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CUR Focus

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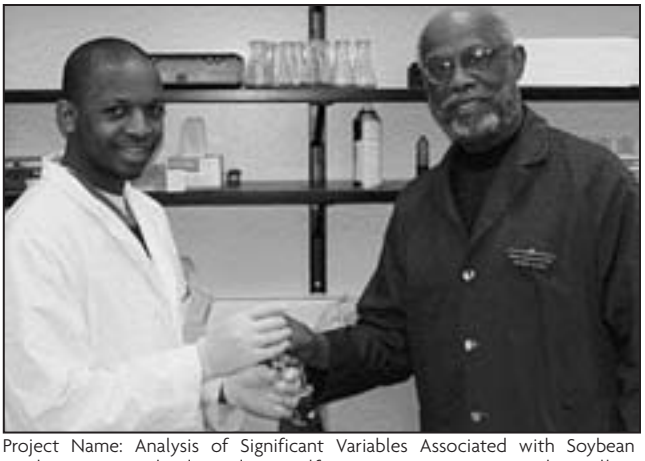
Developing A Complete Research Cycle (CRC) In Science, Technology, Engineering, And Mathematics (STEM)

Rationale And Review Of Literature

Professional literature consistently reflects student interest as a key influence affecting the choice of science, technology, engineering, and mathematics (STEM) disciplines as a major field of study among underrepresented groups. Morgan, Isaac, and Sansone (2001) report that student awareness of attractive career alternatives and the availability of opportunities was a critical influence on choice of major. Other authors report that large numbers of students who leave STEM fields of study do so because they found other fields more interesting (Civian & Schley, 1996), or have determined that continued study in the STEM disciplines will have very little meaning or value for their current or future lives (Strutchens, 1995). Additionally, many institutions experience the phenomenon whereby minority students are entering into scientific and technical disciplines at the same rate as others, but, in general, are matriculating much more slowly and are less involved in extra or co-curricula activities.

As a means of addressing these concerns, colleges and universities are implementing structured undergraduate research programs to enhance student involvement. Katkin states in The Boyer Commission Report and its Impact on Undergraduate Research that a substantial number of universities have begun to realize that undergraduate research is a real asset, thus, they are identifying more resources and expanding opportunities to involve more students (Katkin, 2003). Undergraduate research projects, cooperative education, and internships provide students with opportunities to think like a scientist or engineer (Bradburn, 2001). Student research projects also provide opportunities to increase the interdisciplinary nature of coursework and encourage student participation in solving real life problems (Freeman, 1980). More interestingly, community and collaboration applied to undergraduate programs enhance appreciation, use, and interest in science, mathematics and technology among underrepresented minorities, including women (Johnson & Parrott, 1992). Collaborative workshop experiences for minority students help set higher goals, teach them to work both independently and in groups, and prepare them for the kind of work conditions that are frequently encountered in research laboratories and high-technology think-tanks (Culler et al., 1986). In addition to improved participation and student performance, instructional approaches that emphasize



Project Name: Analysis of Significant Variables Associated with Soybean Production. Maryland Student: Salfu Kanu; Mentor: Dr. Arthur Allen, Department of Agriculture

community and collaboration create an environment that helps alleviate the feelings of isolation and lack of support for underrepresented students in university settings (Alexander et al., 1997). Unfortunately, a large number of collegiate settings are experiencing financial conditions that warrant the streamlining of resources and look to external sources to implement or continue co-curricula research experiences.

The University of Maryland Eastern Shore (UMES), a Historically Black College and University (HBCU), is a campus of approximately 3,500 students (950 in STEM disciplines) and has implemented undergraduate research programs through grants from the U.S. Department of Education and the National Science Foundation (NSF). The programs give junior and senior students an opportunity to work with faculty members on projects that not only utilize knowledge and techniques learned through traditional coursework, but also expose students to current trends and practices in their disciplines. The programs serve as the basis of a Complete Research Cycle (CRC) that emphasizes development and maintenance of research interest, inquiry-based activities, formulation of proposed activities to attract support, sustained periods of investigation, and presentation of results. The primary objective of the Complete Research Cycle is to provide STEM students, along with their faculty mentors, a complete exposure to the common aspects associated with sponsored research. Too often, undergraduate research projects are conducted during summers or

