Science Related Degrees: Improving the Retention of Women and Minorities through Research Experience, Mentoring and Financial Assistance

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I. Theoretical Backgrounds

The importance of retaining and advancing women and minorities in science related fields has been supported by several arguments. The first argument relies upon the concepts of fairness and equity. By not participating in science related fields, women and minorities are barred from the economic rewards of these fields[1, 2]. More recent arguments recognize that not only is female and minority participation advantageous to the individual, but also to the advancement of a given field. Women and minorities have made contributions to fields that are unique from that of the majority population [3-8].

There is evidence that the participation of women and minorities has had positive results in both educational and work environments. For example according to Johnson[5], the increase in female enrollment at the Massachusetts Institute of Technology (MIT) that resulted from affirmative action was coupled with an increase in the overall quality of students. Linn[8] reported that businesses in marketing and consumer product development have also witnessed unexpected benefits from the increase in the number of female employees. According to Astin[6], the extent to which students socialize with different racial groups is positively related to both their overall academic achievement and their knowledge gains within a given discipline. Similar benefits may result from an increased participation of women and minorities in science related fields. However, due to the low percentage of women and minorities that are currently in these fields, it is difficult to predict the nature of these benefits.

Wulf [9], the president of the National Academy of Engineering, has speculated that increasing the number of women and minorities in engineering would result in an increase in productivity in the field. He has argued that creativity, which is central to engineering, is influenced by background. Women and minorities bring to the field a background that is different from that of their white male counterparts. If, as has been found in other fields, women and minorities make unique contributions, then their under representation within a given field is detrimental to that field.

Wulf has also raised concerns that U.S. enrollment in engineering has been declining since 1983. Over this same period, the enrollment of minorities in engineering has dropped by three percent. Although the enrollment of women in engineering has remained relatively stable during this period, the enrollment of women in computer science has witnessed a substantial drop[10]. As a

result of the overall decrease in enrollment in science related fields and the economic expansion that has resulted from technological advancements, the U.S. is currently experiencing a shortage of trained scientists and engineers. The government responded by increasing the annual number of temporary, professional-worker visas from 65,000 to 115,000 [11] for a three year period in the American Competitiveness and Workforce Improvement Act of 1998. This number was increased for another three year period, to 195,000 through the American Competitiveness in the Twenty-first Century Act of 2000 [12]. After the year of 2003, it is hoped that the availability of U.S. trained scientists and engineers will increase to the level that is necessary to fill the available positions. The project described in this article is a direct response to the current shortage of U.S. scientists and engineers. One manner in which to increase the overall pool of trained scientists and engineering majors is to increase the participation of underrepresented groups within these fields [9, 10, 13].

Colorado School of Mines (CSM) is dedicated to the belief that women and minorities can make unique and substantial contributions to science related fields. "Science related fields" refers throughout this document to mathematics, computer science, biology, engineering, and the physical sciences (e.g., chemistry, physics). Programs, such as the Women in Science, Engineering and Mathematics program (WISEM) and the Minority Engineering Program (MEP), are dedicated to improving the retention and advancement of women and minorities at CSM. Additionally, the National Science Foundation's (NSF) Division of Undergraduate Education's Computer Science, Engineering, and Mathematics Scholarship (CSEMS) Program has recently awarded CSM a grant (DUE-9987037) that provides qualified women and minority students with scholarships that will assist these individuals as they continue their degrees and participate in mentored research projects.

Applicants to the NSF program at CSM must have a grade point average of 2.5 for undergraduates and 3.0 for graduate students. All undergraduates must be qualified for the U.S. Pell grant. Seven undergraduates and twenty-two graduate students were selected to participate in the NSF Scholarship Program in the fall of 2000. Only one of the selected students was a minority and this student was an undergraduate Hispanic male. All students received a scholarship in the amount of $2500 for the academic year 2000/2001. In this article, we will describe the purpose, the design and the results of the first semester of the NSF sponsored project, *Science Related Degrees: Improving the Retention of Women and Minorities through Research Experience, Mentoring and Financial Assistance.*

II. Project Plan

CSM is the second oldest and one of the largest colleges of mineral engineering and applied science in the country. Both CSM's undergraduate and graduate programs are well known for the high quality of education that is provided to students. In the fall of 2000, there were 177 faculty members of which 29 were female (16%) and 24 were minorities (14%). The total enrollment in the fall of 2000 was 3,278 of which 827 were female (25%) and 389 were minorities (12%). CSM has in place institutional support structures that are designed to improve the retention and advancement of female and minority students. The current project seeks to build upon these structures and add a research component to the educational experiences of a selected group of

undergraduate and graduate female and minority students. This section describes the support structures that are already in place and the research activities that have been added as part of the current project.

