adaptable to the characteristics of individual STEM disciplines, for enhancing the diffusion of innovation in STEM undergraduate education, and

Distribution of the frameworks, in print and electronic forms, along with suggestions for initial actions to key opinion leaders in academic associations, disciplinary societies, and university departments.

Discussion of the workshop findings at professional meetings for various STEM disciplines as well as academic associations.

Intellectual Merit:

This workshop builds upon existing research in innovation and organizational change and applies that research in the novel context of undergraduate STEM education. Specific emphasis is placed on motivating STEM faculty to engage in behaviors that will enhance student learning. In so doing this workshop brings researchers in diffusion of innovation, social marketing, and the psychology of compliance together with STEM faculty focused on traditional research in physical science and engineering disciplines, but with an interest in effective instruction. In addition to the individuals directly affected, this activity brings together the intellectual resources of the National Academy of Engineering, Project Kaleidoscope, and our colleagues on over 700 college and university campuses. As a result of the implementation activities that will result form this workshop, there will be testbeds that may contribute to both theory and practice in the diffusion of innovation.

Broader Impacts:

By enhancing the probability of successful dissemination of educational innovations, this project will contribute to the better development of the human resource base in STEM disciplines through improved instruction resulting in enhanced recruitment into, retention within, and graduation from undergraduate STEM academic programs. More efficient diffusion of educational innovations should result in more efficient use of faculty time across the entire range of research, instruction, and service. Additionally, this project may stimulate more research on diffusion of educational innovations.

Project Description:

Promoting Effective Diffusion of STEM Educational Innovations

Overview

Under the terms of Master Agreement No. 0239565 for unsolicited proposals, the National Academy of Sciences requests $73,545 as one year's support to hold a national workshop that brings together innovators in undergraduate education from an array of science, technology, engineering, and mathematics (STEM) disciplines with experts in diffusion of innovation, social marketing, and the psychology of compliance in order to develop strategies for increasing awareness and use of innovative science and engineering education research and practice focused on undergraduate education.. The work will be performed by the National Academy of Engineering in collaboration with Project Kaleidoscope of the Independent Colleges Office.

Background

While diffusion of innovation as an output of graduate research and education in science, technology, engineering, and mathematics (STEM) fields (e.g., technology transfer) has been much studied [1] , relatively little exploration has occurred with respect to diffusion of innovative practices that enhance instructional effectiveness and student learning within STEM undergraduate education. In 1999 Elaine Seymour received, via the Innovation and Organizational Change (IOC) program, National Science Foundation (NSF) grant SES-9906162 to investigate “whether and how the diffusion of education innovation can occur in chemistry departments and their institutions.” This work appears to be discussed in the broader context of change in STEM education in a 2002 paper [2]. A key finding of this work is that “[f]inding the means to leverage relevant shifts in departmental values and practices is the critical factor in determining whether the efforts of faculty . . . will be able to improve the quality of STEM education . . . .”

Peter Smith and his co-workers received support under NSF IOC grant SES-0080704 “to investigate organizational change an innovation in higher education, particularly as regards the applications of technology.” He observes in January 2004 issue of Change magazine [3] that “. . .[C]hange persists and succeeds when it is sufficiently comprehensive to be self-sustaining within the larger culture and when it is actively supported by the assumptions, services, rewards, and incentives of the organization.”

Karen Seashore and her co-workers received support under NSF IOC grant SES-0080304 to explore “how external demands and internal processes combine to produced sustained improvement in productivity in here schools districts in Minnesota, North Carolina, and Iowa.” But this work was principally concerned with the role of external mandates more so that building collegial consensus for diffusion of innovation.

William Ouchi received support under NSF IOC grant SES-0115559 to investigate “the organization and management” of the New York , Chicago, and Los Angeles public school systems. However, this work speaks to organizational effectiveness and not directly to the process of building buy-in or acceptance either within an organization or across organizations.

Statement of Need/Opportunity

Over the past decade or so, numerous reports have encouraged greater attention to the quality of undergraduate instruction in science, mathematics, engineering, and technology (STEM) fields [4-18]. And yet, it can be argued that relatively little has changed in the content and conduct of undergraduate STEM instruction [19].

