Final Evaluation Report on the Manufacturing Engineering Education for the Future Program

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Prepared for
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Executive Summary

The three-year (1994-97) Advanced Research Projects Agency-Technology Reinvestment Project (ARPA-TRP) grant "Diversity and Cultural Change: Manufacturing Engineering Education for the Future" (MEEF) to the University of Wisconsin's-Engineering Research Center for Plasma-Aided Manufacturing, was launched in spring of 1994 in a “reform ready” context that was prepared by the College of Engineering’s Ad Hoc Curriculum Committee and Teaching Improvement Program. The ARPA MEEF program goals were congruent with goals of a substantial set of faculty leaders in COE, and were supported by campus administrators, as indicated by the grant “match” provided by College of Engineering, the College of Letters and Science, and the Graduate School. The ARPA MEEF programs and courses were designed to address retention issues by emphasizing improvements in the pre-engineering experience, and to create a more student-centered curriculum with emphasis on connections to manufacturing throughout the four years of the major. As stated in the proposal, the principal investigators of the grant were interested in fostering cultural change at UW-Madison, not just funding isolated programs or courses.

Evaluations conducted by researchers from the LEAD Center and other organizations show that the intended outcomes for students were achieved. The intended outcomes were: increased retention rates in engineering, particularly among underrepresented groups; improved student learning through shifts toward collaborative, hands-on assignments that emphasize critical thinking, teamwork, and communication skills; and improved student attitudes through increased understanding of the engineering profession and a broadening of perspective about the type of people who succeed in engineering. We found that the MEEF-funded initiatives encouraged important and significant improvements in student learning, and improved students’ abilities to transfer that learning to real-world problems. Our data also show that EPD-160 significantly boosted the retention rates of female engineering students, and that the Summer Internships in Manufacturing Technology successfully encouraged participants to go on to graduate school. We found that that participants in the Wisconsin Emerging Scholars calculus program (comprising 40% minority students and 50% women) performed, on average, statistically better than comparable students not in the program, but were retained in engineering only at rates statistically comparable to those of students who did not participate in the program. Desired learning outcomes were found for other MEEF-sponsored programs and courses, but retention to major data associated with these activities are not yet available.

We conclude from these findings that obtaining higher engineering retention rates may involve more than just providing students a more collaborative and supportive learning environment in one or two of their prerequisite courses. We suggest that to achieve higher retention rates, particularly for women and underrepresented ethnic groups, it may be necessary to both (1) provide a critical mass of courses using active learning strategies like those used in WES and Chem 110, and also (2) provide students opportunities (like EPD 160 and the Summer Internships) that help them determine if there is a “good match” between a student’s interests and the career opportunities available with an engineering degree.

LEAD Center evaluators also determined that two of the intended outcomes for the COE--the institutionalization of successful MEEF-funded reforms at both the course and program level, and a change in faculty culture that would support and encourage collaborative learning and other reforms in engineering education—were achieved at a high level, and that significant improvement was made with respect to the third goal for the COE-- enhancement of the role of industry in engineering education. For the most part, initiatives funded by the grant have made the difficult transition from soft to hard money, although a few have yet to secure permanent funding. Cultural changes within the college which can be attributed to the ARPA MEEF grant include the creation of a more student-centered learning environment, the development of forums in which instructors can focus on pedagogy, the establishment of lasting cross-departmental and cross-college connections, and increased collaboration with industry on educational initiatives. In addition, the pedagogical and curricular components of the MEEF-sponsored initiatives have been adapted by others on a local and national level. UW-Madison faculty from the COE and other colleges have had the opportunity to learn about the reform efforts and in some cases have incorporated aspects of the MEEF initiatives into their own courses. On the national level, faculty and evaluators have produced numerous articles, reports and conference presentations on the MEEF initiatives.

With respect to the implementation and institutionalization of the MEEF-funded reforms, we found that certain strategies were essential. First, a match between the vision and programmatic efforts of the ARPA MEEF grant and the mission and priorities of the College of Engineering was essential in encouraging the participation and support of faculty and administrators in grant-sponsored initiatives. Second, the successful implementation and institutionalization of many of the grant-sponsored initiatives required the ownership and the commitment of faculty, who were needed to play the primary role in designing and implementing initiatives. Other players whose commitment and skill was essential include: the paid program coordinators, who did most of the networking and handled important logistical matters; trained TAs and SAs, who played critical roles in facilitating collaborative group work; and supportive administrators like COE Dean John Bollinger and Associate Dean Mike Corradini, who found continued funding and administrative "homes" for successful initiatives. The utilization of formative and summative evaluation data to "fine-tune" initiatives and to gain support for their dissemination was also essential to their success.

In sum, the ARPA MEEF grant was successful in encouraging the development, implementation, and institutionalization of collaborative learning approaches for students and in fostering desired cultural change in the College of Engineering and at the UW-Madison more generally.

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Appendix A.

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Part One: Introductory Material

This report provides a history of the processes and outcomes of the three-year (1994-97) Advanced Research Projects Agency-Technology Reinvestment Project (ARPA-TRP) grant "Diversity and Cultural Change: Manufacturing Engineering Education for the Future" (MEEF) to the University of Wisconsin's-Engineering Research Center for Plasma-Aided Manufacturing (ERC for PAM), under grant #EEC-8721545 (administered by the NSF). This evaluation was conducted by the UW-Madison's Learning Through Evaluation, Adaptation and Dissemination (LEAD) Center.[1] It is based on interviews with key participants in the grant and the grant-funded programs, historical documents (such as the annual reports to the NSF), and the evaluators' knowledge of the ARPA MEEF programs from three years of involvement as the evaluators for these programs. (See Appendix A for sample interview protocol.)

I. Background

A. History and context of the grant

The ARPA TRP grant proposal was written at a time when two simultaneous efforts to improve the student learning experience of engineering majors were underway. One of these efforts was the College of Engineering's Ad Hoc Curriculum Committee, consisting of a faculty member from each degree major. In 1993 this committee was formed to examine the current engineering educational experience and to determine ways in which it could be improved based on employer and alumni needs. A primary conclusion of this committee was the need to improve the retention of women and minorities in the College of Engineering. The other initiative was a Teaching Improvement Program (TIP) which was formed in spring 1993 as part of a doctoral dissertation project of an Industrial Engineering degree candidate. Originally the TIP consisted of six engineering faculty meeting regularly to discuss ways to improve their teaching and student learning. The TIP group focused on the need to increase pre-engineering students' motivation for learning and to engage students in active learning.

In the summer of 1993, Leon Shohet, Director of the ERC for PAM and Professor Denice Denton, the leader of two of the ERC's research thrust areas, applied for the ARPA TRP grant. Their grant proposal focused on curricular and pedagogical reform within the COE, outreach to pre-college students, and the evaluation and dissemination of these reform initiatives. Per the requirements of the request for proposals, dollar-per-dollar "match" was provided in the budget, with campus resources from the COE, the College of Letters and Science, the Graduate School and industrial match from various ERC partners. The goals of this grant were consistent with the vision of the Curriculum Committee and the efforts of the TIP group in that the grant called for innovative courses and programs which were well-suited to achieving the goals of those groups and gave interested faculty in the COE the opportunity to put their ideas into practice. Several of the courses or programs were based on successful models being used on other campuses.

[1] Established in August of 1994, the LEAD Center supports individuals engaged in educational reform activities at both the baccalaureate and graduate levels. The LEAD Center focuses on student learning experiences and faculty adaptation and dissemination processes. It provides clients with both summative and formative evaluation.

The proposal was funded in spring of 1994 at about half the amount requested, and with a start date of July 1, 1994. Professor Denton acted as the Thrust Area 5 (education and outreach) leader and MEEF project manager for the first two years. When she left UW-Madison for another position in summer 1996, Associate Dean Mike Corradini assumed this role.

B. The goals of the grant

Program goals as listed in the grant proposal are as follows:

1. Produce baccalaureate-trained engineers who are well-prepared to contribute to and advance the manufacturing productivity of the US economy.
2. Graduate a substantial number of UW-Madison undergraduate engineers who are women, and/or underrepresented minorities.
3. Directly involve industry in the enhancement and reform of the undergraduate education process.
4. Educate engineering faculty about manufacturing and incorporate practical manufacturing-based materials and problems including economic and environmental factors into engineering instructional programs.
5. Introduce undergraduates from other colleges (Letters and Science, Education, Business) and other institutions to engineering principles and manufacturing in order to improve U.S. productivity.
6. Produce materials about innovative and effective educational models on the basis of extensive evaluation and assessment and disseminate these documents to the broader engineering education community.

In broader terms, the ARPA MEEF programs and courses were designed to address retention issues, with an emphasis on improving the pre-engineering experience, and to create a more student-centered curriculum with emphasis on connections to manufacturing throughout the four years of the major. As stated in the proposal, the principal investigators of the grant were interested in fostering cultural change at UW-Madison, not just funding isolated programs or courses.

II. Descriptions of the Key Elements of the MEEF-Sponsored Initiatives

Below we provide a brief description of each of the MEEF-sponsored initiatives. These are grouped by programs, courses, or evaluations. (In some cases the grant provided funding for an evaluation of a course that involved innovative pedagogical methods in order to assess the student learning outcomes rather than supporting the course itself.) In addition we describe the Industrial Advisory Panel that was formed as a result of the grant.

A. Programs

1. Wisconsin Emerging Scholars Program

The Wisconsin Emerging Scholars (WES) Program was piloted in 1994 by the Department of Mathematics. The program targets underrepresented minorities, women, and rural students though it is open to traditional students as well. Students in the WES program attend large lectures, do regular homework problems, and are graded in the same fashion as students enrolled in the traditional discussion sections. However, instead of enrolling in regular discussion sections, WES students enroll in a "workshop" that meets for a longer period of time and more frequently than regular discussion sections. During workshop sessions, instructors provide the WES students with worksheets comprised of carefully designed, difficult problems that can best be solved collaboratively. In groups of three or four, WES students work the problems together, while the TA and student assistants circulate the room asking strategic questions and offering hints when particular groups are obviously frustrated. The workshop instructors avoid directly answering students' questions, and try to assist the students in answering their questions themselves. Through the use of collaborative groups WES assists students in acquiring new approaches to learning that are student and group centered rather than the traditional "teacher" centered. Because the MEEF PIs recognized the need to support innovative programs that assisted in the retention of first year pre-engineering minority students, they funded two additional WES sections with the proviso that they enroll pre-engineering students.