A. Female Institutional Support Systems

In 1998, CSM celebrated the hundred year anniversary of its first female graduate, Florence Caldwell. High quality programs, such as the Women in Science, Engineering and Mathematics program (WISEM), continue today with the purpose of enhancing the opportunities available to women in science and engineering careers[14].

The programs offered through WISEM include such activities as the Graduate Women's Forum, the Female Faculty Meetings, and the Chevron Lecture Series. The Graduate Women's Forum meets throughout the year with the purpose of providing female graduate students the opportunity to discuss research and other issues relevant to graduate student life. The Female Faculty Meetings serve a similar purpose with a focus on faculty members rather than on graduate students. Both the Graduate Women's forum and the Female Faculty meetings help CSM women to identify themselves as members of a community of female scholars rather than as minorities in their discipline. The Chevron Lecture series [15] is designed to expose males, as well as females, to the perspective of industry leaders who are female.

WISEM also coordinates activities with the CSM Society of Women Engineers (SWE). The CSM chapter of SWE is the eighth largest chapter in the nation and is the largest professional organization on campus. Forty percent of undergraduate women are members. In 1999, SWE received the regional award for Excellence of the Overall Program. In 1993 and 1998, SWE was selected as the Best Student Section in the Region.

As a result of these efforts, female enrollment at CSM has seen a gradual increase[16]. For example in 1994, 731 out of 3,146 (23%) enrolled students were female. Currently, 827 out of 3,278 (25%) enrolled students are female. Additionally, the persistency rate for women into their second year is 93% as compared to an 84% for the broader population of students.

B. Minority Institutional Support Systems

CSM also boasts an impressive array of programs designed to improve the retention and advancement of minority students. Each of these programs is offered through the Minority Engineering Program[17]. Examples of these programs include the Freshman Retreat, Professional Development Weekend, the Exam Simulation Program and the Academic Tracking program.

The Freshman Retreat introduces new minority students to the campus through a series of competitions. The Professional Development Weekend focuses on career-related activities such as researching companies, writing cover letters and resumes, networking and interviewing. The Exam Simulation Program and the Academic Tracking program are each designed to improve the academic performance of minority students.

The impact of these programs as well as the many other programs offered through MEP has resulted in a gradual increase in the retention of minority students at CSM [16]. For example, of the minority students who entered as freshman in the fall of 1992 only 44% of them continued to CSM four years later. Of the minority students who entered as freshman in the fall of 1996, 64% continued to attend CSM four years later. In other words, the persistence rates of minorities students at CSM is improving.

The director of MEP, Ms. Judi Diaz-Bonacquisti, also acts as a co-advisor to the following minority student organizations: American Indian Society of Engineers and Scientists (AISES), Asian Student Association (ASA), National Society of Black Engineers (NSBE), and The Society of Hispanic Professional Engineers (SHPE). MEP provides these chapters with administrative, financial and organizational support. The MEP staff meets with the officers of each of these organizations at the beginning of the year to provide guidance in the development of the organizations' goals and plans to reach those goals.

C. Mentored Research Experience

The current project expands the opportunities that are already available to female and minority students to include research experience. Each scholarship recipient spends five hours a week working with a research advisor on a project within his or her field of study. When possible, undergraduate and graduate scholarship recipients have been paired together with an advisor as a research team. The original intention of this program was to have all undergraduate scholarship recipients working with graduate scholarship recipients. This was not possible due to the diversity of fields and research interests that were represented across the undergraduate and graduate scholarship recipients. However, the majority of our undergraduate students have had the opportunity to work with graduate students. Although these graduate students are not necessarily part of the program, their interaction with the undergraduates is still of great value. Since many of the undergraduate students participating in this project are the first generation of their family to attend college, these students may view the undergraduate degree as an end in itself. By exposing these students to graduate school and research, some of these undergraduates may consider continuing their education. Prior research[18] suggests that students who participate in research projects as undergraduates are more likely to pursue graduate degrees.