For large-scale change (or diffusion of existing pilots of change) in the quality of undergraduate STEM education to occur, three conditions must be met individually and collectively by STEM faculty:
Acceptance of a vision of change,
Stimulation of the will to achieve the change, and
Acquisition of the knowledge and skills required to execute the change process.

The first condition is actually a compound one requiring a) recognition that a problem exists, b) agreement that suggested solutions are feasible, and c) concurrence among interested stakeholders that the solutions under consideration benefit would-be change agents more than the status quo. Nonetheless, across 17 years of reports, Project Kaleidoscope has observed a consistent vision ". . . of an environment in which all American undergraduates have access to learning experiences that motivate them to persist in their studies and consider careers in [STEM] fields; it is of an environment that brings undergraduates to an understanding of the role of science and technology in their world. It is a vision that calls for attention to practices and policies that affect shaping the curriculum and building the human and physical infrastructure to sustain strong programs. It is a vision that calls for collective action. [20]"

With respect to the third condition, Seymour [2] lists the resources needed by faculty innovators as the following:
Access to pedagogical and assessment expertise;
Teaching and learning assessment materials in accessible form;
Digests of pedagogical and assessment techniques;
Syntheses of the theoretical and research bases for these methods; and
Evidence of their efficacy.

We are clearly making progress to identification and development of these resources. For example, our increased understanding of learning, assessment and their implications for education processes and their assessment (e.g., as documented in NRC report on *How People Learn* [13]) has dramatically increased our ability to provide interested faculty with assistance in developing practical working knowledge of these areas. And the NRC's Committee on Undergraduate Science Education has observed that the scholarly literature and an increasing number of web sites provide practical guidance on techniques for improving undergraduate student learning [9].

The major remaining challenge to diffusion of instructional innovation in STEM education would appear to be "stimulation of the will to achieve change". Froyd has suggested that irrespective of your theory of change, careful attention must be paid to how faculty are made aware of education innovations. Information must be presented in such a manner as to facilitate

the faculty members transition through stages of readiness for change [21]. Ramaley makes a similar argument at the institutional level [22].
However, given the many competing demands on the time of faculty members, affecting their individual and collective will to change is often dependent upon convincing them that the benefits to be derived from change are worth the investment of time and energy [23-26]. Tobias [27] frames the issue as follows "The process of transforming innovation into change . . . of getting teachers to accept the findings of educational research . . . is essentially a political process. . . . Many educational reformers-scientists in particular--fail to acknowledge how political this process is and--even when they do--don't have the diplomatic skills (or the stomach) to see it through."

In crafting the best possible case to make to their peers, we believe that would-be change agents among STEM faculty would benefit from discussions with researchers drawn from the fields of diffusion of innovation, social marketing, and social norms theory.. Therefore, we propose to host an invitation workshop linking key opinion leaders drawn from across natural science and engineering disciplines with experts in the aforementioned fields.

Rogers, in the fourth edition of Diffusion of Innovations [28], observes that, "Getting a new idea adopted, even when it has obvious advantages, is often very difficult. … Therefore, a common problem for many individuals and organizations is how to speed up the rate of diffusion of an innovation." He goes on to state that, "The essence of the diffusion process is the information exchange through which one individual communicates a new idea to one or several others." Thus, a key task is to help educational innovators effectively communicate their ideas to their faculty peers.

The field of "social marketing" has been defined by Andreasen [29] as "the application of commercial marketing concepts and tools to . . . influence the voluntary behavior of target audiences where the primary objective is to improve the welfare of the target audiences and/or the society of which they are a part." The target audience here is STEM faculty and the behavioral that we wish to influence is their active engagement in high quality undergraduate instruction. While it appears that much of the social marketing literature is heavily concerned either with modifying personal behaviors (e.g., smoking, drug use, or inclination toward contribution to a given charity) it would be interesting to explore the application to professional behaviors. The work of James Deering, a co-worker of Everett Rogers, would appear relevant given his research on diffusion of innovation theory with emphasis on the ability to purposively spread effective interventions and programs through professional networks of potential adopters. An example of his work in the area of AIDS prevention appeared in the Journal of Health Communication [30].