2. Freshmen Learning Community Program

The Freshmen Learning Community Program (FLCP) involves learning community groups consisting of 20 students each who are co-enrolled in the same two or three large lecture classes. The group of classes is referred to as a course cluster. Past course clusters have included introductory first- or second-semester calculus and chemistry, pre-calculus and first semester chemistry, and third semester calculus and physics or engineering statics. Weekly meetings with voluntary attendance are held for all of the students in the learning community. During these meetings the students work in groups on coursework with guidance from their teaching assistants and the program coordinator. In addition, the students have the opportunity to hear from guest speakers from industry and to participate in fieldtrips to local industrial plants.

3. Statics Workshops

Prior to the creation of a freshmen engineering design course, Statics, Engineering Mechanics and Astronautics (EMA 201), was the first course in engineering taken by most engineering students. In a given semester, the enrollment of EMA 201 averages around 200 students, and the course is taught by a single senior lecturer in two large lecture sections. There are no formal recitation sections where students process course material in a small group setting.

For many years, the course had a high rate of student withdrawal. In order to address this problem, in the Spring of 1996 supplemental instruction sessions for EMA 201 were offered. The objective of these sessions was to provide academic support that supplemented the lecture presentation and enabled students to work on course homework in a collaborative learning environment. The students worked in small groups on the assigned homework problems with guidance from undergraduate senior assistants (SAs). Sessions met twice a week for one hour. Approximately 25 percent of the students enrolled in the course took advantage of this opportunity each semester. Each session was comprised of 8-10 students assigned to one SA. Although attendance was voluntary, regular attendance was strongly encouraged and was exhibited by most students. The SAs received guidance from a faculty member from the Engineering Mechanics Department (not the course instructor) and a professional advisor from the COE Office of Academic Affairs.

4. Saturday study/tutoring sessions for engineering students

In 1996, members of several student engineering organizations--the Society of Women Engineers (SWE), the Society of Hispanic Professional Engineers (SHPE) and the Wisconsin Black Engineering Society (WBESS)--took the initiative to begin tutorial and study sessions for engineering students on Saturday afternoons. This program was coordinated by a volunteer student and staffed by paid upper-division science students. Students were encouraged to attend these sessions for help on any engineering course, with emphasis on sophomore and junior level courses. In the Spring of 1997 the Diversity Affairs Office in collaboration with the pre-engineering office worked together to expand the tutorial and study sessions to times throughout the weekday and weekends. The program is now open to all students, although minority and female students are the primary target of this effort.

5. K-12 Science and Engineering Outreach

The K-12 Outreach Program was created and developed by ERC faculty and academic staff. In this program, junior and senior engineering students receive course credit for going to area schools to give hands-on outreach presentations based on the central theme of the manufacturing of everyday items using plasma technologies. The program goals are for K-12 students to learn about plasmas and their use in manufacturing and for undergraduates to gain real-world public speaking and teaching experience to complement their in-class education. The outreach kit, which consists of numerous examples of plasma-based manufacturing technology, was developed in part through donations from the ERC industrial partners and local manufacturing companies. The program is coordinated by an academic staff person.

6. Summer Internship Program in Manufacturing Technology

The ERC is currently active in a number of programs placing minority college students in summer intern positions at the UW-Madison. The ERC's programs accommodate undergraduates from Historically Black Colleges and Universities and women's colleges. In particular, the ERC has worked with campus-wide summer programs to develop a Summer Internships Program in Manufacturing Technology. The undergraduate participants interact with ERC faculty, staff and students to conduct nine-week research projects. Students also participate in a number of professional and social activities, including a three-part series of lectures on engineering ethics. In addition, the students interact with numerous industrial visitors during the ERC Site Visit and weekly group meetings. In addition to placing undergraduate students in summer programs at the UW, the Summer Internship Program also facilitates placement of ERC undergraduate and graduate interns with ERC industrial partners. As such the ERC has produced a Student Resume Book which helps industrial partners become familiar with the COE graduates in order to consider them for available internships.

B. Courses

1. Introduction to Engineering (EPD 160)

A team of engineering faculty developed a customer-centered, project-oriented, team-based cross-disciplinary engineering design course for freshmen, Introduction to Engineering (EPD 160). The objectives of the course are to introduce freshmen to engineering by actively engaging them in engineering through the design process. It is desired that students develop the ability to work in teams, learn to think in terms of the design process, and develop confidence that they can be successful in engineering. Such an experience is believed to be a strong factor in attracting and retaining women and underrepresented minorities

Teamwork is stressed throughout the course. The course is team-taught by the faculty and supported by a team of senior, undergraduate assistants. The course schedule includes two large lecture meetings for the students in addition to small (14-16 students) laboratory sections. The large group meetings are used to introduce fundamentals of the design process, develop selected technical knowledge needed for the designs and expose students to the range of engineering disciplines. The labs, each of which works on a design problem posed by local industry, provide an opportunity for students to develop basic hands-on design experience. Small design teams are used in the labs to allow students to learn how to work in a team environment in context of the engineering process and to improve their confidence in their ability to be successful in engineering. The end product of these efforts is a completed design project which each lab builds, tests, and finally demonstrates to the class and the teams' industry "customers."

EPD 160 Special Women's Issues Section

A Special Women's Issues laboratory section of EPD 160 was developed and piloted in Fall 1996. This section maintained the basic structure of the original course but also focused on special concerns faced by women engineers. The intent of the all-women's section was to boost the confidence, interest and ultimately the persistence of prospective women engineers by educating them about topics of special concern to women engineers and providing them with important resources and connections to other women in the field. The faculty member who designed the course hoped to establish a supportive all-female environment in which these young women could share their concerns about entering and surviving in a challenging and predominantly-male field. She also hoped to become a resource and role model for her female students and to introduce them to other successful women engineers who could provide the same support. The faculty member for this section was assisted by an experienced female undergraduate student assistant.

2. Advanced Manufacturing Design Course

In the Spring of 1996 a course on advanced manufacturing techniques based on micro-electromechancial systems (MEMS) was offered with partial funding by the ARPA MEEF grant. This course covered a broad array of topics including areas as diverse as x-ray lithography, bulk-silicon, and surface micromachining, and high-aspect-ratio structures. Students designed and fabricated MEMS devices. The class included two main student projects. One project involved modeling, design, layout and the creation of a written report for a sample MEMS device. The other project used the previous semesters' written reports and suggested process instructions to actually fabricate the devices. The course was offered to a cross-disciplinary group of advanced undergraduate and graduate students.

3. Electrodynamics I & II

Electrodynamics I and II is a required, two-semester sequence of fundamental content regarding electromagnetic fields and waves for undergraduate Electrical and Computer Engineering (ECE) students. Most students begin the sequence as second-semester sophomores or first-semester juniors. This course represents an attempt to integrate new pedagogical methods into core engineering courses. The course incorporates a cooperative learning component into a traditional lecture-oriented course that includes group problem solving as well as a team-based design project.

4. Student-Focused Active Learning (SFAL) Approach to Introductory Analytic Chemistry (Chem 110)

In spring of 1995, the ARPA MEEF grant collaborated with the UW Chemistry Department's NSF-funded "Establishing New Traditions" (NT) chemistry reform project by helping to fund a cooperative learning-based approach to, and an innovative evaluation of, a gateway course that enrolls a high proportion of pre-engineers. To teach this class, the NT professor used seven cooperative learning strategies, each of which was designed to interact with and support the other strategies. In addition, this professor arranged, with LEAD Center support, to conduct a course assessment by asking 25 faculty colleagues from other SME disciplines on campus to conduct oral interviews with all the students in his section and in a second section that was taught by a highly regarded professor who used more typical lecture methods.

C. Evaluations

Along with funding for materials and staff, the ARPA MEEF grant provided funding for evaluations of the WES Program, the FLCP, the Statics Supplemental Instruction Sections (workshops), the K-12 Science and Engineering Outreach Program, the Introduction to Engineering course, the Special Women's Issues Section of the Introduction to Engineering course, Electrodynamics I& II, and Chemistry 110. See the Student Outcomes section for findings from these evaluations.

1. Evaluations conducted by the LEAD Center

- WES
- FLCP
- Statics Workshop
- Introduction to Engineering (EPD 160)
- Special Women's Issues Section of Introduction to Engineering (EPD 160)
- Chemistry 110
- Summer Internships in Manufacturing Technology (This evaluation was funded by the UW-Madison's Graduate School as part of a project to evaluate the Summer Undergraduate Research Programs.)

2. Evaluation conducted by Testing and Evaluation

- Assessment of Cooperative Learning in Electrodynamics I & II

3. Evaluation conducted by the Engineering Research Center

- K-12 Science and Engineering Outreach Program

D. The industrial advisory Panel

In Year Two of the ARPA MEEF grant, an Industrial Advisory Panel was formed to enhance the role of the industrial partners in engineering education and to increase the level of manufacturing content in the curriculum. This panel consists of 7-9 representatives from local industry. Throughout the academic year the panel meets monthly with ERC staff, COE faculty members involved in MEEF sponsored courses, and LEAD evaluators to be briefed on the progress of the ARPA MEEF courses and programs and to provide input for further innovation.

III. Research Questions and Methods

The program evaluation of the ARPA MEEF grant was guided by addressing the research question on the impact of the ARPA MEEF grant, particularly in the area of the affect on students and on the institutional culture of UW-Madison.

1. Outcomes for students:

- Have retention rates, particularly among women and minorities, changed as an effect of the grant?
- How has student learning been affected?
- In what other ways has the grant affected students? For example, have there been affective outcomes relating to professional identity, and attitudes toward engineering?

2. Institutionalization and culture change:

- To what degree have the reforms become institutionalized?
- In what ways has the faculty culture changed as a result of the grant?
- What was the process of institutionalization?

We address Research Question #1 about outcomes for students by summarizing the evaluation findings for the programs which were formally evaluated.

Our findings regarding Research Question #2 about institutionalization are based on interviews with key participants in the grant and the grant-sponsored programs, historical documents (such as the annual reports to the NSF), and the evaluators' knowledge of the development and institutionalization processes of the ARPA MEEF programs gained through their role as the primary evaluators for the grant sponsored initiatives. The goal of this evaluation was to document successes as well as failures in the institutionalization process of the ARPA MEEF initiatives in order to contribute to an understanding of the successful institutional pathways and existing barriers to institutionalization.

