MPSAC - EHRAC Joint Working Group

E^2: Expeditions in Education

a white paper – August 2012

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Global competitiveness requires a workforce capable of dealing with the scientific, economic, and social challenges we now face as well as those problems that will arise in the future. In responding to this need, the overall objective of NSF's E^2 initiative is to "*integrate STEM education research and development to improve learning in science and engineering disciplines and capitalize on the scientific assets across NSF to bring engaging new evidence-based practices, content, knowledge, and real-world applications to more learners*."

Under the umbrella of this activity, the EHR and MPS Advisory Committees have established a Joint Working Group to explore opportunities where both communities could, in a collaborative transdisciplinary approach, engage the STEM and Education communities to develop research programs aimed at addressing our society's future STEM needs.

Recommended Strategic Approach

The Joint Working Group recommends a strategic approach whose initial focus leverages NSF's strengths in undergraduate education and research with specific short term (1-3 years) goals, while concurrently developing a broader long-range plan through the enhancement of existing and the establishment of new collaborations between STEM and education researchers.

Initial Focus

The initial stages of E^2 should be focused on the retention of undergraduate STEM majors by transforming their early STEM experience at both four-year and two-year institutions.

If the US is to meet the projected need for one million more STEM graduates in the next decade as expressed in the 2012 PCAST report, the Joint Working Group recommends that an immediate focus should fall on current undergraduate STEM education practices. Identification of this cohort is supported by suggestions that a significant fraction of students intending to major in a STEM discipline leave STEM within the first two years of their undergraduate experience. For instance, a recent NYT article, noted that 40% of students who claim to want to be STEM majors in the fall of their freshman year no longer wish to do so by the end of their first term[1]. A focus on first few years of science education would not only contribute to the retention of STEM majors, but also enhance the understanding and appreciation of the role of

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[1] Studies have found that roughly 40 percent of students planning engineering and science majors end up switching to other subjects or failing to get any degree. That increases to as much as 60 percent when pre-medical students, who typically have the strongest SAT scores and high school science preparation, are included, according to new data from the University of California at Los Angeles. That is twice the combined attrition rate of all other majors. (http://www.nytimes.com/2011/11/06/education/edlife/why-science-majors-change-their-mind-its-just-so-darn-hard.html?_r=1&pagewanted=all)

STEM among non-STEM majors. In this increasingly technological world, such results could help pave the way towards a more science literate society.

Involvement in actual scientific research should be a cornerstone of undergraduate STEM education.

Research is NSF's strength and the place where NSF can have the most impact. Engaging in undergraduate research provides students with a broad set of professional and personal gains and has been shown to increase retention of members of under-represented groups in STEM majors (Lopatto 2010, Laursen et al. 2010). Preparing students for undergraduate research and scaling the number of opportunities for students to experience aspects of research can be leveraged by integrating more research-like experiences into undergraduate teaching laboratories. Undergraduates in their early years can accomplish meaningful scientific research. There is research that indicates information and computing technologies have been effectively used to develop proper scaffolding for discovery-based STEM research courses. Research projects that use existing or produce large quantities of data lend themselves to the kinds of citizen science projects that are suitable for first-year college students.

The PCAST Report: *Engage to Excel* (PCAST, February 2012) specifically recommends "replacing standard laboratory courses with discovery-based research courses." Standard undergraduate laboratory courses typically do not capture, instill, or inspire the creativity involved in actually engaging in the practice of science. In many cases the typical lab experiment entails blindly following instructions and recording data. In the current educational milieu the goal for many students is simply completion of the experiment, not fundamental understanding of the underlying science. While not all aspects of laboratory learning are suitable for inquiry or discovery based learning (e.g. using equipment and following chemical safety procedures), our working group encourages the appropriate integration of more research-like experiences into the undergraduate curriculum. Effective laboratory learning experiences follow the design principles in *America's Lab Report* (2005) and: 1) have clear learning outcomes, 2) are thoughtfully sequenced into the flow of classroom science instruction, 3) integrate the learning of science content with learning about science practices, and 4) incorporate ongoing student reflection and discussion

Enhanced implementation of evidence-based teaching practices will improve undergraduate learning.

STEM education reform will require far more than engaging undergraduates in research. Both the PCAST report and the Discipline-Based Education Research report (DBER, NRC, May 2012) call for the improvement of undergraduate learning by the implementation of evidence-based teaching practices. The DBER report provides a thorough analysis of the research on undergraduate learning in science and engineering. There is now a strong evidence base that student-centered, collaborative instructional strategies are more effective than traditional lectures[2] in enhancing students understanding of concepts, improving their problem solving

[2] Examples of several teaching concepts in physics are given in references 8 and 9.

skills, and supporting their spatial reasoning. Yet widespread implementation of these approaches has not occurred.