Given the importance of peer recognition within faculty domains, it would seem reasonable to also incorporate representation of "social norms" theorists. Perkins [31] has observed that, "Group norms reflected in the dominant or most typical attitudes, expectations and behaviors no only characterize these groups but also regulate group members' actions to perpetuate the collective norm." Berkowitz [32], social norm theory states that our behavior is influenced by incorrect perceptions of how other members of our social groups think and act. Further, "[b]y presenting correct information about peer group norms in a believable fashion, perceived peer pressure is reduced and individuals are more likely to express pre-existing attitudes and beliefs . . . ." This would seem one means of addressing the challenge of faculty who profess a personal inclination to engage in educational innovation, but express deep concerns about how such a focus would be perceived by their peers. However, care must be taken, Caldiani warns that interventions based on social norms can backfire from their intended effect [33]. Caldiani's research looks broadly at the psychology of compliance and how the actions of others can be effectively influenced [34, 35].

We could not uncover relevant precursor work among STEM faculty. We did uncover a studies, that looked nationally at the medical community [36] and locally at marketing professionals within a single firm [37], of successful attempts to change the behavior of professionals. Within an academic context, such efforts must be related to faculty reward systems [19, 38, 39].

Recent Similar Meetings

We know of no other workshops held within higher education STEM communities that have explicitly focused on marketing to one's peers as a means to influence professional behavior.

Workshop Organizers

The principal workshop organizers are Dr. Norman L. Fortenberry, who serves as the director of the Center for the Advancement of Scholarship on Education (CASEE) at the National Academy of Engineering (NAE), and Ms. Jeanne Narum, Director of the Independent Colleges Office and Project Kaleidoscope (PKAL). In planning this workshop Fortenberry and Narum have drawn and will continue to draw upon the broad experience and expertise of the CASEE Advisory Committee (see Exhibit 1) and the PKAL Network Advisory Committee (see Exhibit 2).

CASEE represents an effort to encourage research on engineering education and to translate research results into improved teaching and learning in engineering classrooms and at engineering worksites. CASEE has organizational affiliates on more than 25 university campuses. Exhibits 3 through 7 show CASEE's organizational and individual affiliates. As one of the premier leadership efforts in the engineering community, CASEE maintains liaison with faculty at more than 330 colleges and universities. A key part of NAE's strategy is bringing together diverse constituencies (engineering and non-engineering faculty, policy makers, and employers) to forge working relationships in support of our aims.

In this effort, we will work collaboratively with Project Kaleidoscope (PKAL) of the Independent College's Office. Since 1989, PKAL has worked with faculty and administrators to promote learning environments that attract and sustain undergraduate students to the study of science, technology, engineering, and mathematics (STEM) and entry into related career fields. With support from colleges and universities, government agencies, and private industry, PKAL has become a national leader in uncovering and reporting what works in undergraduate STEM education. PKAL has more than 1500 members of its Faculty for the 21st Century located on more than 400 college and university campuses. More information on PKAL is available at <http://www.pkal.org>.

Workshop Logistics

Our intent is to hold a one and one-half day workshop for approximately 100 attendees. The workshop will occur in January 2005 in Washington, DC using the facilities of the National Academies. The date was selected it allows a natural follow-on to a PKAL meeting scheduled to be held in the late fall of 2004 that seeks to identify mechanisms for STEM faculty to form effective networks devoted to high quality undergraduate education. That is, once potential attendees know the basics of forming themselves into a self-sustaining community, they can seek to grow the community by influencing others. As a demonstration of interest and commitment to the topic of this meeting, attendees will be asked to pay their own way.

Workshop Design and Implementation

The workshop is designed as a series of working sessions around which attendees will develop plans for peer marketing in a manner that will best serve their individual needs. The workshop is organized around three plenary sessions: one each focused on diffusion of innovation, social marketing, and the psychology of compliance. Thus, attendees are led from understanding the dynamics of diffusion, to developing a peer marketing plan that recognizes these dynamics, and on to tailoring the plan to the psychology of their particular audiences. Each plenary includes ample time for questions and answers since many in the audience are likely to be unfamiliar with the topics. Each plenary is followed by an intensive working session wherein attendees build upon their understanding of the plenary to develop specific plans that they will take back to their disciplines and their organizations. A draft agenda is shown in Exhibit 8. The speakers indicated have not been confirmed, but serve to give a sense of the type of speakers sought.