PART TWO: Outcomes from the ARPA MEEF Grant

I. Changes in Student Learning Outcomes

A. Programs

1. Wisconsin emerging scholars program

Goals: WES sections were designed to meet some of the special needs of women and underrepresented minorities (URM) (URM includes African-/Native-/annd Hispanic-American.) The WES program seeks to increase the participation of underrepresented students in the mathematics-based disciplines through the formation of a socially based academic community. There are three key learning objectives for the workshops. Students will:

- learn the calculus at a sufficiently deep level that they would feel secure in the knowledge that they are not just "going through the motions" plugging numbers into formulas;
- cultivate a capacity to use multiple ways to solve problems; and
- develop their ability to rely on themselves to formulate and solve problems.

Two other more general goals stated that the course will:

- provide a math experience that attracts more students into math, science, and engineering majors; and
- provide informal academic and personal advising, and both planned and informal socializing opportunities to help first-year ethnic minority and rural students adjust to a research university.

Quantitative Outcomes:
During the Fall semesters from 1993 to 1996 the UW-Madison Department of Mathematics ran a total of 11 Wisconsin Emerging Scholars (WES) sections distributed over several first-semester calculus (Math 221) lectures. The students considered here were all first-semester freshman with no advanced standing, were 18 or 19 years old, and had enrolled in Math 221 in one of those four Fall semesters. Overall, we compared 169 WES students to 3,871 non-WES students.

We examined the WES program in terms of its impact on students:

1. success in calculus
2. retention in science, math, engineering, or technology (SMET) majors.

"Success" in calculus was quantified in terms of the proportions of students receiving a B or above in calculus. Specifically, for the various groups of students of interest, we analyzed the "odds of success," defined as the ratio of the number of students in the group with a B or above to the number with a BC or below. This measure was chosen because it concisely captures the most relevant part of the distribution of grades for our purposes. In contrast, differences in "mean" grades, for example, leave unanswered the question of whether one groups' higher average was due simply to more Cs in proportion to Ds, as opposed to more As and Bs in proportion to Cs and Ds.

Both of these factors were broken down by several other factors of interest. These include prior achievement or preparation (e.g., ACT, SAT math scores, UW-math placement scores, etc.), calculus lecture, gender, minority status, and whether the student was in the College of Engineering.

Impact of WES on success in calculus

No matter how we cut the data--by gender, minority status, engineering status, or prior achievement--the odds that WES students received a B or above in calculus were observed to be about twice that of their non-WES counterparts, with a 95% confidence interval for this odds of success ratio of about (1.5, 3.0).

Impact of WES on retention in Science, Mathematics, Engineering, and Technology (SMET) majors

There was no statistically significant association between persistence in a SMET major or more specifically persistence in engineering, and participation in the WES Math 221 program. That is, retention rates for the various groups were about the same for the WES participants as their non-WES counterparts. In fact, for some groups the retention percentages for WES were actually lower, though this was not found to be statistically significant. Another study of large cohorts of UW-Madison freshmen enrolled in both math and chemistry in their first semester indicates that success (B or above) in first semester calculus is strongly correlated with persistence in SMET majors (Kosciuk, 1996). However, our sample of WES students who enrolled as pre-engineers and are not juniors or seniors is too small to determine if there is a similar correlation between success in calculus and retention in engineering or SMET. In fact, conclusions drawn from the total WES sample of 169 should also be treated with caution (Kosciuk, 1997).

Qualitative Outcomes:

Qualitative analysis of student interviews showed that, through participating in WES, students were able to make connections between calculus and other disciplines as well as acquiring an understanding of real world applications. Through the process of solving challenging problems within a student centered, interactive environment, WES students developed confidence in their math abilities as well as a sense of mastery of the material. In addition students learned to engage in, and value, multiple ways of problem solving. These findings hold across student differences by gender and ethnic background, as long as the workshop section is comprised of a balanced mix of students of diverse backgrounds. We also learned that program effectiveness depends on factors such as TAs and undergraduate student assistants being trained as “guides on the side,” the use of very difficult problem sets, and attention to group work dynamics. (Alexander, Burda & Hwang, 1995; Alexander, Millar & Lewis, 1995; 1995; Alexander, Burda & Millar, 1996; Alexander, Millar, Lewis & Levin, 1995; Millar, Alexander & Lewis, 1995).

2. Freshmen Learning Community Program

The College of Engineering designed and piloted the FLCP during the Fall of 1995. The program was designed primarily to accomplish the long-term goal of increasing retention rates among engineering majors. The short-term goals of the program are: 1) to create the experience of a smaller college within a large university, 2) to foster collaborative learning, and 3) to promote understanding of interdisciplinary connections.

1995-96 Program Evaluation Findings

Based on recommendations from the fall,1995 evaluation of the pilot FLCP changes in the implementation of the program were made in spring 1996. Evaluation data showed that these program changes greatly increased the number of benefits and the percentage of students who benefited. Findings indicated that the spring program was effective for most participants in addressing key problems faced by students at a large university. Most notably it functioned to "shrink the size" of the university in several ways. The program appeared to foster a sense of group identity, providing students with a sense of belonging at the university. It also had a significant impact on student learning processes primarily through fostering a more collaborative learning approach. Participating students gained an appreciation for the value of group work. They described the following effects of group work on their learning process: 1) reinforced understanding and increased confidence, 2) provided a foundation for independent learning, 3) greater efficiency at problem solving 4) increased generation of ideas and exposure to multiple ways of problem-solving. The third goal of gaining an appreciation and understanding of interdisciplinary connections was not achieved (Alexander and Penberthy, 1995; Alexander and Penberthy, 1996; Alexander, Penberthy, McIntosh & Denton, 1996; Foertsch, Alexander & Penberthy, 1997).

3. Statics Workshop

The goal of the statics workshops provide academic support that supplements the lecture presentation and enables students to work on course homework in a collaborative learning environment. A small evaluation was conducted, producing limited findings. Students reported that the collaborative work was a valuable tool for successfully completing the homework problems, provided that all members of the group were prepared and motivated. They stated that the collaborative work facilitated their making connections between the lecture material and the homework assignments.

4. K-12 Science and Engineering Outreach Program

Goals: To expose children and young adults to science and engineering through introducing them to manufacturing technologies and to assist them in acquiring an understanding of the role of engineers in this area.

During 1996 the program gave presentations to 2700 K-12 students in 90 local classrooms. This represents a 10% increase over the previous year bringing the total number of classrooms to over 220 representing approximately 8000 students. This program conducted its own evaluation through the use of surveys. Findings indicated that the program was very successful and well received. (Zwickel, 1997)

5. Summer Internships in Manufacturing Technology

In 1996-97 the LEAD Center evaluated the seven summer undergraduate research programs funded in part by the UW-Madison Graduate School. One of these programs was the Summer Internships in Manufacturing Technology offered through the Engineering Research Center for Plasma-Aided Manufacturing, and funded in part by the MEEF ARPA grant. The main goals of these seven programs were the following:

- to give undergraduates from smaller schools the opportunity to do research in their field
- to recruit women and underrepresented minorities into research careers
- to recruit program participants to enroll in graduate school, particularly the Graduate School at UW-Madison.

The evaluation found that the UW-Madison's summer programs were very successful at meeting all of these goals. Survey respondents and interviewees who participated in the programs rated their experiences in the programs very highly, and most said the programs played a major role in helping them to decide whether they were interested in careers in research, whether they wanted to enroll in graduate school, and where they wanted to enroll. For those participants who had graduated and been tracked by the time of the evaluation, 42% had gone on to graduate school (38% of whom had already received advanced degrees) and an additional 23% had gone on to professional school (26% of whom had already received advanced degrees). By comparison, according to the Baccalaureate & Beyond longitudinal survey done by the NCES, only 8.8% of all underrepresented minorities who received baccalaureate degrees from 1992-1993 have gone on to enroll in graduate schools and only 8.2% have gone on to enroll in professional schools. Since the UW-Madison's programs began in 1986, 35% of program participants who are known to have graduated came back to UW-Madison for their advanced degrees, and many of the current undergraduates LEAD interviewed (about 45%) expressed a strong interest in eventually enrolling at UW-Madison.

B. Courses

1. Introduction to Engineering (EPD 160)

Goals: The primary goal of the design course is to provide an experientially based introduction to the field of engineering that can serve to increase student retention in engineering. The course is intended to provide students with the opportunity to:

- work constructively in a design team
- learn some engineering principles
- find and use information from diverse sources
- learn from and teach your colleagues
- get to know your customers and their needs
- communicate your designs effectively
- learn about various engineering professions
- appreciate the broader engineering issues

Quantitative Outcomes: Students who completed the first-year design course were retained in engineering at a higher rate than students who did not enroll in the course. In addition, students who completed the course chose a greater variety of engineering disciplines to pursue as a major, than students who did not enroll but were on the waiting list.

The Fall '95 cohort was large enough that LEAD was able to examine retention based on gender and ethnic breakdowns. With regard to high school math achievement, although there were no remarkable differences in retention between the male EPD-160 students and the male controls, there were considerable differences between the two groups of female students. Among the female students, 78% of the EPD-160 group received two A's in their 2nd and 3rd year of high school math, compared to 56% for the female controls. Within this "high math achievement" group, 79% of the female EPD-160 students were still majors in the College of Engineering as of spring '97, compared to only 63% for the female controls, (Chi-square < 0.09). Moreover, all of this group of EPD-160 females were still enrolled at UW-Madison Spring '97, while 13% of the controls were not registered, which is statistically significant (Fisher's Exact Chi-square $p<0.02$).

Qualitative Outcomes: Analysis of student interviews and surveys showed that students who participated in the design course experienced engineering in a personal, supportive, team-oriented environment. Students found the course instructors to be instrumental in helping them make informed career-decisions, and began to develop a sense of professional identity. Through participating in the design course, they gained an understanding of the context for math and science courses, and gained motivation to pursue engineering as a career (Courter and Millar, 1995; Squire & Lyons, 1995; Courter, Millar & Lyons, 1996a; Courter, Millar & Lyons, 1996b; Courter, Lyons, Millar & Bailey, 1996; Squire & Lyons, 1996; Alexander, Foertsch & Gunter, 1997).

<u>EPD 160: Special Women's Issues Section</u>

Goals: The special women's issues section was created to address retention issues among women in the COE. In addition to the overarching EPD 160 goals, this section also had the following unique goals:

- to increase women's confidence in their ability to do hands-on projects;
- to ameliorate women's concerns about careers in engineering;
- to provide women with female role models in engineering; and
- to encourage women to persist in engineering.

Outcomes: Analysis of student interviews and surveys indicated that women became more comfortable working on unfamiliar mechanical tasks. They also made connections with other female engineering students and gained access to potential role models and advisors through class presentations and panels. Women in this special section showed a much smaller decline in confidence and interest in engineering than women in the mixed-gender sections (Alexander, Foertsch & Gunter, 1997).

