INTEGRATING RESEARCH AND EDUCATION:

MOVING FROM INDIVIDUAL FACULTY INITIATIVES TO INSTITUTIONALIZATION

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Introduction

An interesting transition occurs when you are tenured. You open your eyes after five years of focusing on your work, your teaching, your research and realize that you need to think about the health of not only your individual program, but of the department—and college and university. You know that your research program won't thrive without good students, solid teaching and cooperative colleagues. It is during this period that a faculty member starts to look outside her immediate interests and considers the needs of the institution around her.

Two components of a successful research program are funding and high-quality graduate students, and the two are often linked. In the last few years, the National Science Foundation (NSF) has re-emphasized the connection between education and research and the responsibility of researchers to be involved in both. Their guide to grant programs says:

> One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects and activities it supports at academic and research institutions.
>
> These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students, and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

NSF requires that proposals address two separate merit criteria: one focuses on the intellectual merit of the work (Criterion 1) and the second asks the proposer to specify the "broader impacts" of the proposed work (Criterion 2). Proposals that do not separately address both of these criteria are returned without review. The emphasis on education and outreach is an explicit part of larger, group proposals such as Materials Research Science and Engineering Centers, but an education component is also required in the single-investigator proposals that are the mainstay funding for many researchers in math, science and engineering.

There are two major consequences of this emphasis. First, most faculty members have no training in what constitutes a good—or effective—education/outreach program. There are a lot of floundering scientists, mathematicians and engineers who are stuck when asked to specifically show how they are addressing "Criterion 2". The second issue is that the graduate students we are educating eventually will have to fulfill these requirements, so in addition to preparing them to do research (and write grants, and teach, and …), we have to give them the tools that will enable them to be competitive in the new arena.

Project Fulcrum, which is funded through NSF's GK-12 initiative, will be presented as a case study to emphasize two points: the enhancement of graduate student preparation through the involvement of graduate students in education and outreach programs, and how a program developed by individual faculty members can be institutionalized to benefit a wider group of faculty as they attempt to meet both of NSF's criteria.

Motivation for the GK-12 Program

The state of K-12 science and mathematics education has received a lot of attention due to increased accountability, decreased numbers of students entering math and science careers and decreased science literacy.[1,2] K-12 school systems must address the needs of an increasingly diverse population while meeting national and state standards[3,4] and developing assessments—all with diminishing resources.

NSF introduced the Graduate Teaching Fellows in K-12 Schools (GK-12) program in 1999 to produce scientific research leaders who are aware of and sympathetic to the challenges facing K-12 education. Graduates of this program will support the continued involvement of scientists, mathematicians and engineers in K-12 education in the future and will be in a position to understand how to most effectively participate. GK-12 awards primarily fund graduate student fellowships (with the same stipend as NSF research fellowships), plus some funding for teachers and administrative structure. While the program has a much broader focus—the goals include improving math and science education, building partnerships between universities and schools districts, and providing resources to teachers—the idea that the graduate students are the focus is the key.

Project Fulcrum Details

The University of Nebraska was awarded a GK-12 grant in 2001 to Principal Investigators Diandra Leslie-Pelecky (Physics), Gayle A. Buck

(Teaching, Learning and Teacher Education), Sue Kirby (Teacher, Clinton Elementary School), Roger D. Kirby (Chair, Physics) and Patrick Dussault (Chair, Chemistry). The project was named Project Fulcrum in honor of a quote from Archimedes: "Give me a long enough lever and a place to stand and I can move the Earth."

Project Fulcrum is a collaboration between the College of Arts and Sciences and the College of Education and Human Sciences, in cooperation with the Lincoln Public Schools. Thirty graduate Fellows over three years will serve as resources for elementary or middle schools. Fellows partner with a lead teacher at the school to develop efforts that address that school's particular needs. Those ideas are used as a platform for the Fellow to reach out to other teachers and classrooms. In 2002-2003, graduate Fellows worked with 10 Lead Teachers, 37 additional "cooperating" teachers and over 2,300 students.