This workshop builds upon existing research in innovation and organizational change and applies that research in the novel context of undergraduate STEM education. Specific emphasis is placed on motivating STEM faculty to engage in behaviors that will enhance student learning. In so doing this workshop brings researchers in diffusion of innovation, social marketing, and the psychology of compliance together with STEM faculty focused on traditional research in physical science and engineering disciplines, but with an interest in effective instruction. In addition to the individuals directly affected, this activity brings together the intellectual resources of the National Academy of Engineering, Project Kaleidoscope, and over 800 affiliated organizations. As a result of the implementation activities that will result form this workshop, there will be testbeds that may contribute to both theory and practice in the diffusion of innovation.

As a result of this workshop, STEM faculty will better understand impediments to the diffusion of innovations in undergraduate education, and have developed peer marketing frameworks, tailored to the characteristics of individual STEM disciplines, for enhancing the diffusion of innovation in STEM undergraduate education.

Plans for Speaker and Attendee Recruitment

We have identified multiple potential speakers for each of the three plenary sessions. We are in the process of contacting these individuals to confirm their interest and availability.

Potential speakers on Diffusion of Innovation include:
Everett M. Rogers, Regents' Professor of Communication and Journalism, University of New Mexico (and a CASEE Affiliated Scholar)
James Dearing, Professor of Communication Studies, Ohio University (and a member of the PKAL National Advisory Committee)

Potential speakers on Social Marketing include:
Dr. Alan Andreasen, Professor of Business Administration, Georgetown University
Nedra Kline Weinreich, President of Weinreich Communiations, Greenbrae, CA

Potential speakers on the Psychology of Compliance include:
Robert B. Cialdini, Regents Professor of Psychology, Arizona State University
Donald A. Redelmeier, Professor of Medicine, University of Toronto

Potential speakers on Social Norms Theory include:
H. Wesley Perkins, Professor of Sociology, Hobart and William Smith Colleges
Alan Berkokwitz, Independent Scholar, Trumansburg, NY
William DeJong, Principle Investigator, Social Norms Marketing Research Project, Educational Development Center

We will select approximately 100 attendees who are representative of innovators in the various STEM disciplines as well as relevant individuals from disciplinary societies and academic associations. Attendees will be selected on the basis of application materials to be solicited from the following sources:
Recipients of the NSF Director's award for Distinguished Teaching Scholars <http://www.ehr.nsf.gov/ehr/DUE/programs/dts/>;
STEM faculty within the Carnegie Academy for the Scholarship of Teaching and Learning (CASTL) <http://www.carnegiefoundation.org/CASTL/>;
Grantees of the NSF CAREER program,
Member representatives of PKAL's Disciplinary Society Educational Association (which includes disciplinary, institutional, and advisory groups) <http://www.pkal.org/template2.cfm?c_id=160>;
CASEE organizational and individual affiliates (see Exhibits 3-7)
PKAL Faculty for the 21st Century < http://www.pkal.org/template2.cfm?c_id=153>.

Applications will also be solicited from general STEM faculty via a web site and broadly distributed information on the planned workshop.

Underrepresented populations will be engaged through targeted contacts with the professional societies of underrepresented populations in science and engineering (e.g., American Indian Science and Engineering Society, Association for Women in Science, National Black Physicists Association, and the Society for the Advancement of Chicanos and Native Americans in Science, etc.), institutional associations of minority serving institutions (e.g., HBCU Engineering Deans, American Indian Higher Education Consortium, etc.).

Applicants will be required to submit statements on challenges they face in their local environments and how they hope to apply what they learn at the workshop to the resolution of those challenges.

Plans for Assessment

Subsequent to the workshop, after attendees have had time for reflection, workshop participants will be queried electronically to determine their judgment as to whether and to what degree

The workshop increased their understanding of impediments to the diffusion of innovation in undergraduate STEM education and how to overcome these impediments,

The workshop helped them to develop realistic action plans for increasing peer acceptance and support for their efforts in educational innovation, and

The workshop brought them into contact with professionals from outside their normal circle of colleagues who might form a supportive resource network for their efforts at educational innovation.

