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October 19, 2004

Dr. W. Carl Lineberger, Chair
NSF MPS Advisory Committee
Department of Chemistry and Biochemistry
Joint Institute for Laboratory Astrophysics
University of Colorado at Boulder
UCB 440
Boulder, CO 80309-0440

Dear Carl:

Attached is the final report from the EHRAC/MPSAC Joint Subcommittee on Undergraduate Education in the Mathematical and Physical Sciences (JSAC) that we submit for approval by the MPS Advisory Committee (MPSAC) at their upcoming meeting in November. Since much of the background material is contained in the interim report that was submitted last April, you may wish to consider having the interim report included in the AC briefing book for the meeting. I will be present to discuss this final report at the joint session of the EHRAC and the MPSAC on Wednesday, November 3 at 4:30 PM.

Finally, along with the specific recommendations contained in the report, the EHR/MPS JSAC also wishes to express its dismay at the continual decline of the budget for the Division of Undergraduate Education (DUE). The Joint Subcommittee urges the MPSAC to continue to voice their strong support of this unit as one of the foundational pillars of undergraduate education in the mathematical and physical sciences at NSF.

I look forward to seeing you in November.

Sincerely,



Jeanne E. Pemberton
for the EHRAC/MPSAC JSAC

Attachment

cc: M. Aizenman, J. Sunley, H. Blount, M. Turner

Undergraduate Education in the Mathematical & Physical Sciences:
Report of the Joint Subcommittee of the NSF EHRAC and MPSAC

October 2004

Undergraduate education in STEM disciplines is of vital importance to the nation. Within the mathematical and physical sciences, the core disciplines of mathematics, chemistry, and physics play a central role in producing baccalaureate degree recipients who support the graduate enterprise in these and related disciplines, who become K-12 STEM teachers, and who represent the entry-level technical workforce in many industries. The research and education frontiers of these disciplines are changing rapidly with important implications for the nature of modern professional practice, the preparation of new professionals, the creation of pathways that broaden participation, and the education of the U.S. citizenry. Assessing the implications of these changes in the context of undergraduate education in these disciplines is essential to ensure maintenance of a robust and dynamic undergraduate enterprise responsive to the scientific and technological needs of the U.S.

This study was undertaken at the request of the Education and Human Resources (EHR) and Mathematical and Physical Sciences (MPS) Directorates of the National Science Foundation (NSF) in order to assess the current state of the undergraduate education of majors in the mathematical and physical sciences, with a focus on the core disciplines of mathematics, chemistry, and physics, and to provide recommendations to EHR and MPS for activities that they might undertake to improve undergraduate education in these areas. Towards this end, the EHR and MPS Advisory Committees established a Joint Subcommittee on Undergraduate Education in the Mathematical and Physical Sciences and NSF staff charged it with conducting this study. This Subcommittee met three times during the past 18 months, held numerous discussions both among its members and with representatives from the affected communities, and held conversations with NSF senior management from EHR and MPS. Much background material on the current state of undergraduate education in the mathematical and physical sciences can be found in the interim report from this Joint Subcommittee and is not repeated here. Based on instructions from Assistant Director Judith Ramaley of EHR and Assistant Director Michael Turner of MPS, the Joint Subcommittee has cast the **additional** recommendations contained herein as focused, actionable steps that can be implemented immediately for positive impact on undergraduate education in the mathematical and physical sciences. These recommendations are made here without extensive written justification or background.

It is imperative that these recommendations be considered in the context of the current activities of NSF in undergraduate education in the mathematical and physical sciences.

Discussions of the Joint Subcommittee with NSF staff revealed a commitment on the parts of both EHR and MPS to the cooperative spirit that underlies this joint activity of the two Advisory Committees. Indeed, innovative activities and programs have been initiated over the past several years that have been borne of the vision and creative collaboration of senior management and staff throughout all levels of EHR and senior management and staff from several Divisions and the Office of Multidisciplinary Activities within MPS. Thus, the recommendations contained here should be viewed as additions to existing activities and programs designed to improve undergraduate education in the mathematical and physical sciences.

The Joint Subcommittee offers the following recommendations:

Recommendation 1: Although undergraduate research has proven to be a highly effective pedagogical tool, it is not being used sufficiently to broaden participation in the mathematical and physical sciences.¹ Therefore, the Joint Subcommittee recommends that EHR and MPS jointly develop a new program called **Research Experiences for Early Career Undergraduates (REECU)** with funding for both sites and award supplements. This program would use the existing Research Experiences for Undergraduates (REU) program as a model but would be targeted exclusively to freshmen and sophomore students in the mathematical and physical sciences.