CSM has a number of faculty who have volunteered to act as research advisors for the NSF Scholarship Program. In the fall of 2000, there were 29 proposed research projects and 23 volunteer faculty advisors. Twenty-four of these projects had scholarship recipients assigned to them. These projects were drawn from a variety of different fields (e.g., Computer Science, Chemical Engineering, Chemistry and Geochemistry, Electrical Engineering, Geological Engineering, Environmental Science, Mathematics). In order to illustrate the high quality research experiences provided to the NSF Scholarship Recipients, abstracts of some of the projects are provided below.

Chemistry and Chemical Engineering- Advised by Dr. Kim W. Williams

This project uses analytical chemistry and chemical engineering principles to design better water filtration membranes. Humic substances comprise a large group of organic compounds

that are the products of the decomposition of plant and animal debris. As a result of being present in all aquatic and terrestrial systems, humic materials pose a wide variety of problems. The impact humics have on membrane performance becomes an important factor in municipal and commercial water treatment plants and systems.

The purpose of this project is to correlate fouling resistance with chemical, physical and flux properties of different membranes. By using the field-flow fractionation, an analytical separation method, in an innovative manner the following can be accomplished:

1) *measurement of sample loss and thus, membrane fouling,*
2) *examination of the effectiveness of various procedures to clean and regenerate membranes.*

The results of this project will greatly benefit the municipal and commercial water treatment plants. Optimum operating conditions will be determined for each membrane type tested. The proposed studies will produce guidelines for the design of new and improved membranes with specific chemical and physical properties.

Environmental Science and Engineering - Advised by Dr. Junko Munakata-Marr

The research topic being explored is an innovative technology for biomediation of organic solvents in groundwater aquifers. Harnessing the activities of microbes to degrade contaminants in the environment has become a very successful technology for in situ site remediation. Combining the fields of microbiology and hydrogeology, this project explores the potential success of injecting specific microbes into the subsurface via hydraulic fracturing.

Hydraulic fracturing, historically used to enhance oil recovery, has recently been to used in environmental applications as a delivery mechanism for remedial agents. Thin "pancake"-like fractures (about 1/4 inch in width) are created in the subsurface and filled with a proppant (coarse sand or porous ceramics). By inoculating this proppant with contaminant degrading microbes, zones of enhanced biodegradation can be created. While this technology has been used in a limited number of test sites, these systems are not well characterized and many questions remain unanswered. Of specific interest are the questions:

1) *In what types of systems is this technology applicable?*
2) *Can the microbes survive emplacement conditions?*
3) *Will the microbes adhere to the proppant (i.e., avoid washout)? How can we improve their adherence?*
4) *Can we achieve hydraulic capture, directing flow of contaminants into the fractures?*

Geological Engineering -Advised by Dr. John E. McCray

The goal of this research is to quantify watershed-scale cumulative effects of decentralized wastewater systems using an existing or modified mathematical model. This project will develop and test a methodology for assessing the water quality impacts of decentralized wastewater systems, including individual and cumulative effects, on local watershed supply wells and

downstream receiving waters. The project will include field and laboratory work, modeling, and stakeholder involvement. Field and laboratory work will enhance the understanding of the transport/fate of chemicals in soil-based wastewater treatments systems and enable site-scale model development. The site-scale source/transport/fate expression will be incorporated into an existing watershed model. The model will also be used as a decision support system to engage stake holders in the development of Total Daily Maximum Loads (TMDLs) for onsite wastewater system discharges. The methodology will be developed and tested in a mountain river watershed in Colorado.

III. Evaluation

Evaluation is a central component of this project. The evaluation activities are designed both to support the continual improvement of project activities and to examine our success in improving the retention and advancement of female and minority students at CSM. Toward these goals, the following assessment activities are being completed.

Regular meetings are being held between the project staff and research advisors. Research advisors are encouraged to share any difficulties that emerge as a result of project activities. Additionally, beginning in the spring of 2001, scholarship recipients will be invited to participate in focus group activities. Prior research suggests the effectiveness of this approach for program improvement with the current student population [19]. At the end of each term, the scholarship recipients and their faculty advisors are asked to complete questionnaires. These questionnaires have been designed to evaluate the quality of their research experience. At the end of the year, the scholarship recipients write a report based on their research activities.

In order to examine the impact of project activities on the retention rate of scholarship recipients, a comparison will be made at the end of this project between the retention of project participants and the retention of the general population of CSM. We are also hoping that project participation will provide the students with the necessary skills to acquire immediate employment at the conclusion of their degrees. A comparison will be made at the graduate and undergraduate level between the placement statistics for project participants and the general population of CSM. Undergraduate students may select upon graduation to attend graduate school rather than acquire a job. A comparison will be made between the proportion of scholarship recipients that attend graduate school and the general population. Since there are confounding variables inherent in each of the above comparisons, additional comparisons will be made between scholarship recipients and a set of students who are matched by gender, ethnicity and academic standing.