Assessment results will be incorporated into the final report of the workshop and broadly distributed.

Workshop Follow-Up

Subsequent to the workshop we will take the following actions to disseminate results of the gathering:

Distribution of prepared remarks, presentation materials, summaries of Q&A sessions, the attendee produced frameworks for promoting diffusion of education al innovations within their disciplines, and suggestions for initial actions by STEM faculty. Distributions will occur in print and electronic (compact disk) forms, to attendees as well as to key opinion leaders in academic associations, disciplinary societies, and university departments. The materials will also be available via the web.

Application will be made to organize interactive sessions to discuss the frameworks at professional meetings for various STEM disciplines as well as academic associations (e.g., American Association for the Advancement of Science, American Chemical Society's Biennial Conference on Chemistry Education, the ASEE/IEEE Frontiers in Education Conference, Sigma Xi, etc.)

Outcomes from the workshop will include the following:

A better understanding of impediments to the diffusion of innovation in undergraduate STEM education by workshop attendees as well as those reading the proceedings,

A framework, adaptable to the characteristics of individual STEM disciplines, for enhancing the diffusion of innovation in STEM undergraduate education, and

Distribution of the framework, in print and electronic forms, along with suggestions for initial actions to key opinion leaders in academic associations, disciplinary societies, and university departments.

Discussion of the workshop findings at professional meetings for various STEM disciplines as well as academic associations.

Major Budget Elements

An explanation of the projected costs is shown in the budget detail section. The major direct cost elements include

Writing, producing, and distributing the conference proceedings,
Workshop publicity, outreach, and logistics including sponsored travel for invited speakers,
Labor charges including 5% of the principal investigator's time, 10% of an administrative assistant's time, modest honoraria to plenary speakers and key breakout panelists, and support for a consultant to aid in evaluation of the workshop's impact on participants.

Support Requested from Other Sources

No other sources have been approached or support of this workshop. The NSF IOC program represents the only credible source of which we are aware for support of this workshop.

Results of Prior Support

In April 2003, the National Academy of Engineering (NAE) of the National Academies received a 12-month planning grant (EEC-0242554) for $199,999 in support of initiation of the Center for the Advancement of Scholarship on Engineering Education (CASEE). During it's initial year of operation CASEE sought to finalize its strategic and operational plans such that by virtue of its operation CASEE serves
to promote discovery, recognition, and extension of new knowledge on effective practices in engineering education, and
to ensure widespread awareness and use of the new knowledge through broad engagement of relevant stakeholders in the engineering and science communities.

A five-part strategy guided this initiation of activities while also serving to advance awareness of CASEE in the engineering and science communities and to advance attainment of its goals:
Establishment of a broadly representative advisory committee,
Validation and prioritization of the CASEE research agenda,
Establishment of application procedures and initial membership for the CASEE Research Community (primarily campus-based centers for engineering education research) and the CASEE Implementation Network (academic and industrial test-beds for educational innovation),
Establishment of application procedures for CASEE Senior and Post-doctoral Fellows, and
Initiation of planning for a multi-disciplinary periodic compendium of education research in engineering and science fields.

At the end of the 12-month period covered by the award, the above strategies will have been fully implemented. The details are available at our web site <www.nae.edu/CASEE>. Additionally we have named 4 individuals as NAE Education Senior Fellows.

Dr. Norman Fortenberry was the author and original PI for grant DUE-9653388, which sought to create self-sustaining connections among science and engineering faculty at minority serving institutions and between such faculty and faculty at majority institutions by offering annual five-day workshops. The workshops emphasized a review of best pedagogic practices, strategies for initiating or revitalizing a research program, and instruction on effective mentoring practices for undergraduate students. However, Dr. Fortenberry departed the project very soon after its initiation to assume the responsibilities of director of NSF's Division of Undergraduate Education. Ms. Doris Roman subsequently was named as principle investigator.
Exhibit 1. CASEE Advisory Committee
Exhibit 2. PKAL Network Advisory Committee

Exhibit 3. CASEE Research Community Affiliates
Exhibit 4. CASEE Implementation Network Affiliates
Exhibit 5. CASEE Dissemination Channels
Exhibit 7. CASEE Senior Fellows
Exhibit 7. CASEE Affiliated Scholars
Exhibit 8. Draft Workshop Agenda