Many models are conceivable for the increased use of research at the early undergraduate career stage as a mechanism for broadening participation in the mathematical and physical sciences. The Undergraduate Research Center (URC) and Undergraduate Biology and Mathematics (UBM) programs have recently been implemented at NSF and represent two such models. The Joint Subcommittee recommends that the REECU program be initiated in addition to these existing programs, since all three approaches represent new paradigms for broadening participation in undergraduate research in the mathematical and physical sciences and each has the potential to have a favorable impact on a different segment of the student population.

In addition to the inherent strength of research as a pedagogical tool, its use at the early undergraduate level also has the potential to facilitate development of a greater multidisciplinary perspective on the part of participating undergraduates. Moreover, REECU sites based on multidisciplinary research might provide a foundation on which to base development of true multidisciplinary undergraduate programs in which an early career undergraduate research experience serves as a central element.

¹ Statistics that support this position are available in S. H. Russell, *Evaluation of NSF Support for Undergraduate Research Activities: 2003 NSF-Program Participant Survey* (DRAFT REPORT), SRI International: Menlo Park, CA, 2004.

Recommendation 2: Two-year colleges are playing an increasingly important role in undergraduate education. Although the range of capabilities of two-year colleges and two-year college faculty in research is highly variable, efforts should be made to increase the capacity of these institutions to engage in research through an experimental program that supports **Research Experiences for Early Career Undergraduates at Two-Year Colleges (REECU-TYC)**. The expectation is that these programs would be of smaller scope than their REECU counterparts. Such programs have the potential to produce mid-career undergraduates better equipped and better motivated to pursue four-year degrees in the mathematical and physical sciences and to reinvigorate two-year college faculty in a way that should have long-term positive benefits.

Recommendation 3: A gap in culture exists between the EHR and MPS Directorates that must be bridged to further undergraduate education in the mathematical and physical sciences. Both Directorates fund exceptionally successful programs related to undergraduate education, but these are in somewhat discrete domains. Multiple opportunities exist for more cooperative efforts, but no effective mechanism for identification of the appropriate connections between the two Directorates has been sustained over time. Nonetheless, several recent examples (e.g., NSSE, NUE, URC, Discovery Corps in CHE, QuarkNet and PhysTEC in PHY, and UBM in DMS) from the interaction of the CHE, PHY and DMS Divisions of MPS with multiple units of EHR suggest that EHR and MPS working in cooperation can indeed achieve results that are greater than the sum of the parts. As a mechanism for facilitating greater interaction between the two Directorates, the Joint Subcommittee recommends that a joint **EHR/MPS Undergraduate Education Working Group**, comprised of representatives from DUE, HRD and REC within EHR and representatives from each of the Divisions within MPS along with senior staff from these Directorates as deemed appropriate by the Assistant Directors, convene on a regular basis to discuss existing or potential programs that impact undergraduate education. The Joint Subcommittee anticipates that this Working Group would provide a vibrant and multifarious environment from which concepts for new programs could emerge and within which new program solicitations for any program impacting undergraduate education could be productively and efficiently considered. In short, such a body would provide a core group through which to explore emerging areas of common interest between the Directorates in undergraduate education in the mathematical and physical sciences.

Recommendation 4: Considerable expertise in program assessment and evaluation exists within EHR, particularly in the REC Division. MPS has not yet taken full advantage of this expertise in the development of program guidelines and solicitations for programs impacting education. For all such programs, **MPS should seek the expertise in EHR (e.g., in REC, DUE, and HRD) on program assessment and evaluation during development of program solicitations**. As has been amply demonstrated by several recent examples from the CHE Division (e.g., URC, Discovery Corps), such expertise can greatly enhance new programs with components related to education and may help build capacity for

assessment and evaluation activities within the MPS disciplinary communities with whom MPS interacts.

Areas for Future Joint EHRAC/MPSAC Attention in Undergraduate Education

The EHRAC and MPSAC are encouraged to request regular reports on progress towards implementation of the recommendations made here. Moreover, several important areas of undergraduate education were not adequately addressed by this study as a result of time limitations. These areas are ripe for future exploration in a manner that brings the expertise of the EHR communities and the MPS communities to their consideration. Specifically, these areas include:

- 1. Preparation of K-12 teachers in the mathematical and physical sciences.**
- 2. Transitions of two-year college students to four-year programs in the mathematical and physical sciences.**

Such complex issues, like others in undergraduate education, are more amenable to exploration with the broad expertise available within these two communities than by either community individually. Indeed, success in addressing these issues will require systems-level efforts that are best conceived through such joint consideration. Therefore, the Joint Subcommittee strongly urges the EHRAC and the MPSAC to accept these important challenges in undergraduate education as the basis for future joint activities.

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