2. Introductory Analytic Chemistry (Chemistry 110)

The primary reason that the MEEF grant funded the Student-focused Active Learning (SFAL) approach to Chem 110 was to respond to the course designer's request for resources to conduct a systematic and formal comparative assessment to determine if cooperative learning methods can be used effectively in a large-lecture gateway SME course. A secondary reason for the funding was to supplement course expenses associated with the innovations used in this course.

Goals: Both the SFAL and reference professors who were assessed in this study designed their Chem 110 course to be a challenging and stimulating experience for the students who are serious about science and scientific thinking. In addition, the SFAL professor structured his course to develop his students as independent critical thinkers who can use scientific methods effectively in novel contexts. By contrast, the reference professor structured his course to primarily to develop in them mastery of the lab skills and conceptual material presented in the course.

Quantitative Outcomes: A novel assessment was designed to determine if faculty who teach courses "downstream" from introductory chemistry would judge students in a section that intensively used an SFAL approach to be more competent than students in a closely matched reference section that used active learning strategies only in an informal and limited way. In other words, an assessment method was designed to determine how well the criteria for judging student learning—as determined and then applied by each individual in a broad cross section of SME faculty at Wisconsin--aligned with the goals for student learning that guided the SFAL professor's teaching strategies. Thus, in a broader sense, the study design measured how well the criteria for effective learning held by a community of SME scholars was aligned with the goals of both the SFAL and the reference section professor. To make this determination, SME faculty external to the Chemistry Department conducted oral interviews with blind samples of SFAL and reference students. Qualitative research methods also were employed to, among other things, identify the reasons for any differences (see below). The results show that faculty who emphasize "meta-awareness" as a key criterion for assessing competence strongly preferred the students from the section that used SFAL approach. This preference was established through statistically significant differences in faculty assigned ranks and questionnaire responses.

Qualitative Outcomes: SFAL students paid as much or more attention to how much they gained from their fellow students than from the professor. They stressed the value of learning with and from other students in their small groups, with many expressing surprise at how much they enjoyed the atmosphere of support and cooperation fostered by the professor and TAs. At the same time, a small proportion of the SFAL students expressed distress about dysfunctional student groups. However, even SFAL students with dysfunctional groups tended to stress the value of research-oriented, structured group activity and indicated that group interactions helped connect the lecture, laboratory, and other course components. The large majority of SFAL students conveyed that they enjoyed the challenge of solving very difficult open-ended problems, and acquired an awareness of the complexity and frustrations that accompany genuine team-based research work. Many reported developing greater self-reliance and confidence as a result working on hard problems in a group. A relatively small proportion (about 20%) of the SFAL students resisted the small-group approach, and continued to work independently when possible (Millar, Penberthy & Kosciuk, 1995; Millar, Kosciuk, Penberthy & Wright, 1996; Millar & Squire, 1996; Wright, et al, 1997).

3. Electrodynamics

Goals: To integrate new approaches to teaching into core engineering courses. In particular, to use a cooperative learning approach with the goal of enhancing the student learning experience and to better prepare students for the cooperative team style of work that is characteristic of industrial manufacturing environments.

The ARPA MEEF grant provided funding for a two-part study of the student outcomes of this implementation of cooperative learning. The first study compared learning experiences of students in a special section extensively implementing small group strategies with two control sections utilizing more conventional teaching techniques. Results indicated that the students learning cooperatively developed more positive attitudes toward cooperative learning, engaged in more focused social interaction with team members outside of class, and sustained more interest in the subject matter, yet spent the same amount of time working on the homework. The second study investigated cooperative learning as a vehicle for teaching higher-order thinking (analysis, synthesis, and evaluation of information). Preliminary results indicates that there was a significant improvement on homework and exam scores for the students participating in the collaborative learning section compared with the control section (Booske, Cohen, Kim, Shohet & Wendt; Booske, Cohen, Shohet, Wendt & Kim**).**

II. Structural Changes in Programs and Courses

In this section we discuss the degree to which the ARPA MEEF-sponsored initiatives were institutionalized, the degree of dissemination of these efforts, and other types of institutional change which were fostered by the grant. This set of outcomes exhibits the degree of lasting impact of the grant.

As indicated throughout the literature on educational reform, often when grant funding ends the programs supported by the grant are terminated, never becoming a permanent part of the recipient institution. By and large, the initiatives which were funded by this grant have made the difficult transition from soft-to-hard money. There are a few, however, for which permanent funding has not been secured, but for which there is a long-range plan for full integration.

Institutionalization of the MEEF programs and courses primarily was established through the administrative efforts of the Associate Dean of Academic Affairs, Michael Corradini. He sought the most appropriate administrative homes for the grant-sponsored activities based upon a determination of which programs or courses naturally fell within the purview of particular departments and which were cross-departmental, thereby falling within the more general rubric of Academic Affairs. For those under the academic affairs rubric, he has utilized the Engineering

Learning Center (ELC), established approximately two years ago, to provide an administrative home.

It is important to note that several program implementers indicated that they did not define success or degree of institutionalization for their programs in terms of continually increasing the numbers of students served. They stressed that the primary goal was to maintain quality and the vision of the program and to serve the targeted group of students well. For EPD 160, increasing the number of students served would have necessitated a higher student-faculty ratio, and this would have changed the quality of the program. In the case of programs which were specifically designed to serve women and minorities (the Special Women's Issues Sections of EPD 160 and the WES Program), the targeted group was small because the pool of these students is small at the University of Wisconsin-Madison. Staff that were implementing these programs felt that it was important to keep the emphasis on the target group.

Below, we discuss the development from pilot to scale-up, including details on the administration and current funding source, for each of the grant-sponsored initiatives

A. Programs

1. WES: Promises to be fully institutionalized by 1999

The College of Engineering, through the ARPA MEEF grant, funded 6 sections of the WES workshops offered by the Department of Mathematics. The COE academic advising office took on the important role of assisting the WES Program in reaching its target population by recommending the program to many qualified pre-engineering students from underrepresented populations. This played an essential role in assisting the program in fulfilling its mission of addressing retention problems for underrepresented minorities and women in science, math, and engineering fields. The coordination between the COE and the Department of Mathematics was facilitated through the administrative support provided to the WES Program by the MEEF grant. The link that was initially established through the grant between the COE and the WES Program will continue under the administrative sponsorship of the Engineering Learning Center (ELC).

The Department of Mathematics has committed funding to the WES Program through 1999, at which time they will vote on whether to include it as a permanent part of its budget in the College of Letters and Science.

2. Freshmen Learning Community Program (FLCP): Promises to be fully institutionalized by 1998.

The College of Engineering is committed to the continuation of the FLCP and thereby has agreed to administratively oversee the program through the Academic Affairs Office. The logistics involved in scheduling the course clusters will be taken over by the staff in the Engineering Learning Center. Funding for the program during the 1997-98 academic year will be sought through TRP grant extension monies. After this period the COE will make efforts to fund the program. Further, the program is being scaled-up from one course cluster (math, chemistry, psychology) to two clusters (math and chemistry; math and physics), and there are plans for the implementation of a third course cluster (math and engineering statics). Since the spring of ’96 the Chemistry Department has been involved in funding and implementing some of these clusters, in collaboration with the MEEF-funded programs.

3. Statics Workshops: Institutionalized through the structural changes that have been implemented in the EMA 201 course

Due to the merging of the Nuclear Engineering and Engineering Physics (NEEP) and the Engineering Mechanics and Astronautics (EMA) Departments into the Department of Engineering Physics, the administration of the EMA degree (of which the statics course is a part) has been assumed by this new department. Associate Dean Corradini negotiated to have the statics course structured and funded differently, based on the success of the supplemental sessions sponsored by the ARPA MEEF grant. Future offerings of EMA 201 will now require recitation sessions for all students. These will be run by TAs and SAs using the model developed by the MEEF-sponsored supplemental instruction sections and will be funded by the Engineering Physics Department budget.

4. Saturday Tutoring/Study Sessions for Engineering Students: fully institutionalized

ARPA MEEF provided funding for a coordinator to facilitate Saturday tutoring and study sessions in its pilot stage. While all engineering students are welcome to attend, students have been, and continue to be recruited from the Society of Women Engineers, the Society of Hispanic Professional Engineers, and the Wisconsin Black Engineering Society. The opportunity for organized study and tutoring sessions is valued by the students and continues to be supported by the College of Engineering. This initiative will now be administered by the Diversity Affairs Office. They have expanded the tutorial and study sessions to times throughout the weekday and weekends in order to reach more students.

5. K-12 Science and Engineering Outreach: will be fully institutionalized by 1999

The K-12 outreach activity originated through the Engineering Research Center (ERC) prior to the ARPA MEEF sponsorship. The grant funded a coordinator to oversee the program. The focus of the program is being expanded to include other aspects of manufacturing with mechanical and civil engineering, involving automated systems and robotics as well as constructed materials, respectively. In addition the number of students reached has grown considerably, with approximately 8,000 students being exposed to the outreach "road show" over the course of the grant. Although the outreach program originally targeted only Madison-area schools, the service area has expanded to include outlying towns. The program currently serves mostly middle schools, but is expanding to visit more elementary school classrooms. This program is currently being coordinated by a staff member from Engineering Professional Development and funded in part by the Academic Affairs Office. The plan for full institutionalization is to house the outreach program within the Engineering Professional Development in association with the ELC because part of the function of this department is to be involved in outreach.

6. Summer Internship Program in Manufacturing Technology: institutionalized through the life of the ERC for PAM

The MEEF grant provided supplemental funding for additional students to participate in these internships. The internships will continue to be offered through the ERC for PAM after the MEEF grant ends.

B. Courses

1. Introduction to Engineering (EPD-160): fully institutionalized

This course has been scaled-up and fully institutionalized. The pilot version of the freshmen design course (Fall 1994) served 80 students. In the Fall of 1995, the class size grew to 225, the number of faculty involved increased from 7 to 11, and the number of SAs increased from 7 to 14. The Fall 1996 version of the course retained this size. In 1995 the course became officially approved as Engineering Professional Development (EPD) 160. In 1995 the course became completely supported by the College of Engineering instructional budget. The course is now a technical elective for most of the engineering majors and is required for completion of the Industrial Engineering, Engineering Mechanics, and Nuclear Engineering baccalaureate degrees. In addition to the original 7 faculty, 9 new faculty have taught the course. Although there are some who are interested in seeing that all pre-engineering students be required to take EPD 160, for now the faculty plan to maintain the class size and recommend that students either take EPD 160 or EPD 101: Contemporary Issues in the Engineering Profession. In addition to the basic course, one section of the Special Women's Issues section was added in the Fall of 1996 with an increase to two sections offered in the Fall of 1997. Also, with the assistance of UW-System grants of over $175,000, COE faculty have begun to develop a strategy to disseminate this course to Wisconsin high schools and UW-Center campuses, a primary source (over 150 students per year) of transfers to the UW-Madison's COE.