IV. Results of Student Questionnaires

The fall of 2000 was the first semester of the NSF Scholarship Program. With the exception of on-going meetings, the only assessment instrument that has been implemented to date is the Student Questionnaire. At the end of the fall semester, all scholarship recipients were asked to complete a survey that was designed to evaluate their experiences in the program. This survey is shown in Figure 1.

End of Semester Survey

The following questions are designed to evaluate the impact that the NSF Scholarship program has had on your educational and professional experiences. Please be as complete in your responses as possible. If you need to attach additional paper, please feel free to do so. Although your research advisor will be provided with a summary of the information that is collected here, this information will be provided in a summary form. In other words, the faculty advisors will not know which student provided a given comment.

1. How has participating in the NSF Scholarship Program contributed to your educational experience at CSM?
2. How has participating in the NSF Scholarship Program influenced your future goals within your area of study?
3. As part of the NSF Scholarship program, have you had the opportunity to meet and work with graduate/undergraduate students in your area of research? _____ If yes, has this influenced your future educational or professional goals? Explain.
4. What have you learned as a participant in the NSF Scholarship Program?
5. What recommendations would you make to improve the NSF Scholarship Program for future Scholarship recipients?
6. Have you published any conference papers or journal papers while participating in the NSF Scholarship program? If yes, please provide the complete reference for each paper.
7. Have you received any academic or professional awards during the time that you have participated in the NSF Scholarship program? If yes, please list these awards.

Figure 1. End of Semester Surveys

The only difference between the undergraduate and graduate survey was that in question three, undergraduate students were asked whether they had the opportunity to work with graduate students whereas graduate students were asked whether they had the opportunity to work with undergraduate students. The remainder of this section discusses the students' responses to the survey questions.

Question 1: All of the undergraduate students indicated that the opportunity to complete research had enhanced their learning experiences. Five of the seven students further indicated that their efforts on the research project provided them with "real" applications of the concepts that they had been studying through their course work. One undergraduate student explained, "I have learned information in my research that has helped me out in my classes. Learning about depositions and how changing different variables effect the thickness and deposition uniformity, has helped me to better understand fluids, physical chemistry, and thermodynamics". Another student wrote, "The research that I have completed as part of the NSF Program 'gave meaning' to much of my course work. Previously, I had failed to see the relevance of Organic Chemistry to my future area of work. However, as I did my research there were several instances where the knowledge of the subject would have been useful. I then had new motivation with which to apply myself in this course. The same is true for other courses."

Although several graduate students (i.e., five out of 22) also identified the opportunity to participate in research as a positive contributor their educational experience, graduate students additionally indicated the following benefits (parenthesis indicate the number of students that identified the given benefit):

- Provided me with needed financial support (7),
- Provided necessary motivation to work hard towards my degree (3), and

- Provided me with a research mentor (2).

The most common of the above-mentioned benefits was financial support. One graduate student wrote, "If I had not received this scholarship, I would not have been able to afford my expenses without working a lot more. If I had to work more, I'm sure my studies would have suffered" and another graduate student wrote, "The scholarship has allowed me to focus on my studies and research (don't have to worry about holding a job to help fund school)." In other words, a common concern of the graduate students was how they would afford to continue their education. The scholarship helped to reduce this concern.

Another benefit that is worth discussing is that participation in the research projects provided the students with a mentor. Two graduate students directly identified this as a benefit of the program. Three others graduate students indicated the value of their research advisors through their responses to other questions. One graduate student explained, "…the guidance and support of my faculty advisor has been tremendous. He has acted as a mentor in all aspects of my experience here at CSM, not only in my research."

Question 2: Three undergraduates indicated that the program had stimulated their interest in pursuing a graduate education, e.g., "This program has confirmed that I belong in my chosen field and that I want to continue to pursue mathematics for my graduate work". Two other undergraduate students indicated that participation in the program had stimulated their interest in pursuing careers that contained a research component. Only one undergraduate student indicated that, thus far, her goals had not been influenced by participating in the scholarship program.