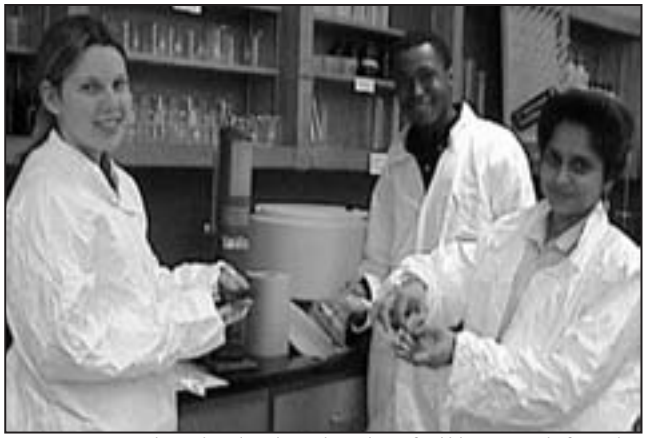
other shortened periods, or concluded without determining possible extensions or formally presenting results in scholarly venues including professional meetings, conferences, and journals. This practice fails to maximize the student's opportunity to attract internal or external resources to continue research efforts, enter graduate programs or gain employment in STEM careers. The CRC is consistent with the preparation, presentation, and publication sequence identified as essential by Nnadozie et al. as early as 1983 (Nnadozie et al., 1983).

CRC Description and Funding

The Department of Education sponsors the Minority Science and Engineering Improvement Program (MSEIP) in the form of grants to minority serving institutions as a means of increasing the number of underrepresented minorities, especially women, in careers related to the sciences and engineering. These types of grants, though modest, are generally available in large numbers and award up to $300,000 over three years. A detailed description of this program can be viewed at http://www.ed.gov/programs/iduesmsi/index.html. Specifically, UMES obtained a three-year institutional grant in the amount of $243,000 from the U.S. Department of Education (2001-2004) to support the UMES MSEIP Program. The UMES MSEIP Program had two major objectives. The main objective of the program was to create an undergraduate research infrastructure that introduced students to co-curricula activities that enhanced their mastery of scientific content while creating awareness and stimulating interest in STEM graduate education and career opportunities. The second objective was to develop strategies for a complete review of the STEM curricula and support revisions that ensured relevance of components, collaborative/cooperative structures, and the infusion of technology in instruction. Under the UMES MSEIP program, the major activities of the CRC component helped students in: (1) developing research interest in STEM disciplines; (2) identifying and responding to research grants and other support resources; (3) developing procedures and timelines to ensure productive research periods; (4) preparing results for presentations at scientific meetings, competitions, and seminars; and (5) simulating the peer-review process associated with disseminating results of research in scientific publications. At the conclusion of the three-year UMES MSEIP, the CRC program was reinstated through the UMES Advanced Curriculum and Technology-Based Instructional Opportunities Network Program (ACTION), funded by a 5-year/$2,500,000 (2004-2009) grant from the National Science Foundation, under its Historically Black Colleges and Universities Undergraduate Program (http://www.ehr.nsf.gov/hrd/hbcu.asp). This program provides support for enhancement of the instructional infrastructure at historically black institutions as a means of increasing the retention of underrepresented minorities in science, technology, engineering and mathematics disciplines.

To maximize MSEIP resources, the CRC program targeted junior and senior STEM majors or underclassmen that faculty identified as having appropriate coursework and skills necessary to perform intense research. As more funds and resources became available through the UMES ACTION Program, inquiry-based activities were developed and implemented to include more freshmen and sophomore STEM students. The list below gives a more detailed description of the implementation of the major components of the CRC.

a. *Grant Proposal Preparation.* To simulate the sponsored research environment, the project directors developed and released, through the campus information systems network, a request for proposals (RFP) to faculty/student (generally junior and senior students) teams in STEM departments seeking financial resources to conduct research projects. The RFP outlined the objectives of the program and made available awards in the range of $6,000-10,000 per project (average award was $3,500/faculty, $2,500/student, and $3,000 for supplies and travel allowance). The RFP was released during early February with a thirty-day deadline for proposal submission. Because students, typically unfamiliar with the research process, may demonstrate reluctance or inability to respond appropriately to these types of opportunities, faculty were encouraged to identify and solicit potential student participants, delineate research activities, and identify necessary materials and facilities. Proposal preparation was deemed an essential learning opportunity, therefore, the proposal format was designed to require extensive student involvement in its preparation. It was expected that after receiving comments from the internal review board, the faculty/student team would have an opportunity to revise and resubmit the proposal if necessary. Junior level faculty received guidance and support on proposal preparation functions including appropriate roles for students, budgeting, timelines, and management. An internal proposal review board was formed to evaluate each proposal in terms of precision, potential for successful completion of proposed



Project Name: Ecological and Biological Studies of Edible Seaweeds from the Chincoteague Bay. Students: Varney Clarke, Gabe Ladd; Mentor: Dr. Madhumi Mitri, Department Of Natural Sciences

activities, scientific merit and impact, and potential for extension. The review activities were directed toward providing students with evaluation and feedback rather than ranking proposals.