2. Advanced Manufacturing Design Course: plans for full institutionalization

This course was first offered in Spring 1996. Due to the departure of the course instructor, it was not offered in the Spring of 1997. There are plans for the Electrical and Computer Engineering department to offer the course again in the 1997-98 academic year since two new faculty have been hired in the area of MEMS research and development.

3. SFAL Approach to Introductory Analytic Chemistry (Chemistry 110): Being institutionalized through New Traditions National adapt/adopt effort

One outcome of the Chemistry 110 faculty assessor experiment was that 25 faculty from diverse SME disciplines across campus became aware-through their own assessments—of an effective active learning-based course. In other words, the innovative assessment method that was partially funded by MEEF functioned both to produce substantial positive assessment data, and also to disseminate information about the course quite broadly on campus. Six TAs are trained in the SFAL approach and the course will continue to be taught by its developer. Efforts are also underway by the New Traditions Chemistry group to attract other professors to this method.

4. Electrodynamics: Still being offered by original faculty developer

This course is still being offered by the faculty member who developed it. Plans for institutionalization are uncertain.

III. Dissemination of the MEEF Programs

In addition to successful implementation and institutionalization of many of the grant-funded courses and programs, an outcome of the grant-funded programs was the dissemination of the pedagogical and curricular components of these reforms to other faculty members. There were efforts to disseminate on both a national and a local level. Most of the ARPA MEEF instructors indicated that they were quite interested in national dissemination of their reforms. They saw the MEEF programs not only as effective for UW-Madison, but as models for reform around the country. As such, the ARPA MEEF instructors and evaluators produced numerous articles and papers, some of which were presented at national conferences. **(**In addition, the LEAD Center evaluation reports of the MEEF reforms were distributed (For a complete list of journal articles, conference proceeding and presentation, see Appendix B).

On a local level, through multiple dissemination efforts, some UW-Madison faculty were motivated to incorporate aspects of the MEEF-sponsored initiatives into their own courses. Examples include but are not limited to the following: the FLCP course cluster model has influenced the Chemistry Department's implementation of their course cluster; a UW Chemistry Department faculty member utilized pedagogical ideas developed in the FLCP in his second semester introductory chemistry course; another Chemistry faculty member altered his discussion sections to include pedagogical methods utilized in the WES Program; the Introduction to Engineering (EPD 160) faculty indicated that frequently other engineering faculty members would observe their classes and adopted some pedagogical methods based on their observations for use in their own classes; one of the teaching assistants for the WES program is now teaching a non-WES calculus discussion section and has modified his section to incorporate key methods developed and used in the WES Program.

Another major local dissemination effort was the November, 1996 UW-Madison Learning Community Conference funded in part, by the MEEF grant.[2] This conference was presented in accordance with one of the primary goals of the grant: to help realize the vision of creating and enhancing horizontal links across departments and colleges in order to ensure a more integrated student educational experience. True to this mission, the conference was a highly collaborative effort involving diverse groups from across the campus. The conference involved more than 160 faculty, staff and administrators from more that 80 different campus departments and programs. It was facilitated by Jean MacGregor, director of the National Center for Improving the Quality of Undergraduate Education at the Evergreen State College, Washington, Fred Campbell, Vice Provost for undergraduate Education at the University of Washington; and Robert Cole, a

[2] The bulk of the funding provided by an NSF grant to the Chemistry department (New Traditions: Revitalizing the Curriculum); supplementary funding was granted by 6 other departments or colleges and the UW's central administration.

physicist from Evergreen State College who has been involved in several science-based course clusters. The conference provided an opportunity to create and enhance connections among faculty. It also helped to spark faculty and administrator interest in linked courses and other types of learning communities, such as the WISE Residential Learning Community.

IV. Cultural Changes Within the University

Below we discuss changes in the UW-Madison institutional culture which are partially attributable to the ARPA MEEF grant.

A. Creating a more student-centered learning environment

Many of the ARPA MEEF-sponsored programs and courses had as part of their vision the creation of a more student-centered learning environment. A student-centered learning environment is defined as one in which the focus is on the students' learning process rather than the instructors' "information-delivery system." In this type of learning environment students are actively engaged in utilizing the course material. Instructors act as guides-on-the-side who assist the students in their struggle to understand the material, but do not simply provide answers. This pedagogical approach tends to de-emphasize lecture and emphasize group problem-solving. To varying degrees, the following 6 MEEF-sponsored programs embraced this innovative pedagogical approach: the WES Program, the Introduction to Engineering, the Statics workshops, the FLCP, Chemistry 110, and Electrodynamics. All of these programs were evaluated, and students who were interviewed about these programs confirmed that they were experiencing a new type of learning environment which facilitated their taking more responsibility for their learning and placing greater emphasis on student-to-student interactions. In conducting the overall program evaluation, the evaluators began to observe that as a group the MEEF initiatives were working to create a more student-centered learning environment which went beyond single courses or programs and constituted a change in the educational culture within the COE. In part, because of the success of these courses there is a movement to increase the number and availability of these courses so that these types of learning environments are available to students throughout their undergraduate years (e.g. strong faculty involvement, from both the COE and math and science departments in Engineering Education Scholars Program (EESP) and strong interest from same group in becoming a "committed campus" member of the NSF's Engineering Division's Foundation Coalition).

B. Development of forums in which instructors can focus on pedagogy

1. Student instructors gained valuable training from a faculty teaching-mentor

In several of the MEEF-funded programs the student instructors (either undergraduate student assistants or graduate teaching assistants) spent considerable time with the faculty member teaching or coordinating the program in what can be characterized as a community of instructors with the faculty member acting as the teaching-mentor. The WES TAs, the Statics help session SAs, and the EPD 160 SAs, the Chemistry 110 TAs and the TAs associated with the FLCP all had this type of experience. This was a unique opportunity for these students to gain mentoring beyond academic content in the area of pedagogical methods. Academics, particularly in the sciences, are becoming increasingly concerned with training future faculty members in the area of teaching, as evidenced by the establishment of new faculty development programs such as the Engineering Education Scholars Program,[3] and by a proposal by UW-Madison biology faculty for training students and assistant professors in teaching methods. The MEEF programs provided a forum for this type of training in context. The student instructors were not only mentored on teaching, they were able to actively engage in the use of these new pedagogical methods which for the most part were unfamiliar. TAs valued this teaching experience and felt that it would assist them in securing faculty positions.

It is noteworthy that the grant-funded programs utilized undergraduate SAs. Prior to MEEF, the use of SAs was fairly uncommon at UW-Madison, at least in the College of Engineering. Thus, the grant allowed undergraduates the opportunity to gain valuable teaching experience in addition to other important benefits.

2. Faculty gained the opportunity to apply new ideas about teaching and learning in MEEF sponsored initiatives

As previously discussed many of the ARPA MEEF faculty members had been involved in discussing issues related to teaching and learning in the Teaching Improvement Program prior to receiving the grant. The grant provided them with the opportunity to create courses and programs in which they could apply and test their ideas about teaching and learning. Most of the faculty who were interviewed indicated that they considered this a learning process involving trial and error. This was considered an opportunity which they highly valued. They tended to indicate that they had become more skilled in the use of the new pedagogical methods through this experimentation process and that they had developed new techniques, particularly in the use of cooperative learning. Several stated that they had modified their teaching in non-MEEF sponsored courses or programs to incorporate what they had learned from this process.

C. Lasting cross-departmental or cross-college connections

Program participants indicated that through the ARPA MEEF-funded programs on-going cross-departmental and/or cross-college connections were established. Several examples are discussed below.

An essential collaboration was established between the Math Department and the COE with respect to recruiting students for the WES Program. The WES program coordinator indicated that the COE advisors were the most successful recruiters of qualified underrepresented minorities for participation in the program. This provided the program with enough targeted students to keep the program viable. In addition, the grant funded two of the WES sections. This collaboration between the Math Department and the COE served the goals of the Math Department to provide a quality program for high-achieving women and minorities, as well as

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[3] This is a national program that is sponsored by the NSF. The UW-Madison's COE hosts one of the programs.

those of the COE, to increase the pool of female and minority engineering majors by assuring that they succeed in gateway courses. Although the funding provided by the grant is ending and there is no longer a formalized tie between the COE and the WES Program, the program coordinator for WES feels that this tie will continue and has paved the way for future joint efforts.

The creation and implementation of the Introduction to Engineering (EPD 160) course brought together faculty from multiple departments within the College of Engineering. This initiative was an unprecedented cross-departmental collaboration. Although the initial faculty members involved in this course were originally brought together through their participation in the Teaching Improvement Program, the grant sponsored their first opportunity to pilot a new course and teach together as a collaborative group.

The FLCP also involved collaboration among faculty and staff from the COE and various departments in the College of Letters and Sciences. For example, to create the pilot program, Chemistry, Mathematics, and Psychology department chairs worked with Denice Denton, the first ARPA MEEF Program Director, to identify faculty who would be interested and willing to participate. The faculty members who participated in the course cluster worked together to varying degrees to coordinate aspects of the program. In addition, the TAs for each of these courses and the FLCP Program Coordinator, an engineering graduate student, worked closely to prepare for and facilitate the weekly FLCP student meetings.

Through the development of the FLCP there was a collaborative relationship established between MEEF and the New Traditions Chemistry grant, and therefore between the COE and the Chemistry Department faculty. The FLCP was funded in fall, 1995 by the MEEF grant and was then sponsored by the New Traditions grant in spring, 1996. The Chemistry 110 Faculty Assessor Study also was funded by a combination of MEEF and New Traditions.

An unanticipated but very welcome additional outcome of the MEEF grant is that the NSF-sponsored Foundation Coalition has asked the UW-Madison COE to join as a new member in its proposal for a second five year period. The core group of MEEF-involved faculty, plus a substantial number of additional faculty from diverse COE and several Letters and Science (Chemistry, Mathematics, Computer Science, Physics) departments have indicated they want to join the Foundation Coalition. Proposal activity is under way at this time. With this development, cross-departmental and cross-college connections will be further developed, and multiple new cross-institution connections established as well.