GK-12 Fellow stipends are the same as NSF Research Fellowships ($27,500/year for 2003-2004, plus a $10,500 cost of education allowance). Fellows spend 8 hours per week in the schools working with teachers and students, 2 hours per week planning with teachers, and up to five additional hours in preparation. The time required is comparable to a teaching assistantship. Prior to entering the schools, Fellows and their Lead Teachers have a one-week Summer Institute where the Fellows learn about education and the specific issues we want to address in the schools, partnerships are formed and strengthened, and the initial planning is accomplished.

Lincoln Public Schools (LPS) is an urban district serving 32,000 students. An extensive self-analysis based on recent student achievement data led LPS to identify grades 4-9 (and particularly 6-8) as targets for improving student achievement. LPS historically is a high-achieving school district, but while elementary-grade student achievement in math/science has advanced in the last 5 years, middle-level achievement has remained relatively stable and behind elementary level achievement. This reflects a national trend of poor performance of U.S. middle level students when judged against international competition.[5] In addition, girls' interest in math and science decreases significantly in these grades compared to boys' interest.[6] LPS has developed a No Child Left Behind Middle Level Plan focusing on improving math and science achievement and narrowing the achievement gap for ethnic minority and low-income students. We meet LPS needs by working primarily in middle schools plus a limited number of elementary schools that feed into the targeted middle schools, and addressing achievement gaps in at-risk populations.

Goals

NSF's request for proposals was very explicit: In addition to goals for the graduate Fellows, teachers, and students, they wanted GK-12 programs to impact the institutions involved. The fourth and fifth rows of Table 1 illustrate

Project Fulcrum's infrastructure goals. This requirement is one of the elements that encourage individual faculty members to look beyond their own interests to how they can influence the priorities and programs of the institution.

Table 1: Project Fulcrum goals	
Fellows	(1) Understanding how scientists and mathematicians can help address K-12 education challenges, (2) Improved communication skills, especially with non-scientists, (3) Early exposure to educational research and the professional education community, (4) Develop abilities to continue working with K-12 outside the project.
K-12 Students	(1) Increased science and math understanding, (2) Increased experience with inquiry, leading to facility with the scientific method, (3) Appreciation for the relevance and applicability of science, (4) Exposure to diverse role models, (5) Increased self-confidence and interest in science.
Teachers	(1) Increased teacher comfort with science and math content, (2) Increased understanding of the design and assessment of inquiry-based instruction, (3) Improved working relationship with the university and university personnel,[2,5] (4) Development of leadership skills.
LPS	(1) Enhanced in-service opportunities for all teachers, (2) Establishment of a community that discusses and advocates for science education, (3) Closer linkage with the University.
UNL	(1) Improved cooperation between the College of Arts & Sciences and the College of Education and Human Sciences (formerly Teachers' College), (2) Increased exposure of faculty scientists to the Lincoln Public Schools and the impact of standards; (3) Increased faculty interest in teacher education.

Outcomes

The outcomes from the first two years of Project Fulcrum are shown in Table 2. The outcomes for teachers and student were very favorable, but the comments in this section will focus on the impact of the program on the graduate Fellows, faculty members, and the institution.

Impact on Graduate Students

The primary impact of graduate Fellows in elementary and middle schools is that the Fellows are walking examples of the scientific method. The graduate students model the scientific process, have the confidence to jump into a problem they don't already know the answer to, and excel at troubleshooting everything from computers to lab equipment. Teachers appreciate having a ready resource for content questions. In many cases, the Fellow may not know the answer off hand, but does know where to find the answer quickly.

Our external evaluators found that the opportunity to form collaborations with people from other departments greatly enriches the Fellows' experience. Mentoring received through the program is especially important for students who will do a coursework Master's degree and those students who have not yet found a thesis advisor. This support network of project management and participants is especially important for those women who are significant minorities in their home departments.

The benefits are not only in the personal arena. We have at least one example where two Project Fulcrum graduate Fellows in disparate fields started a joint research project that would not have happened without their involvement in Project Fulcrum. Our external evaluation showed that, while Fellows identified themselves with Project Fulcrum, their participation did not adversely affect the graduate students' progress or sense of "belonging" in their home departments.