b. *Creating a Research Environment.* Approved proposals received funding to support stipends to both faculty and students, as well as supply and equipment needs, travel to regional and national competitions and conferences, and publication costs. Typically, most research experiences for undergraduates are conducted during the summer. However, through this program, the faculty/student collaborations could be extended through the academic year as a means of fostering enhanced research experiences. During this period, students were encouraged to submerge themselves completely in the project, develop time-lines and milestones, and contingencies. Faculty assumed responsibility for reporting and management along with other advisement duties. Faculty exercised wide latitude, and the level of their involvement was determined by the scope and complexity of research projects and the ability of the student participants. Some faculty served solely in an advisory capacity to students working independently while other faculty were more directly involved in the research activities.

c. *Articulating Results.* Since spring semester classes at UMES do not commence until the last week of January, student researchers had an opportunity, during the winter break, to attend national or regional conferences to learn about current trends in their discipline and other aspects of scholarly meetings. Additionally, the MSEIP Program hosted a two-day research exposition and retreat during the second week of January in years 2003 and 2004. This activity exposed students to many aspects of conference participation including, but not limited to travel agenda planning and authorizations, PowerPoint presentation preparations, plenary session attendance, and question/answer sessions. Such sessions were devoted to curriculum revision, graduate school opportunities, faculty development, recruiting practices, and preparing proposals for external funding. However, the highlight of the program was students' presentations detailing the results of the supported projects. Such an occurrence has been noted by Chapman who suggests that student showcase provides a public forum that reflects the quality of the research experience for students and faculty alike (Chapman, 2003). Hence, the presentations were video-taped and formatted to digital video files to be shared on the World Wide Web (WWW) or stored on a CD-ROM. This served as a forum for peer and mentor response and feedback. Students and advisors utilized these responses for the purpose of further revision and refinement of projects in preparation for publication.

d. *Preparing Results for Publication.* The University of Maryland Eastern Shore Science, Technology, Engineering, and Mathematics (STEM) Research Exposition Proceedings (STEM REP) archives final versions of the student/faculty research projects thereby extending and preserving the quality of faculty and student achievement. Papers were submitted to the editorial/review board consisting of nationally-recognized experts in STEM disciplines, thus, providing students with opportunities to experience the traditional peer-review process that generally precedes scholarly publication. Again, the emphasis of the peer-review process is toward support of student success rather than rejection, and some writers required several iterations of the review, revise, and resubmit process. This document is in press and will capture all accepted manuscripts over the three-year funded project period. Students and faculty are strongly encouraged to expand this activity by submitting their abstracts and manuscripts to nationally-recognized research journals for publication.

Implementation and Results

To aid in the implementation of the CRC component, a departmental coordinator was identified in each of the STEM Departments (Natural Sciences, Mathematics and Computer Sciences, Engineering and Technology, and Agriculture) to assist with promoting the program in faculty meetings, identifying potential students, and pre-screening research proposals to ensure minimum guidelines were met. The coordinators, also participating as research mentors, alerted the project directors of possible difficulties or obstacles that may prevent their students from completing all of the required tasks and helped determine solutions. The success of the CRC component is largely due to the participation of the STEM Departments in the implementation phase and their efforts to disseminate and encourage their student majors.

Over the three-year period, the UMES MSEIP Program supported 18 undergraduate projects accounting for approximately $157,000 of the total 2001-2004 MSEIP award ($243,000). Table 1 lists the percent distribution of undergraduate research projects by STEM department. Generally, the students have had junior or senior classification.

Table 1. Distribution of Student Projects by Departments, 2001-2004

STEM Department	Distribution (# of projects)
Engineering and Aviation Sciences	16.67% (3)
Mathematics and Computer Science	38.89% (7)
Natural Sciences	22.22% (4)
Technology	22.22% (4)

The ultimate goal of the CRC component is to encourage each student/faculty team to prepare a manuscript for dissemination in peer-reviewed literature in their field. To date, 56% (10 of 18 student participants) of the students supported by this program have successfully submitted manuscripts for publication in the STEM REP journal. Of those students, two (2) have successfully co-authored, with their faculty research mentors, abstracts or manuscripts accepted for publication in national research journals. Two (2) students are in final preparations to submit their manuscript to other journals such as Primus, and Cryptologia, publishers of manuscripts in mathematics, computer science, and cryptology. Others are still involved in the review-revise-resubmit process which, in most cases, will produce an acceptable manuscript. We are working toward 100% of the students producing a manuscript to be published in the STEM REP and ultimately in national science publications.