In essence, the ARPA MEEF-sponsored programs brought together faculty and staff from different departments and colleges to achieve a common goal, thus creating a meaningful context in which to interact. Having worked together on these successful joint ventures, it seems likely that the faculty and staff who were involved in these connections will continue to find ways to work together to meet the shared goal of strengthening ties within and across SMET disciplines in an effort to enhance students' educational experiences.

D. Collaboration with industry on educational initiatives

One of the goals of the ARPA MEEF grant was to involve industrial participants in pedagogical and curricular reform with a particular emphasis on bringing manufacturing and real-world problems into the classroom. As in any partnership, the goal was for this joint effort to benefit both sets of participants, the COE and the industrial partners. Below we discuss the outcomes of these collaborative efforts.

1. Creation and institutionalization of an industrial advisory panel

In response to the 1995 NSF Site Visit Team's recommendations, an Industrial Advisory Panel (IAP) consisting of 8 local industrial representatives was created to enhance the level of manufacturing content in the classroom and increase the role of industry. This group met with program staff and faculty members approximately once a month during the academic year. Participants indicated that this effort was innovative in that it involved formalized collaboration between faculty and industrial participants on post-secondary educational issues. Perspectives of the industrial members vary on the actual role of the IAP. One participant felt that the IAP had primarily played the role of reviewing evaluation data on the MEEF courses and programs and providing input and advice on possible modifications or additions to the curriculum. Another member felt that the role of industry had been unclear and that there needed to be more guidance from the faculty leaders whom the IAP was created to serve. Both indicated that the role of the IAP was in transition now that the grant funding was ending and the administration of the grant had changed hands from the original Project Director to the Associate Dean of Academic Affairs, Mike Corradini. Future post-grant plans for the Panel are that it will become an advisory group to the COE through the Engineering Learning Center. Because the original advisory panel served the ERC, the diversity of the types of industrial representatives was limited to certain engineering sub-disciplines. Now that the panel will be advising the COE, it will be expanded to include at least one representative of each of the engineering sub-disciplines offered as majors in the COE.

The industrial partners indicated that they benefited from their involvement in the IAP. For example, through the connections established by the IAP, existing research partnerships on research have been strengthened and several new ones have been created. In addition, industrial partners indicated that through their participation on the IAP they felt better able to find qualified COE students for internships and professional positions.

2. Utilizing efforts of the industrial partners in the classroom

All of the staff from the grant-sponsored programs or courses who were interviewed indicated that they had explored the possibility of incorporating industrial participants into what they did in the classroom in their courses or programs. Some found that they were able to do so, and others did not. Below we describe some of these efforts.

Industrial partners as providers of " props" for the K-12 outreach "road show"

The members of the IAP provided several of the props for the K-12 road show. Also, alumni of the COE who had participated as volunteers in the Outreach Program and were now employed in local industry maintained a connection with the program through becoming important suppliers of materials for this show.

Involving industry in a “show and tell’ capacity was helpful for some

A few faculty described using industrial partners to provide “show and tell” for students by having practicing engineers come into the classroom and discuss what they do, or having the students go on fieldtrips to see practicing engineers at work.   For instance, one of the faculty arranged for an industrial partner to come talk to her students in a senior level class. However, not all faculty members found it easy to incorporate industrial representatives in this way. Some felt that especially for freshmen students whose background knowledge was limited, the industrial engineers' perspective was difficult to incorporate in ways which were meaningful to the students.

Another variation on using industry was through bringing practicing female engineers as representatives of the experience of women in engineering into the Special Women’s Issues Section of EPD 160. The engineers gave a panel discussion and met individually with small groups of students. Students indicated that it was important for them to hear women engineers talking about their work and additionally, that is was empowering to realize that they as freshmen used language about the design process that was similar to that of the practicing engineers.

Having industry design problems or assignments was not considered appropriate in many settings

Several of the program staff or faculty members indicated that they had considered incorporating problems or projects which were designed by industry into their course or program, but in most cases, they decided that this was not the best way to spend students' time. For programs which were associated with courses that did not emphasize applications to the "real world" or interdisciplinary connections (the FLCP, WES, the Statics Help Sessions, and the tutoring program), it was at times difficult to justify having the students spend time solving "real-world" problems. This was primarily because the courses which were linked with these programs (introductory calculus and chemistry, and other gateway courses) were considered difficult and students were most interested in completing their assignments and working on other material which they knew would help them succeed on course exams. Although the program coordinators understood that problems which stressed applications to the real world would probably pay off for the students on their exams, it was difficult for them to envision convincing students of this given the work load and time pressure that many students experience in these courses.

For the Introduction to Engineering (EPD 160) course it was at times difficult to involve industry because industrial partners tended to suggest projects which were too narrow and difficult for freshmen students. One EPD 160 faculty member indicated that in order to involve industry in any meaningful way in the course, the industrial partners would have to spend much more time than was feasible for them. Thus, meaningful involvement was precluded by time limitations.

PART THREE: Key Strategies for Implementation/Institutionalization of Innovative Reform Efforts

In Part Three we provide an analysis of the successful implementation/institutionalization strategies used by MEEF participants. We also provide a discussion of selected suggestions by program staff for strategies necessary to fully institutionalize some of the initiatives and achieve the goals of the MEEF grant.

The outcomes described in Part Two demonstrate a high degree of success both in terms of implementation and institutionalization of the MEEF-sponsored initiatives. What follows is an analysis of the key strategies that appeared to underlie these successful initiatives and which may be applicable in future reform efforts locally and nationally.

I. Vision and Programmatic Efforts of the Grant Matched the Mission and Priorities of the Institution

The programs and courses that were proposed and implemented through the ARPA MEEF grant were consonant with the current objectives and priorities of the COE. This is evidenced by the COE's creation of the Ad Hoc Curriculum Committee in 1993 to examine the engineering educational experience. This committee concluded that changes were needed particularly in the area of improving the retention of women and minorities, and indeed all undergraduates in the College of Engineering. Simultaneously, there were faculty members that were beginning to be involved in efforts that explored issues of teaching and learning. The ARPA MEEF grant, with its goals of improving the retention of women and minorities through innovative pedagogical initiatives, not only matched the current institutional goals but positioned itself to play a role in furthering those goals. This strategy was essential in encouraging the participation and commitment of faculty in the grant-sponsored initiatives as well as the support by COE administrators of the MEEF-sponsored initiatives. This point and others that are developed below are presented in a different format in an article about the Introduction to Engineering Course that appeared in Prism (Millar & Courter, 1996).

II. Key Players Necessary for Successful Implementation and Institutionalization

Faculty, administrators, program coordinators and student instructors all played key roles in the MEEF-funded programs and courses. Below we discuss the ways in which each of these "key players" were necessary in implementing and/or institutionalizing the programs.

A. Faculty involvement and commitment necessary

1. Faculty need to play the primary role in designing and implementing initiatives

Though a grant proposal can provide a rough outline for an innovation, for an initiative to be successful it is important to have key faculty involved in the creation and implementation, such that they have ownership and are committed to the initiative. Behind virtually all of the MEEF-sponsored initiatives there was one or more committed, reform-ready faculty member who designed and shepherded the innovation.

The Introduction to Engineering course provides a particularly strong example of this strategy. Although the ARPA MEEF PIs proposed the creation of an introductory design course in the preliminary proposal, they sought a group of faculty members who would be interested in the idea of the course and then completely turned over the design and implementation of the course to those faculty members. The faculty that were chosen had been meeting as a group for over a year discussing ways to improve the students' learning experience, prior to the MEEF grant as part of the Teaching Improvement Program. Coming into the course design process with a well-defined vision and already proven ability to work together, this group was able to negotiate the difficult task of designing a team-taught course. In interviews these faculty members stressed that before they would take on this time intensive task of creating a new course they sought assurance that they would have complete freedom and would not be micromanaged by the administrators of the grant. They also sought assurance that there was sufficient administrative support from the COE. With these assurances they invested substantial commitment to seeing this project through by devoting the necessary time and energy.

The story of the FLCP provides a counter-example. Although this program is considered quite successful with respect to meeting two of its major goals, providing students with access to a community that "shrinks the size of university" and fostering collaborative learning, it has not reached the goal of fostering student understanding of interdisciplinary connections. This is in large part because, unlike the first two goals, this third goal requires considerable faculty involvement and the faculty who taught the FLCP courses were not heavily invested in the program. They lacked ownership and commitment to the program largely because they were not involved in designing the program from the ground up. Their participation was sought late in the planning process, when the basic design of the program had already been established. These faculty members discussed that they would have designed the program differently in order to achieve the goal of fostering interdisciplinary connections. In particular, they would have chosen different courses to be part of the course cluster. Fortunately, the FLCP had two other important goals which could be and were achieved by graduate instructors (a Program Coordinator and TAs).

2. A cross-departmental, collaborative faculty group maximizes the chances of institutionalization

An additional lesson to be learned from the success of the Introduction to Engineering course is that because it was a cross-departmental course that required an additional allocation of funds, it was essential that a cross-departmental, collaborative faculty team spear-headed the project. The fact that this group was comprised of diverse faculty from multiple engineering sub-disciplines helped to foster support from across the college. The process of bringing in new faculty to teach the course was facilitated by the larger informal network established by linking faculty from many departments making it easier to find new faculty to teach the course. In addition, having faculty in multiple departments who were involved and committed to this course made it much easier to justify COE funding for the course.

In addition, the collaborative effort was instrumental in the successful creation and institutionalization of the Introduction to Engineering Course. Research on the institutionalization of reform initiatives indicates that a committed social network of faculty can be critical in both initiating and sustaining innovative courses and programs (Kozma, 1985)

Widespread faculty commitment necessary for successful institutionalization of expensive programs

Because there are competing demands for limited funds, widespread faculty support within the relevant department is necessary in order for grant-funded programs to make the transition from soft to hard money. This is particularly true for those courses or programs which are considered expensive. For example, the WES program, because it is quite expensive, will require considerable faculty buy-in within the Math Department in order for that faculty group to approve its continuance. The FLCP, on the other hand, is relatively inexpensive, and as long as it is considered successful by those who are involved and key administrators, widespread faculty support is not necessary to justify its budget.