8:30	Opening Keynote – Everett Rogers, University of New Mexico "Diffusion of Innovation" Q&A
9:15	Break
9:30	Topical Breakout Groups – by major discipline groups Identification of process or content innovations that are a) likely to have most significant impacts, and b) are most likely to spread
11:00	Break
11:15	Reporting Back to Larger Group
12:15	Break
12:30	Luncheon Keynote - . Alan Andreasen, Georgetown University "Social Marketing" Q&A
2:15	Break
2:30	Topical Breakout Groups – by major discipline groups Development of "Peer Marketing" plans.
4:15	Break
5:15	Reporting Back to Larger Group
6:15	Adjourn for the day
	Dinner on your own

Draft Workshop Agenda – Day Two

8:30	Keynote – Robert Caldini – Arizona State University "Psychology of Compliance" Q&A
9:15	Break
9:30	Topical Breakout Groups – by major discipline groups Identification of leverage points for implementation of marketing plans
11:00	Break
11:15	Reporting Back to Larger Group
12:15	Wrap-up and Adjourn

Reviews:

Panel Summary:

The IOC Panel met on April 1-3, 2004 and evaluated a total of 47 proposals. The panel judged 10 to be of significant scientific merit (fundable or co-fundable) and 5 of the remainder showed considerable promise for revision. This proposal ranked in the middle third of all proposals. This proposal is for a workshop that brings together innovators in undergraduate education with experts in the diffusion of innovation, social marketing, and the psychology of compliance in order to develop strategies for increasing awareness of and use of innovations in undergraduate STEM education.

(1) Scientific Merit:

The proposal was judged by panelists to be an application of existing knowledge about organizational innovation, focused almost exclusively on dissemination. Panel members also found the activity's conception of "educational innovations" too broad. It was difficult to get a sense of what the substance of the activity would entail. Other panel concerns include:

* no plans for follow-up, data collection, etc.
* While the workshop participants will give feedback, there is no plan for systematically evaluating this data and doing anything with it.
* some concern that neither of the applicants have been through the promotion and tenure process as a STEM faculty member
* concerns about lack of commitment from "potential speakers" For example, Everett M. Rogers is mentioned, but is known to be gravely ill and not speaking in forums like this.

(2) Broader Impacts:

The aims of this project are judged to be worthy and noble. Bringing experts in diffusion of innovation together with educational innovators from the sciences, engineering, and technology could have a profound impact on the likelihood of success of both ongoing and future reforms in all of those fields. One concern is that given the heavy emphasis on undergraduate engineering education implied throughout this STEM education proposal, the omission of the American Society of Engineering Education in the lists of advisors, affiliates, dissemination channels (particularly the ASEE journals), and sources for potential workshop attendees is troubling. The proposed workshop topic seems suitable as an entire track at an ASEE conference (and perhaps other STEM related educationally-focused societies as well).

Panel Recommendation: Do Not Fund

REVIEW # 1 – Rating: Poor

What is the intellectual merit of the proposed activity?

This is a proposal for a workshop with no discernible research component. The project summary alludes to the hope that testbeds will be created, but creating and analyzing testbeds is not part of the scope. This is a practical application of past research results, not creation of new knowledge. The proposal does suggest that the workshop will assess how social marketing is applied to professional behaviors. But, there are no plans for follow-up, data collection, etc. The workshop participants will give feedback, but there is no plan for systematically evaluating this data and doing anything with it. There is no comparison to alternative education modes or a control group.

What are the broader impacts of the proposed activity?
The proposed workshop addresses an important area that needs improvement (STEM education), but this is not research.

REVIEW # 2 – Rating: Poor
What is the intellectual merit of the proposed activity?
The PI proposes to conduct a workshop bringing together innovators from a variety of science and engineering fields to discuss ways of diffusing innovations in undergraduate education in science, technology, engineering, and mathematics. That is, the proposal is to actually change the way undergraduate education in these fields is conducted. More to the point, no research will be conducted on effective ways of improving the education of undergraduate scientists and engineers. Although the aims of the workshop are noble, the workshop itself will not add to our corpus of knowledge about the ways of improving organizational change and innovation. The workshop represents the application of existing knowledge about organizational innovation; it will not result in the creation of new knowledge about the phenomenon of innovation.