Our Fellows felt that their communication abilities—especially with non-scientists—were greatly improved through their participation in the program. Although there was a lot of frustration in the beginning as Fellows learned to communicate with each other, teachers and students, the Fellows were proud that they recognized how to adapt their communication patterns so that they would be effective in different environments.

Table 2: Project Fulcrum Outcomes 2001-2003	
Fellows	• Have greater appreciation for the challenges of K-12 education, especially classroom management and the impact of the standards. • Feel they have improved their ability to work and communicate with people from diverse backgrounds. • Feel they made a significant difference in their schools, although their impact was less than they originally expected. • Formed collaborative groups to address special projects such as science fairs. • Intend to continue working with K-12 teachers and/or students.
Teachers	• Find that Fellows are flexible enough to meet their schools' specific needs. • Feel more comfortable making use of university resources (including scientists). • Are more comfortable with their teaching ability and knowledge of science. • Liked having a community of science/math educators within Lincoln Public Schools (LPS). • Recognize the importance of involving many teachers within their school if systemic change is to be sustained.

Table 2: Project Fulcrum Outcomes 2001-2003	
Students	• Show greater enthusiasm for math and science. • General learning efficacy and math efficacy improved at all middle schools; however, preliminary results show that science efficacy remained constant at two middle schools and decreased at the third. • Student images of scientists significantly improved at two middle schools. Images at the third significantly increased for females, but decreased for males. • At the midterm, image of a scientist, general learning efficacy, general learning attitude, math efficacy, math attitude, science efficacy and science attitude all improved in the elementary schools.
UNL and LPS	• The Principal Investigator (PI) was invited to give colloquia in biological sciences and physics at UNL, which increased campus awareness of Project Fulcrum and broadened the graduate student applicant pool. • More UNL faculty and graduate students volunteered to visit K-12 schools. • UNL and the Lincoln Public Schools reward faculty for participation: The PI was tenured last year, in part due to the success of Project Fulcrum. Co-PI S. Kirby has been nominated by her principal for Nebraska Teacher of the Year. • UNL's College of Arts & Sciences has changed faculty effort assignments from the traditional three categories of research, teaching and service to five categories: research, teaching, service, outreach and administration.
Infrastructure	• A formalized framework for the project is in place. • Developed a Summer Institute preparation program for Fellows and Lead Teachers, including a web-based handbook. • Developed a web-based data entry and analysis system. • Establishment of a permanent Project Fulcrum Office (provided by a severely space-strapped Physics Department). • Inclusion of experiments and activities from the PI's previous outreach program. • Participants have given talks/workshops at meetings of the American Physical Society, National Association of Research in Science Teaching, Nebraska Science Teachers Association, Nebraska Educational Technology Association, and National Association of Science Teachers, plus seven invited colloquia at universities and colleges across the country over the last two years.

Impact on Faculty

The faculty coordinating Project Fulcrum get more than summer salary and a good feeling for helping to improve K-12 science education. This project provides many opportunities for research into how scientists can be most effective in the K-12 classroom. We have found that many of our preconceptions—such as believing that putting women scientists in the classroom changes student's stereotypes about scientists—are wrong. The pilot project for our GK12 proposal serves as a good example. Three women graduate students worked with 4th and 5th graders on an electricity and magnetism unit. We consulted with the teachers to determine how to best fulfill their goals, brought lots of equipment and activities for the students to do, and made sure that we were using terms and explanations appropriate to the children's' ages. We even made a video of one of the Fellows in the lab, explaining what she did and the equipment she uses.

Four weeks into the project, interviews with the children showed that they didn't recognize that the women in the classroom were scientists. Student stereotypes were already so strong that the women scientists not only didn't break the stereotypes, they were excluded from being scientists in the minds of the students. The questions we planned on asking about their stereotypes of scientists and how the presence of the women affected these stereotypes could not be addressed because our basic presumption about the project was wrong. This also serves to illustrate the benefits of scientists working with their colleagues in the Education College; few scientists would think to ask whether the kids realized that their visitors were scientists. Without asking these questions, we would have completed the eight weeks, stood back to admire our work, and left, never realizing that we didn't have any impact on the students' stereotypes about scientists.