B. Supportive administrators needed for the successful implementation and institutionalization of all courses and programs

Because of the essential role in providing resources, financial and otherwise, for innovative courses and programs it is essential to have at least one administrator backing a new course or program to ensure support for the initiative. From the beginning of the MEEF grant the Dean of the COE, John Bollinger, supported the reform initiatives. One of the reasons behind this support may have been that Dean Bollinger had been concerned about issues in undergraduate engineering education and had created the Ad hoc Curriculum Committee for the COE (See Introduction: Background) to address these issues. The findings of this committee matched the goals and strategies of the ARPA MEEF grant.

Dean Bollinger showed his support of the grant initiatives in multiple ways. He assisted the grant Project Director, Denton,in finding the appropriate faculty group to create and teach the Introduction to Engineering Course and allocated substantial funding to sustain the course in Year Two of the grant when the course was no longer predominantly grant-funded. The support of key administrators continues to be crucial in supporting innovative programs once the grantfunding comes to an end. In the case of the MEEF-sponsored initiatives, Associate Dean Corradini aggressively sought ways to find permanent administrative and financial support for every one of the programs and courses.

Utilizing existing infrastructure a key strategy for institutionalizing cross-departmental programs

As previously discussed Associate Dean Corradini had a well-defined strategy for institutionalizing the MEEF-funded programs. He sought the most appropriate administrative home based upon which courses or programs fell within the curriculum of individual departments and which fell under the more general rubric of COE Academic Affairs. These decisions were made based upon a determination of where these initiatives would be most likely to be sustained. For those falling within the academic affairs rubric, he utilized the Engineering Learning Center to provide an administrative home. For those courses that related to the curriculum within a departmental degree program he facilitated the transition to departmental support and administration. The key to his institutionalization strategy was to embed the initiatives both administratively and financially in areas where they had a natural "fit" and where responsibility for sustaining the initiative was localized.

C. For successful implementation of programs, paid coordinators are essential

A key player in the implementation of the MEEF programs (such as WES, K-12 Outreach, the FLCP, and Statics help sessions) was a Program Coordinator. Even after the pilot stage, these coordinators engaged in extensive networking with faculty and staff and, in some cases, industrial representatives. They also coordinated TAs and SAs and handled important logistical matters that were critical to the success of the programs. In interviews the program coordinators stressed that paid program coordinators were essential in order to ensure that all of these responsibilities were addressed.

D. Trained and receptive TAs and SAs needed

For courses or programs which utilized TAs or SAs, it was important that these student instructors be trained in the use of new pedagogical methods and be receptive to the goals of the initiatives. For instance, in the WES Program, the FLCP, and Chemistry 110, the TAs functioned as key implementers of the program while SAs were critical to the Introduction to Engineering course and also important in the WES program. Therefore, it was important to have TAs who supported the program goals and were able to help foster these goals through appropriate pedagogical approaches. For the WES program, the TAs were given considerable training and met weekly with the program coordinator who assisted them in developing the necessary pedagogical skills. TAs in Chemistry 110 undergo somewhat less formal training in their weekly meetings with the course instructor, but receive important additional training as the professor continuously models for them how to implement an SFAL approach. The Introduction to Engineering SAs receive formal training prior to the semesster, and meet weekly with the professors to provide feedback from students and participate in course planning.

III. Utilizing Industry in the Educational Process: A Strategy to Achieve Program Goals, Not a Goal in Itself

Although some MEEF programs were able to involve industry, others were not. Because this was one of the primary goals of the grant it is important to understand why some programs were more successful than others at achieving this goal.

One factor that became clear based upon interviews with program staff, was that it was not self-evident to most how they could utilize industry in their programs. The staff indicated that they were primarily interested in creating and maintaining a strong program which achieved its own goals which primarily related to student learning outcomes. Some program staff were able to find ways of using industry as a strategy for achieving the student learning goals. For instance, the Special Women's Issues Section of the Introduction to Engineering Course had the goal of helping female pre-engineering students identify with engineering as a possible career. In accordance with this goal, the instructor arranged for her students to meet with a group of practicing female engineers. According to evaluation data, this activity fostered the above goal. The lesson here is that it is important to match program goals with appropriate strategies. In some cases, industrial involvement is more appropriate than in others.

IV. Importance of Formative and Summative Evaluation Data

The participants in the programs and courses which were evaluated felt that the information they gained from the evaluations was useful not only in the process of implementing the initiatives, but also in institutionalizing them.

Formative, or "real-time," feedback helped faculty and staff know how well they were achieving their goals and provided direction for further improvement of their programs. One example of the use of formative feedback was in the design of the FLCP. Evaluation findings from the pilot semester of FLCP indicated that due to program implementation issues, the program was only benefiting a small subset of the student participants. Based on these findings several specific changes to the FLCP were implemented in the second iteration of the program. Evaluation data showed that the program changes implemented in the second implementation of the program greatly increased the number of benefits and the percentage of students who benefited[4] (Foertsch, Alexander and Penberthy, 1997)

Formative feedback was also critical in the implementation of the Introduction to Engineering course. Faculty found that the evaluation data, particularly during the pilot semester, was instrumental in helping them in refine their course goals and their implementation strategies. Through the evaluation data on the student experience in the course faculty were able to acquire timely information about what was and was not working in the implementation of the course.

Summative feedback, particularly data on student retention and achievement, provided program staff a strong argument for continued support of programs, particularly those that were considered costly. For example, evaluation data showing improved retention rates for pre-engineering students who took the Introduction to Engineering Course helped justify administrative and financial support for the course. For the WES Program, the student outcomes data, which showed an increase in achievement for students in the WES sections, was helpful in gaining support from administrators and faculty members who may have originally doubted that the program would be worth the money. In addition, faculty whose programs were evaluated indicated that the evaluation reports made it much easier to disseminate their pedagogical and curricular ideas because the evaluation reports contained written accounts of their programs and an analysis of the resulting student outcomes.

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[4] For a complete discussion of this process see, [the FLCP, Processual model of change article].

V. Suggested Future Strategies

A. Need for better utilization of existing infrastructure for successful program coordination

It became clear that for several reasons there was a need for better utilization of existing infrastructures and/or the creation of new infrastructures to assist with program coordination. For example, staff for the FLCP and WES indicated that recruiting for their program required considerable time and that if the Diversity Affairs Office could help them streamline this process, it would make recruiting easier.

One of the advising tasks which was particularly time consuming was educating all of the advisors on the specific purposes and activities of the various programs. For instance, the WES Program was sometimes confused with remedial programs for minorities. Thus, students who were not within the targeted group were sent to the coordinator for consideration for program enrollment. A solution would be to have better infrastructure in place to adequately inform advisors and other important staff about the array of available programs, this would allow the program staff to meet their goals of student enrollment and students would be assured of finding the appropriate program that matched their needs.

B. Need for curricular restructuring that allows interdisciplinary connections and "real-world" applications to be fostered

Virtually all of the MEEF program staff agreed that fostering an understanding of interdisciplinary connections and the ability to apply and integrate conceptual knowledge was an important student learning goal. Many indicated, however, that because their programs were attached to courses which did not stress this kind of learning, it was difficult to achieve this goal within their program. This is because programs which are attached to existing courses are limited in their ability to shape the learning experience of the students because they must cater to the reward/assessment structure of the courses with which they are associated.

For example, although the WES program coordinator would have liked to have stressed the connections between engineering and calculus, she felt that to do so would not be an appropriate use of student classtime, because the professors for the large lectures associated with WES did not assess the students for this type of knowledge. It was also difficult to stress interdisciplinary connections and applications in the FLCP, the Statics help sessions and the Saturday tutoring sessions as well.

By and large, introductory courses are still taught with the primary goal of learning basic material, stripped of its connections to the real world and to other disciplines. In order to achieve this final goal, new courses that emphasize this type of learning must be developed. There may be other strategies for achieving this goal as well.

Part Four: Conclusion

The ARPA MEEF grant awarded in the spring of 1994 was intended to foster cultural and curricular change throughout the UW-Madison's College of Engineering. The intended outcomes for students were: (1) increased retention rates in engineering, particularly among underrepresented groups; (2) improved student learning through shifts toward collaborative, hands-on assignments that emphasize critical thinking, teamwork, and communication skills over rote memorization and algorithmic problem solving; and (3) impacts on students' attitudes through increased understanding of the engineering profession and a broadening of students' perspectives about the type of people who succeed in it. The intended outcomes for the College of Engineering were: (1) the institutionalization of successful MEEF-funded reforms at both the course and program level, (2) a change in faculty culture that would support and encourage collaborative learning and other reforms in engineering education, and (3) an enhancement of the role of industry in engineering education. Researchers from the LEAD Center and other organizations conducted evaluations of nine of the MEEF-funded initiatives in order to determine the extent to which the grant's intentions had been realized. These evaluations used qualitative and quantitative methods to investigate the impact of the ARPA MEEF grant on retention, student learning, and student attitudes towards engineering. Interviews with key administrators and staff were then used to determine the degree to which reforms had become institutionalized, the process by which institutionalization occurred, and the impact of the initiatives on faculty culture.

Overall, the impact of MEEF initiatives on students in the College of Engineering has been positive and significant, though the specific outcomes vary from course to course and program to program. EPD-160 significantly boosted the retention rates of female engineering students, and the Summer Internships in Manufacturing Technology successfully encouraged participants to go on to graduate school. The participants in the Wisconsin Emerging Scholars calculus program (comprising 40% minority students and 50% women) performed, on average, statistically better than comparable students not in the program, but were retained in engineering at rates statistically comparable to those of students who did not participate in the program. (Retention to major data associated with other MEEF-sponsored programs and courses are not yet available.) We conclude from these findings that achieving higher retention rates in engineering may involve more than just providing students a more collaborative and supportive learning environment in one or two prerequisite courses. We suggest that to achieve higher retention rates, particularly for women and members of underrepresented ethnic groups, it may be necessary to both (1) provide a critical mass of courses using active learning strategies like those used in WES and Chem 110, and also (2) provide students opportunities (like EPD 160 and the Summer Internships) to determine if there is a "good match" between a student's interests and the career opportunities available with an engineering degree. Courses like EPD-160 and programs like the Summer Internships appear to encourage retention by giving students hands-on experience in what engineers do and broadening their perspective of the options available to them. By interacting with engineers in both academics and industry and having the opportunity to act like "real engineers" themselves, engineering students who might otherwise be put off by the abstract and theoretical nature of their early course work are given the opportunity to experience how this knowledge can be applied to real-world problems—an issue of particular concern to many of the women and ethnic minorities who enter the field.