What are the broader impacts of the proposed activity?
The proposed workshop will almost certainly result in disseminating educational innovations in a variety of fields in science and engineering.

Summary Statement
The aims of this project are worthy and noble. However, IOC supports the creation of knowledge, not the application of knowledge.

REVIEW # 3 – Rating: Excellent
What is the intellectual merit of the proposed activity?
Many efforts to reform STEM education have been carried out in recent decades, but there has been little of a systemic nature that has incorporated what is known about diffusion of innovation and has crossed disciplinary lines. The PIs on this proposal and the organizations they represent (the NAE and Project Kaleidoscope) are ideally positioned to organized such an effort, and they have done their homework well in terms of identifying who should be involved.

What are the broader impacts of the proposed activity?
Bringing experts in diffusion of innovation together with educational innovators from the sciences, engineering, and technology could have a profound impact on the likelihood of success of both ongoing and future reforms in all of those fields. The relatively low investment required to put on the proposed workshop could pay enormous dividends.

Summary Statement
I can think of a hundred good reasons to support this workshop, and none to withhold support. I give the proposal my strongest possible endorsement.

REVIEW # 4 – Rating: Poor
What is the intellectual merit of the proposed activity?
This proposal is to fund a workshop that will be held in conjunction with a larger conference. As such, there is no intellectual merit or novelty to this project. The budget request seems

excessive, especially since the workshop attendees will not be compensated and all the funding request covers the management cost.

What are the broader impacts of the proposed activity?
There might be some broader impact of this activity, if the PI is successful in bringing together 100 or so participants together.

REVIEW # 5 – Rating: Fair
What is the intellectual merit of the proposed activity?
The intellectual merit of the proposed activities is appealing, but needs better support. The proposal appears to assume that instruction in STEM disciplines suffers from a lack of dissemination of educational innovations; however, the proposal does not address the current state of teaching and learning in STEM disciplines. As the proposal notes, STEM faculty are "focused on traditional research in physical science and engineering disciplines" as might be expected since this is what they were trained and educated to do. What percent of STEM faculty have been formerly trained in the basic art and science of teaching? How do we know the broader impact is to be had by focusing on innovation diffusion rather than basic pedagogy? The proposal implies that increasing the effective dissemination of educational innovations will result in "enhanced recruitment into, retention within, and graduation from undergraduate STEM academic programs." Again, is this impact more likely if we focus on diffusing innovations or ensuring STEM faculty have been trained in basic pedagogy?

What are the broader impacts of the proposed activity?
The likelihood of achieving the expected broader impacts is unclear given the number of assertions made without clear explanation of how these activities or results will occur. For example, how will this activity bring together resources from "over 700 college and university campuses" when only 100 participants are to be invited? The plan for recruiting attendees does not mention the expected participation rate by the approximately 100 attendees to be selected and invited. Is the objective to invite 100 participants or to invite participants until approximately 100 have committed to attend?

Another assertion is "More efficient diffusion of educational innovations should result in more efficient use of faculty time across the entire range of research, instruction, and service." Please explain how these efficiencies are to be gained. "Impediments to the diffusion of innovation" are mentioned more than once as an expected output from the proposed activities; however, neither the workshop agenda nor any of the associated activities address the identification of impediments.

Given the heavy emphasis on undergraduate engineering education implied throughout this STEM education proposal, the omission of the American Society of Engineering Education in the lists of advisors, affiliates, dissemination channels (particularly the ASEE journals), and sources for potential workshop attendees is troubling. The proposed workshop topic seems suitable as an entire track at an ASEE conference (and perhaps other STEM related educationally-focused societies as well).

The applicants appear qualified to conduct the proposed workshop; however, it is somewhat concerning that neither of the applicants been through the promotion and tenure process as a

STEM faculty member. While serving as a tenured STEM faculty member may not be absolutely necessary, it could certainly help with understanding and interpreting the results of this conference in light of the trade-offs that tenure track STEM faculty must make in balancing teaching innovation with their other duties. It is also unclear how the results of prior support have been disseminated via channels likely to impact STEM faculty.