Impact on the Institution

Project Fulcrum is a good example of how a project progress with time. We had a difficult time recruiting students during our first year. As the program continued, the publicity it attracted (especially the magnitude of the stipends) drew the attention of students in disciplines we hadn't thought to involve (such as engineering). In 2003-2004, we had 2.5 applicants for each position and had to turn down many very talented students. The growing participation across departments, as shown in Figure 1, increases the potential for campus-wide impact as we develop a reputation as a successful program. The PIs have been invited to give talks in a number of science departments and those talks have drawn a surprising number of volunteers from the campus community.

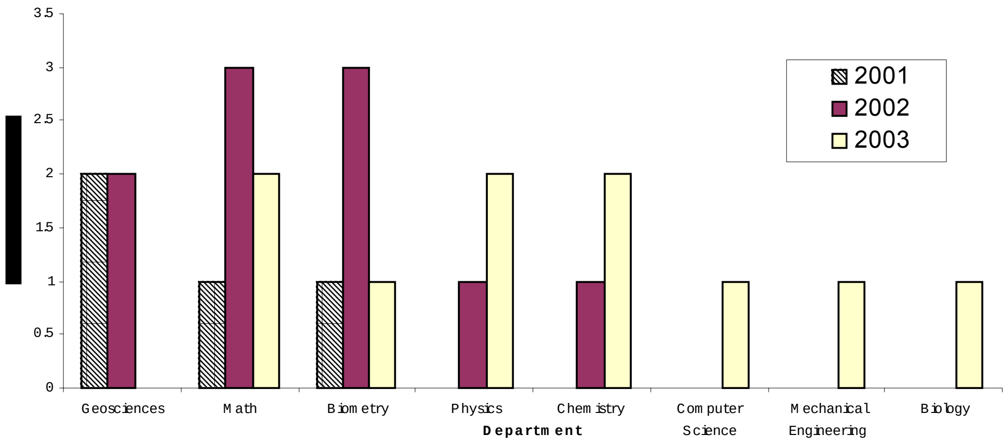

Figure 1: Representation of departments in Project Fulcrum 2001-2003.

A second aspect of the institutional impact is the ability to raise campus-wide attention about the climate for women in science, math and engineering. Our participants are overwhelmingly female (Figure 2). Each year, the percentage of women has been greater than 60%. While not unusual for the population as a whole, the availability of women in the pool of graduate students is approximately 25%. This encourages discussions about the impact of gender in science education at both the K-12 and the graduate level.

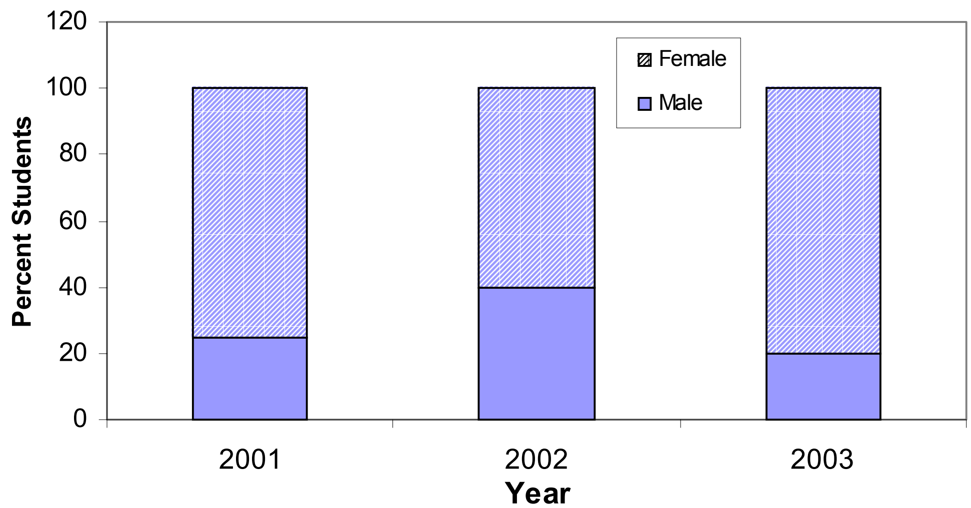

Figure 2: Male and Female participants in Project Fulcrum 2001-2003.