While the impact of MEEF initiatives on student retention has been mixed, the impacts on student learning and student attitudes toward engineering have been consistent and clear: The vast majority of students who participated in MEEF initiatives that utilized collaborative approaches—including WES, FLCP, the Statics Workshop, EPD-160, Chemistry-110, and Electrodynamics—gained an appreciation for working in teams and learned to rely on themselves and their peers as sources of knowledge. Students who were given collaborative, hands-on assignments gained confidence in their problem-solving abilities and interest in the subject matter, whether it was calculus (WES, FLCP), chemistry (Chem-110, FLCP), or applied engineering (EPD-160, Electrodynamics). Our assessment is that students enrolled in these courses and programs emerged better prepared for the cooperative style of work and the open-ended problems that are characteristic of current work environments. Furthermore, evaluations that involved comparisons with a control group found that students who participated in MEEF-funded initiatives outperformed non-participants on measures of learning and content mastery. Students in the WES program and the collaborative learning section of Electrodynamics scored significantly higher on homework assignments and exams than students in the control sections, and Chemistry 110 students who were taught using the Student-focused Active Learning approach outperformed students taught with more traditional approaches in oral exams designed to test critical thinking skills and application of chemical knowledge. By all indications, MEEF-funded initiatives encouraged important and significant improvements in student learning and made students more capable of transferring that learning to real-world problems. In addition, students in EPD-160, Electrodynamics, and the Summer Internship in Manufacturing Technology gained a concrete understanding of the career options available to them and were able to enrich and broaden their perspectives of what engineering involves. The choices that these students ultimately make about their coursework and their careers will be informed by their own hands-on experience.

The impact of MEEF-funded initiatives on the College of Engineering has also been positive. For the most part, initiatives funded by the grant have made the difficult transition from soft to hard money, although a few have yet to secure permanent funding. The Statics Workshops, the Saturday Tutoring Sessions, and EPD-160 have all become fully institutionalized, with sufficient monetary and faculty support to remain viable components of the engineering curriculum long after the ARPA MEEF grant has ended. Other initiatives, like the WES Program, the FLCP, and the K-12 Science and Engineering Outreach Program, have concrete plans for institutionalization within the next two years. A few others, including the Advanced Manufacturing Design Course and the SFAL sections of Chemistry 110, are still advancing towards adoption by additional faculty members. Cultural changes within the college that can be attributed to the ARPA MEEF grant include the creation of a more student-centered learning environment, the development of forums in which instructors can focus on pedagogy, the establishment of lasting cross-departmental and cross-college connections, and increased collaboration with industry on educational initiatives.

Efforts to disseminate the pedagogical and curricular components of the MEEF-sponsored initiatives have occurred both on a local and national level. UW-Madison faculty from the COE other colleges have had the opportunity to learn about the reform efforts and in some cases have incorporated aspects of the MEEF initiatives into their own courses. On the national level, faculty and evaluators have produced numerous articles, reports and conference presentations on the MEEF initiatives.

LEAD Center evaluators explored the process by which successful MEEF initiatives became institutionalized and found that certain strategies were essential to the implementation and institutionalization of MEEF-funded reforms. First, a match between the vision and programmatic efforts of the ARPA MEEF grant and the mission and priorities of the College of Engineering was essential in encouraging the participation and support of faculty and administrators in grant-sponsored initiatives. Second, the successful implementation and institutionalization of many of the grant-sponsored initiatives required the ownership and the commitment of faculty, who were needed to play the primary role in designing and implementing initiatives. Other key players whose commitment as skill were essential include: the paid program coordinators, who did most of the networking and handled important logistical matters; trained TAs and SAs, who played critical roles in facilitating collaborative group work; and supportive administrators like COE Dean John Bollinger and Associate Dean Mike Corradini, who found continued funding and administrative "homes" for successful initiatives. The utilization of formative and summative evaluation data to "fine-tune" initiatives and to gain support for their dissemination was also essential to their success. In sum, the ARPA MEEF grant was successful in encouraging the development, implementation, and institutionalization of collaborative learning approaches and in fostering desired cultural change in the College of Engineering and at the UW-Madison more generally.

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Appendix A.

Protocol for Interviews with Informants for the ARPA-MEEF Program Evaluation:
This general protocol was used for the ARPA-MEEF Program Evaluation interviews. Because each program was different and the roles of various "players" varied, these questions were used as a guideline. The interviewer focused on those questions most relevant to the interviewee's experience, and to the context of the program being evaluated.

Background

1. a) Please tell me a little bit about your role in X (course or program).
   b) How and why did you get involved?

Overall Impact

2. What do you feel the impact of the ARPA-MEEF grant was?
   For students? [Prompt for impact on underrepresented minorities and women.]
   For faculty?
   For graduate students/TAs?
   For yourself?

Institutionalization

Framing: As the ARPA-MEEF grant is coming to an end, the major question is, "What happens to these courses and programs now that the initial funding is no longer there? Will these, or have these, courses and programs become institutionalized." Many of my questions will focus on this issue.

3. Do you consider this courses or program a permanent part of the curriculum? Or, to what degree is it institutionalized?

4. *For WES*: What was the role of the ARPA-MEEF grant in institutionalizing the WES program?

5. If the program or course has expanded or is closer to being institutionalized, can you tell me the key factors that allowed it to move from a pilot to a scaled-up version? Or, tell me how this program/course has developed since the pilot.

6. Are new faculty members now involved with this course or program? If so, how and why did they get involved?

7. Did you or other grant participants encounter barriers to institutionalization?
   a) If so, what were they?
   b) Were you able to overcome some of those obstacles? If so, how?

8. How, if at all, was X program or course supported by the administration?
Was this enough?
How did the grant play into this?
Did this change over time? If so, why and how?

9. a) Did your interactions with students and graduate students play a role in shaping this course or program? If so, please describe.
b) Was this part of the process of institutionalization?

Culture Change

10. Do you believe that the grant had an impact on faculty not initially with implementing the courses or programs? (Was there a second generation of faculty teaching this course or program?) If so, please describe how this happened.

11. Has this course or program influenced faculty teaching other courses or programs? [Prompt for influence on faculty in other departments.]

12. As a result of this grant, do you see changes in the level or quality of interactions among faculty? Participants? Non-participants? Communication among people in different disciplines?

13. a) As a result of this grant, did the level or quality of your interactions with graduate students change? If so, please describe.
b) With students? If so, please describe.

14. a) What, if anything, has been the impact of the interactions among faculty and the industrial advisory board?
b) As a result of this grant, do you see changes in the level or quality of interactions between UW and industry

15. Has your participation in the grant or X course or program affected you personally? In terms of your teaching?

Closing

16. Through your participation in the ARPA-MEEF grant or similar initiatives, what have you learned about the process of institutionalization? What advice would you give a faculty member who had a similar grant?

17. Do you have any other comments about the ARPA-MEEF grant?

18. Do you have suggestions for other people we should talk to about this

19. Any questions for me?

Appendix B.

Journal Articles, Conference Proceedings and Presentations on ARPA-TRP Courses or Programs

Journal Articles, Conference Proceedings and Manuscripts

Alexander, B.B., Burda, A. C. & Millar, S.B., "A Community Approach to Learning Calculus: Fostering Success for Underrepresented Ethnic Minorities in an Emerging Scholars Program." In press, *Journal of Women and Minorities in Science and Engineering.*

Alexander, B.B., Penberthy, D., McIntosh, I.B., & Denton, D., "Effects of a Learning Community Program on the First-Year Experience of Engineering Majors." Frontiers in Education Conference, Salt Lake City, Utah: 1996.

Booske, J., Cohen, A., Kim, J.B., Shohet, J.L. & Wendt, A.E., "An Investigation of Cooperative Learning in Undergraduate Engineering Education." Submitted to the *Journal of Engineering Education*.

Booske, J., Cohen, A., Shohet, J.L., Wendt, A.E. & Kim, J.B. "An Investigation of Cooperative learning in Undergraduate Engineering Education," Madison, WI: 1996.

Corradini, M., Farrell, P., Mitchell, J., Marleau R., Moskwa, J., Sanders, K., & Webster, J., "A Team-Based Design Course for Freshmen." ASEE Conference, Anaheim, CA: 1995.

Courter, S.S., Lyons, L., Millar, S.B. & Bailey, A., "Student Outcomes and Experiences in a Freshmen Engineering Design Course." ASEE Conference, Washington, DC: 1996.

Courter, S.S., Millar, S.B. & Lyons, L.L., "From the Students' Point of View: Experiences in a Freshman Engineering Design Course." Submitted to the *Journal of Engineering Education.*

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Millar, S.B. & Courter, S.S., "From Promise to Reality: How to Guide an Educational Reform from Pilot Stage to Full-Scale Implementation." *Prism,* ASEE (*American Society for Engineering Education),* 1996.

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Thole, K., Alexander, B.B., "Development and Assessment of an All Women's Section of a Freshmen Engineering Design Course." Submitted for review to the *Journal of Engineering Education.*

Wright, J.C., Woods, R.C., Millar, SB., Kosciuk, S.A., Penberthy, D.L., Williams, P., and Wampold, B, "A Novel Comparative Assessment of Two Learning Strategies in a Freshman Chemistry Course for Science and Engineering Majors," NISE Research Monograph No. 9., 1997.

Presentations and Talks

"Effects of a Learning Community Program on the First-Year Experience of Engineering Majors," Frontiers in Education Annual Conference, 1996.

"K-12 Outreach: Plasmas and Manufacturing," Cetrangolo, C. & Sandstrom, P., American Physical Society-Division of Plasma Physics, Denver, Colo., November 1996.

"Minorities and Public Pre-College Education in Wisconsin," Bleicher, M., Session Chair, Quality Education for Minorities Network, Wisconsin Meeting, Milwaukee, Wis., March 1996.

"A Novel Comparative Assessment of Two Learning Strategies in a Freshman Chemistry Course for Science and Engineering Majors," American Society of Engineering Education Annual Conference, Washington D.C. June 1996.

A Panel Discussion of Alternate Pedagogy, Bleicher, M., American Mathematics Society, San Francisco, Calif., January 1995.

"Plasma: The Fourth State of Matter," Cetrangolo, C. & Sandstrom, P., National Science Foundation, Family Science Day and Take Your Daughters To Work Day, Washington, DC, April 1996.

"Plasma: The Fourth State of Matter," Cetrangolo, C. & Sandstrom, P., National Science Foundation, National Science and Technology Week and Take Your Daughters To Work Day, Washington, DC, April 1995.

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“The Wisconsin Emerging Scholars Program-Getting Minorities Over the Hurdles,” Bleicher, M., Quality Education for Minorities Network Annual Meeting, Washington, DC, February 1995.