Appendix C

Grant Publications

For those that are published annually, no NSF publication numbers are shown since they will change. Most of these documents are available on the NSF's online document system (http://www.nsf.gov/publications/ods/). You can also receive publications electronically via e-mail by sending a request for a publication to getpub@nsf.gov. Paper copies may be requested online at http://www.nsf.gov/publications/orderpub.jsp or can be ordered via mail by contacting the NSF Publication Clearinghouse, P.O. Box 218, Jessup, MD 20794-0218 or by phone at (301) 947-2722.

The ***Guide to Programs*** provides background information about all of the Foundation's activities in education and research. The ***Guide to Programs*** is available on the Web at http://www.nsf.gov/pubsys/ods/getpub.cfm?gp.
The ***Grant Proposal Guide*** (GPG) provides extensive guidance for the preparation and submission of proposals to NSF. Some NSF programs have ***Program Solicitations*** that modify the general provisions of the GPG, and, in such cases, the guidelines provided in the solicitation must be followed. The GPG is available on the Web at http://www.nsf.gov/pubsys/ods/getpub.cfm?gpg.
Each ***Program Solicitation or Announcement*** describes the program and indicates the exact format for the preparation of the proposal and the criteria for evaluation.
NSF has published the ***2002 User-Friendly Handbook for Project Evaluation*** (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf02057), ***FOOTPRINTS: Strategies for Non-Traditional Program Evaluation*** (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf9541), and ***User-Friendly Handbook for Mixed Method Evaluations*** (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf97153) that proposers may wish to obtain. There are also two online evaluation resources that proposers may wish to explore: the *Online Education Resource Library* (http://oerl.sri.com) and the *Field-tested Learning Assessment Guide* (FLAG) (http://www.flaguide.org).

Information specific to undergraduate programs can be found on DUE's Web site at http://www.nsf.gov/od/lpa/news/publicat/nsf04009/ehr/due.htm**.** You my also contact DUE by e-mail (undergrad@nsf.gov) or by phone (703-292-8670).

Information specific to engineering education programs can be found on the EEC's Web site at http://www.nsf.gov/div/index.jsp?org=EEC. You may contact EEC by phone (703 292-8380). Information about DUE or EEC funded projects can be found at http://www.nsf.gov/awardsearch/ by searching under the program names.

Appendix D

Gender and Engineering Education Resources

This is by no means an exhaustive resource, but it will give you a foundation for understanding the complexities and some ideas for the narrowing of the gender gap in engineering education.

IEEE Women in Engineering – Contains links to resources on women in engineering, scholarship and job information, as well as current events and programs to promote women in engineering. URL: http://www.ieee.org/portal/site/mainsite/menuitem.818c0c39e85ef176fb2275875bac26c8/index.jsp?&pName=corp_level1&path=committee/women&file=index.xml&xsl=generic.xsl

American Association of University Women (AAUW) Homepage – Contains numerous links to information on women in academia including existing gender equity programs and fellowship opportunities for women. URL: http://www.aauw.org/.

Diversity Institute Homepage – Contains numerous links to literature reviews on diversity in STEM education, links to diversity resources, and a resource book, *Reaching all students: A Resource for Teaching in Science, Technology, Engineering and Mathematics,* on incorporating the research on diversity into your classroom. URL: http://cirtl.wceruw.org/DiversityInstitute/.

Extraordinary Women Engineers Project Homepage – An outreach program designed to encourage young women to choose engineering as a career and to develop a new generation of role models for those already in the field. The site contains a link to the executive summary and full document of their final 2005 report. URL: http://www.engineeringwomen.org/index.cfm.

Society of Women Engineers (SWE) Homepage – Contains up-to-date information on women in engineering including the links to the latest news, public policy information and statistics on women in engineering. URL: http://www.swe.org/.

Standing Our Ground: A Guidebook for Educators in a post-Michigan Era – Contains background information and advice on developing diversity in STEM education and links to recent articles on the subject. This link to the American Association for the Advancement of Science (AAAS) offers a PDF version of the book and ordering information for a hard copy. URL: http://www.aaas.org/publications/books_reports/standingourground/.