Proposals that include approaches that will implement evidence-based teaching practices should be encouraged. This integration of best practices can range from a focus of the broader impacts plan to a much larger-scale collaborative dimension of a proposal clearly linking the PI's research expertise to the curricular implementation. Examples of teaching concepts in physics are given in references 8) and 10)

All E^2 programs should reaffirm NSF's commitment to broadening participation in STEM

Any discussion of increasing retention rates of STEM undergraduates must include retention as it applies to underrepresented minorities (URMs). The Higher Education Research Institute (HERI) at the University of California, Los Angeles, in its report of January 2010 on completion rates for Bachelor's degrees among initial STEM majors indicates that the 4-year completion rate of Latino, Black, and Native American students who started in a STEM field in 2004 was less than 30%. Given the projected demographics of the US, we cannot continue to accept, nor can we afford such a hemorrhaging of potential STEM talent. We must pay increasing attention to the STEM experience of students at our community colleges, where most of the URM population begins their STEM education.

This point was emphasized in the April 2010 MPSAC Working Group report *New Directions for Broadening Participation in MPS*. The section[3] entitled "Strengthening community college to four-year transitions" cites the 2006 Community College Survey of Student Engagement study carried out by the University of Texas at Austin and notes that a key engagement factor includes "Designing engaging instructional efforts that capture students from the moment of the their first interactions with the institution." Within the context of the need for evidenced-based teaching practices in undergraduate STEM education, it becomes clear how essential this is for broadening participation in STEM-related fields.

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[3] In fact, because of the importance of broadening participation and STEM retention, we have included this section of the MPSAC WG report as an Appendix to our report.

Multidisciplinarity

Modern scientific research does not take place in silos.

Transformation of undergraduate STEM education may incorporate strategies that include multidisciplinary/transdisciplinary curricular and pedagogical activities in accord with the OneNSF initiative. Specific incentives need to be incorporated into new E^2 programs and modifications to existing programs that foster multidisciplinary collaboration among and between science researchers and STEM education researchers. As the Expeditions in Education activity is an NSF-wide program, it is a good platform to encourage this multidisciplinary approach to science and STEM education.

Strategies for the Longer Term: Career II

There are experienced disciplinary scientists who can make significant contributions to STEM education.

In addition, NSF may wish to consider the implementation of a program (tentatively labeled CAREER II) at the level of tenured faculty similar to the current Faculty Early Career Development (CAREER) Program for pre-tenure faculty members[4]. CAREER is a Foundation-wide activity that offers the National Science Foundation's most prestigious awards in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research within the context of the mission of their organizations.

CAREER II should be an NSF-wide program supporting tenured faculty through projects that would require collaboration between both education and science/engineering researchers. Tenured faculty have been targeted because they have the job security required to take risks, extensive teaching experience, and research expertise. A component of the CAREER II program should encourage proposals establishing partnerships between faculty at community colleges and four-year institutions with focus on the community college to four-year transition[5,6]. Award

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[4] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503214

[5] The vital contribution of community colleges to undergraduate education must not be ignored. Though community colleges vary in their size and structure, one thing is common; many have a high representation of under-represented minorities (URMs).

[6] In the United States, community colleges, sometimes called junior colleges, technical colleges, or city colleges, are primarily two-year public institutions providing higher education and lower-level tertiary education, granting certificates, diplomas, and associate's degrees. Many also offer continuing and adult education. After graduating from a community college, some students transfer to a four-year liberal arts college or university for two to three years to complete a bachelor's degree. Before the 1970s, community colleges in the United States were more commonly referred to as junior colleges, and that term is still used at some institutions. However, the term "junior college" has evolved to describe private two-year institutions, whereas the term "community college" has evolved to describe publicly funded two-year institutions. The name derives from the fact that community colleges primarily attract and accept students from the local community, and are often supported by local tax revenue. (Wikipedia http://en.wikipedia.org/wiki/Community_college)

amounts would be appropriate to the scope of the project, and would have initial durations of five years. Such awards could serve as a major incentive in bringing the education research and science research communities together to address the problem of developing and sustaining a US STEM workforce.

NSF's long-range E^2 plan should include components devoted to K-12 STEM education research and science literacy.

NSF should continue to study the complex issues surrounding expeditions for K-12 STEM education, as we begin to understand the impacts of E^2 programs on undergraduate STEM education.

Summary of Recommendations

1 All E^2 programs should foster collaboration between disciplinary scientists and STEM education researchers.
2 The initial stages of E^2 (FY12-FY14) should be focused on the retention of undergraduate STEM majors by transforming the early STEM experience at both four-year and two-year institutions.
3 Proposals that include approaches that will implement evidence-based teaching practices should be encouraged
4 NSF should implement a CAREER II program in FY13 as outlined above.
5 CAREER II should encourage proposals that foster "partnerships" between faculty at community colleges and four-year institutions with focus on the community college to four-year transition.
6 As part of the E^2 initiative NSF should expand or enhance the discovery-based research components of the appropriate MPS and EHR programs (e.g. EHR's TUES program, …) while leveraging the Cyberinfrastructure and Large Instrument Facilities (e.g. LIGO, …) for learning with the goal of the developing scaffolding for discovery-based STEM research courses.

References

1. *Science in Solution: the Impact of Undergraduate Research on Student Learning*, D. Lopatto, Research Corporation for Science Advancement, 2010.

2. *Undergraduate Research in the Sciences*, S. Laursen, et al., Jossey-Bass (2010).