Four graduate students indicated that their goals had not been influenced by participation in the program. The remaining graduate students indicated a broad range of different manners in which the program had influenced their goals. These included (parenthesis indicate the number of students to identify the given influence):

- Provided necessary support to continue toward the completion of my degree (5),
- Provided me with reassurance that pursuing a graduate degree is a correct decision (4), and
- Changed the direction of my research (3).

Question 3: Five of the seven undergraduate students have had the opportunity to work with graduate students during their research experience. All five of these students reported that this had been a positive experience and that the graduate student had provided support to them in understanding key research concepts. Three of the undergraduate students further indicated that their interaction with the graduate students had stimulated their interest in pursuing a graduate degree. This is illustrated through the following comments, "It has increased my desire to come back to school to do graduate studies" and "I have also been able to see the many activities they [graduate students] are involved and the excitement they have shown as they each passed major mile-stones in their academic career. (Three of them defended their proposals this semester.) This type of excitement has been extremely encouraging and strongly influenced my desire to continue at the University" [brackets added by authors].

Six graduate students indicated that they had the opportunity to work with an undergraduate student researcher as part of their project. These students indicated that their interactions with undergraduate students had been positive and that these interactions had reinforced the importance of assisting those with less experience, e.g., "It [working with undergraduate researchers] has emphasized the importance of sharing knowledge and experience with those who are less experienced" [brackets added by authors].

Question 4: The vast majority of scholarship recipients, undergraduate and graduate, indicated that they had learned concepts and research skills that were important to their area of study. These skills covered a broad range of areas and included:

- Critical thinking,
- Quantitative research techniques,
- Documentation skills,
- Research methodology,
- New and current areas of research,
- How to examine the validity of research claims, and
- How to utilize tools appropriate to my area of study.

Question 5: The scholarship recipients made a number of recommendations for improving the program. Two undergraduate students suggested that a broader range of projects be made available from which they may select. We are seeking to increase the pool of available projects by broadly advertising the existence of the program to CSM faculty. Although the majority of graduate students did not make recommendations, five graduate students did request the opportunity to meet and share research ideas with the other scholarship recipients. Currently, we are in the process of planning a student research exchange meeting for the up-coming semester. Two graduate students also suggested that the amount of funding be increased; funds are not presently available to make this a reality.

Question 6: Three graduate students reported that they had published journal or conference papers during their participation in the Scholarship Program. Two student had published two papers. Although none of the undergraduate student reported that they had published a paper, four indicated that they intended to seek publication in the up-coming spring.

Question 7: One graduate student has received the Achievement Rewards for College Students.

V. Concluding Remarks

Through WISEM and MEP the infrastructure that is necessary to support some of the social and academic needs of female and minority students is already in place. The current project builds upon this foundation and provides financial support and research experience. The research component is designed to excite the scholarship recipients' interest in science and engineering. After only one semester, we already have evidence to suggest that the project is reaching its goals.

Many of the undergraduate students have expressed an interest in pursuing graduate degrees. These undergraduates directly attribute their graduate school interest to project participation. The graduate students, on the other hand, have indicated that participation in the program has provided them with reassurance that they belong in graduate school. Additionally, the program has provided both undergraduate and graduate students with the necessary financial support to continue their degrees.

The questions that comprised the survey were "open-ended" in that the students were free to respond however they chose. Given that the students were not provided with response prompts, it is surprising that there were so many commonalties across responses. The existence of these commonalties provides strong evidence that participating in the project has consistent benefits to the scholarship recipients. These benefits include:

- Increased academic motivation,
- An increased ability to meet financial obligations,
- Increased understanding of research in their field,
- Increased knowledge of their field, and
- An understanding of how courses work applies to research.

To date, the program has had limited participation by minority students (i.e., one male minority student). We, the directors of the NSF Scholarship program at CSM, are currently working with Ms. Judi Diaz-Bonacquisti, the Director of MEP, to increase minority students' awareness and interest in this program. Ms. Diaz-Bonacquisti was actively involved in the recruitment process for the spring of 2001. All three of the new undergraduate scholarship recipients in the spring of 2001 were minority students. Two of these students are Hispanic males and one is an African-American female.

We are very proud of the accomplishments of our NSF Scholarship Recipients — only one semester into the program. As was mentioned earlier, several of our graduate students have published papers and one student has received an academic award. Many of our undergraduate students are in the process of preparing conference papers. We anticipate even greater accomplishments in the near future. We invite each of you to follow our students' efforts and achievements by visiting our expanding web site [20].

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