It is important to note that Project Fulcrum does not exist in a vacuum at the University of Nebraska. We have a broad variety of math and science education programs that involve many science, math and engineering faculty. We have mounted several initiatives for large multidisciplinary projects. The preparation of future math and science teachers has been identified as an academic priority. Project Fulcrum has both benefited from and strengthened this community.

Project Fulcrum has developed contacts with the school district and—probably more importantly—with individual teachers and their principals. At this point, we have a cadre of teachers comfortable working with scientists. We have a better idea of what types of projects and activities work in the classroom, the potential impact of the Fellows in the school, and the impact of the program on the Fellows. Tangible items, such as a collection of materials that can be checked out and a central office, have helped to give brick and mortar infrastructure to the project. While there is much left to do, we believe that we can call the project—thus far—a success.

Why Institutionalization?

Invitations to submit Track 2 GK-12 grants were issued in 2001. Originally, GK-12 grants were to be one-time awards; however, the data showed that a wealth of information about how scientists interact with K-12 schools offered great promise for further studies. This type of information is exceptionally necessary; a graduate Fellow in a classroom needs to make an impact and that impact needs to be documented. Track 2 grants require programs to use the knowledge they've gained during their first grant to go beyond just executing a program. The goal is to use prior experience to make institutional changes that will continue past the funding period of the grant. This requirement is strong encouragement to faculty to think about the relationship of their program to the institution as a larger entity.

Return again to the changing role of the faculty member as proposal writer. Professor X is joining a science department this fall, and one of the first things she must do is write a grant to request NSF funding for her research. Professor X is interested in working with middle schools, so she needs to identify schools and willing teachers, get permission from everyone involved, develop activities and execute them. One-time visits with "gee-whiz" demonstrations may increase student enthusiasm for a short time; however, most faculty members simply don't have the time to engage in extensive advance planning with the teacher to ensure that their demonstrations meet the goals the teachers need to address that day. Professor X doesn't want to make outreach her career. She wants to propose something that is good enough to get the grant, can be carried out with minimal time and energy, and—most importantly—makes a difference. The NSF mandate for institutionalization has important implications for faculty members. How do we enact change at the university level? In the case of Project Fulcrum, shouldn't there be some way to use what we have established to prevent Professor X (and Professor Y and Professor Z) from having to re-invent the wheel?

Why not use the infrastructure developed by Project Fulcrum to give Professor X a head start? Project Fulcrum already has the contacts with the school district and teachers. We have a pretty good idea of what works, and the materials for these activities are collected, have been designed to be easy to transport, and are maintained. Professor X should be able to leverage what's already been done to propose something that can be done with minimal effort, but that makes a difference in K-12 education.

Institutionalization of the Project Fulcrum infrastructure is the education/outreach equivalent of "tech transfer." Developments in one area are leveraged by others. A faculty member is generally not interested in taking time off from his teaching and research to run such a program, so this is where the institution can play a major role. Establishing a central office responsible for providing logistical support—matching teachers and faculty members, arranging times and equipment, etc., is more efficient than each faculty member doing his or her own coordination. The role of the institution need only be as caretaker: to preserve the elements of the program that were developed during the funding period. The institution could, of course, also contribute to the growth of the infrastructure where possible or desired.

What does the institution get out of it? Faculty members don't spend a significant amount of time doing things they don't have much experience doing, especially those that may already have been developed. These faculty members are likely to have a better education component to their proposals, which can improve the chances of funding. Once funding is secured, the faculty member spends less time, but still makes a large impact. The evidence from all of the GK-12 programs is that the participating graduate Fellows significantly improve their "people skills" and leave the program with a very different attitude about their responsibility toward K-12 education. Research innovation may pay off for universities in terms of patents and publicity; however, institutionalized education and outreach initiatives have the potential to make a big difference in terms of the quality of graduate (and undergraduate) education, the preparation of graduate students for future careers, and the success of the faculty in obtaining grants.