3. *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*, Susan R. Singer, Natalie R. Nielsen, and Heidi A. Schweingruber, Editors; Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research; Board on Science Education; Division of Behavioral and Social Sciences and Education; National Research Council, ISBN 978-0-309-25411-3, May 2012.

4. *Report to the President, "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics"***,** President's Council of Advisors on Science and Technology, February 2012.

5. *America's Lab Report*, Susan R. Singer, Margaret L. Hilton, and Heidi A. Schweingruber, Editors, Committee on High School Science Laboratories: Role and Vision, National Research Council, ISBN-10: 0-309-13934-1.

6. *Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching*, P.A. Kirschner, J. Sweller, R. Clark, 2006, *Educational Psychologist*, p. 76.

7. *Resource Letter ALIP-1: Active-Learning Instruction in Physics*, D. E. Meltzer, R. K. Thornton, *Am.J.Phys*., **80**, No. 6, June 2012, p. 479.

8. *Teaching general relativity to undergraduates*, Nelson Christensen and Thomas Moore, *Physics Today*, June 2012, p. 41

9. *Community College Survey of Student Engagement:Austin, TX,* S. H. Russell, 2006. SRI International: Menlo Park, CA.

Strengthening community college to four-year institution transitions

In 1960, the California Master Plan for Higher Education established "a coherent system for postsecondary education" that includes the California Community Colleges (CC), the California State University (CSU) and the University of California (UC) systems. While specifics of the plan have evolved and adherence to it has varied over the years, the comprehensiveness of the plan made it a national model for public higher education. Consequently, the California Higher Education System reflects both the challenges and opportunities community college students present to the STEM enterprise. In terms of total students enrolled, the California Community College system has more than 7.7x the number of under-represented students enrolled than the UC System and a little more than 2.3x the number in the State College System. Only about 60,000 students of any ethnicity (8.4%) transfer from the CC system into either the State College and UC systems. Of these, only about 4,000 of 13,000 CC transfer students enter a UC with the intent of pursuing a degree in a STEM related field. These trends indicate that CC students represent an untapped reservoir of potential STEM students.

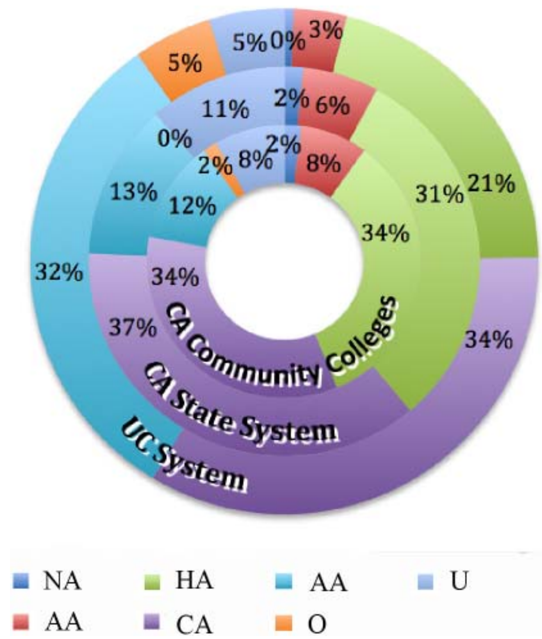

Fig. 1: Student demographics in CA Higher Ed.*

*Non -resident aliens and international students not counted
Undergraduate Student Populations:

CC: 713,100; CSU: 349,845; UC: 168,382

NA: Am. Indian, Pac. Islander, Alaska Native; AA: African American; HA: Latino, Filipino, Hispanic; CA: White: AA: Asian; O: other; U: unknown

A body of literature shows that almost half of the CC students leave higher education before achieving their educational objective (Hoachlander, Sikora, & Horn, 2003) and that CC students need robust opportunities to experience belonging, competency, and autonomy in order to engage and succeed in higher education (Schuetz, 2008). Given the relative low enrollment of underrepresented group students coupled with attrition figures after enrollment, we recommend intervention strategies that provide strong engagement opportunities prior to transfer. As reported by the Community College Survey of Student Engagement study, carried out by the University of Texas Austin (McClenney, K.M. & Marti, C.N, 2006), key engagement factors include: (1) designing engaging instructional efforts that capture students from the moment of their first interactions with the institution; (2) setting goals and providing the support to meet them; (3) setting and communicating high expectations (in high-expectation cultures, students start to believe, some of them for the first time, that they are capable of college-level work); and (4) making engagement inescapable (investing in strong opportunities for student-mentor interaction). The more actively engaged students are – with faculty and staff, with other students, and with the subject matter they study – the more likely they are are to learn and to attain their academic goals. In light of these conclusions, **the ACBPWG recommends the establishment of new REU -like programs specifically targeted to CC students to engage them in research internship programs (short - and long -term) at their intended four -year institution, before transferring**

McClenney, K.M., C.N. Marti, 2006. Community College Survey of Student Engagement : Austin, TX S. H. Russell, 2006. SRI International: Menlo Park, CA.

APPENDIX II -- Membership

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