Further, of the 7 participants who have graduated, 4 of the students have entered graduate programs at University of Maryland Baltimore County, Howard University and Temple University. One (1) student is employed in a scientific laboratory as a research associate here at the University. Other graduates accepted faculty positions in secondary schools or are considering graduate study. We will continue to track the progress of these students as well as the non-seniors who were involved in the program as they progress toward the end of their undergraduate tenure. We are excited about the success of the students in the CRC and look to set baseline data so the effectiveness of the program may become more exposed.

Over 64% of the overall budget allocated for the MSEIP program was expended for faculty/student research (faculty and student stipends, travel resources, equipment and supplies). Approximately 30% of all STEM faculty have directed a faculty/student research project, attended retreats to review curricula components, or helped channel students into CRC activities.

Yet another outstanding result of this Program extends from faculty success in the area of grantsmanship. To date, CRC faculty have secured over $3 million dollars in external funding through the leveraging of resources of the UMES MSEIP Program. Such monies are in the areas of cancer research as funded by the National Cancer Institute (University of Maryland Partnership for Cancer Research and Outreach), faculty development which is funded by the National Institutes of Health (Minority Opportunities for Research Experiences), student development also funded by the National Institutes of Health (Minority Access to Research Careers), and student scholarships funded by the National Science Foundation (Computer Science and Mathematics Scholarships Program).

Future Directions

The CRC component will continue with support from the UMES Advanced Curriculum and Technology-Based Instructional Opportunities Network (ACTION) program funded by the National Science Foundation (NSF). With a ten-fold increase in support, the

ACTION program will also implement additional objectives and strategies that complement the CRC component and enhance the effectiveness of the overall science education infrastructure. These objectives are listed below.

Objective I - Develop expository research opportunities for students completing their first or second year of coursework. Under the MSEIP Program, many members of the faculty choose to attract upperclassmen into the lab to participate in hands-on research activities because they have completed fundamental course work in their respective disciplines and, therefore, are better able to perform tasks in the laboratory. However, there also exists a talent pool among underclassmen who, by asking basic and ordinary questions, can serve to guide the research of the lab into more productive directions. To this end, the ACTION Program focuses on employing students of all classifications in undergraduate research. As a means of fulfilling this objective, up to 20 underclassman are paid a $1,000 stipend during the summer session. Additionally, funds are provided for supplies and travel to regional or national conferences to expose the students to trends in their disciplines. They are required to spend 10-15 hours per week in the laboratory under the direction of a faculty mentor. Students are also required to attend regularly-scheduled scientific seminars on campus.

Objective II - Continue the Complete Research Cycle (CRC) component for faculty/student research activities. Previously, only 18 students were supported to participate in undergraduate research projects. Currently, over $1,200,000 is budgeted to support undergraduate research for upperclassmen. Approximately 100 STEM students will be targeted and supported through the CRC component. Students entering the ACTION Program are made aware of Program expectations which include, but are not limited to publication of research articles in undergraduate as well as nationally recognized research journals. To this end, students and faculty will serve as co-authors on publications resulting from undergraduate research training.

Objective III - Establish internships, summer employment, and other off-campus research related activities. Early exposure to research based activities is expected to increase the computational, critical thinking, and analytical thinking skills necessary to perform productive research during a student's undergraduate tenure. Additionally, these experiences help students learn professional demeanor and etiquette that are necessary when applying for internships, cooperative learning experiences, and other research based opportunities at other institutions, science agencies, and businesses.

Presently, STEM departments have established relationships with local and regional agencies that allow students an opportunity for internships, summer employment, and other research experiences. The National Security Agency, NASA, Lockheed Martin, Essex Corporation, National Institutes of Health, and others have been especially generous in supporting UMES STEM students. Recently, due to the economical climate, agencies are restricting the numbers of students supported through their intern programs. Consequently, deserving students often are without opportunities. The ACTION Program will establish more external relationships and make financial resources available, thereby increasing the likelihood that deserving students will find extramural research experiences and internships.

Other Objectives - The program also has budgeted approximately $650,000 for CRC supportive efforts as STEM curricula revision, enhancement of instructional technologies, and plans for stronger recruitment efforts.

Conclusion

The future of the CRC components of the existing mathematics and science curricula looks promising and the faculty seeks to expand its offerings to more aspiring students. The student participants are enthused about the opportunity to perform in research and laboratory settings. To help UMES attract talented students to its campus, the CRC component aims to promote excellence in the sciences and produce high performing students in the STEM academic and career workplace. Ultimately, this model looks to be institutionalized at UMES and available for other HBCUs or minority serving institutions.

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