

## IMPROVING UNDERGRADUATE STEM EDUCATION (IUSE)

### Overview

A diverse and globally engaged U.S. science, technology, engineering and mathematics (STEM) workforce, able to innovate and well prepared for the changing scientific landscape, is crucial to the Nation's health and economy. Yet there is rising concern across the private, government, and academic sectors that the graduates earning STEM degrees will not be adequately prepared with the STEM skills and knowledge to meet growing demands and to lead in emerging STEM areas. Furthermore, the engagement of people from groups that have traditionally been underrepresented in STEM is still alarmingly low in several fields, indicating that the full and diverse talent of the Nation is not being fully utilized to advance the economic and scientific agenda of the country.

The National Science Foundation (NSF) is committed to continued implementation of a coherent, agency-wide investment approach to achieving goals for increasing the numbers, broadening the diversity, and improving the preparation of STEM professionals through undergraduate education. Recent reports of the President's Council of Advisors on Science and Technology (PCAST)<sup>1</sup> and the National Academies<sup>2,3</sup> support the critical importance of this focus. The National Science and Technology Council Committee on Science, Technology, Engineering, and Mathematics Education (CoSTEM) identified undergraduate STEM education as a priority in its 2013 5-Year Federal STEM Education Strategic Plan.<sup>4</sup> NSF's strategy will incorporate key approaches emphasized in these documents, such as the widespread implementation of evidence-based teaching practices, including the integration of discovery-based laboratories, as having strong potential to enhance retention,<sup>5</sup> and the continued building of the knowledge and evidence base to improve STEM education. Reports and analyses in various specific STEM disciplines that identify key problems and areas of need particular to those disciplines will be important resources for NSF's planning.<sup>6,7,8,9,10</sup>

With an aim to rapidly and dramatically improve U.S. undergraduate education, NSF will undertake more extensive coordination of all of its undergraduate STEM education investments within a coordinated framework designed to accelerate improvement and measurable impact in undergraduate STEM education. NSF took an important first step toward this goal in FY 2014 by introducing a preliminary

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<sup>1</sup> President's Council of Advisors on Science and Technology (2012) *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*, [www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final\\_feb.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf)

<sup>2</sup> National Research Council (2011) *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*. Washington, DC: National Academies Press, [www.nap.edu/catalog.php?record\\_id=12984](http://www.nap.edu/catalog.php?record_id=12984)

<sup>3</sup> National Research Council (2012) *Discipline-based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. Washington, DC: National Academies Press, [www.nap.edu/catalog.php?record\\_id=13362](http://www.nap.edu/catalog.php?record_id=13362)

<sup>4</sup> National Science and Technology Council, Committee on STEM Education (2013) *Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-Year Strategic Plan*. [www.whitehouse.gov/sites/default/files/microsites/ostp/stem\\_stratplan\\_2013.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf)

<sup>5</sup> From the PCAST report, *Engage to Excel*: "Retaining more students in STEM majors is the lowest-cost, fastest policy option to providing the STEM professionals that the nation needs for economic and societal well-being. (p. i.)

<sup>6</sup> American Association for the Advancement of Science (2011) *Vision and Change in Undergraduate Biology Education*. [visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf](http://visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf)

<sup>7</sup> National Research Council (2009) *A New Biology for the 21<sup>st</sup> Century*. Washington, DC: National Academies Press. [www.nap.edu/catalog.php?record\\_id=12764](http://www.nap.edu/catalog.php?record_id=12764)

<sup>8</sup> American Society for Engineering Education (2013) *Transforming Undergraduate Education in Engineering*. [www.asee.org/TUEE\\_PhaseI\\_WorkshopReport.pdf](http://www.asee.org/TUEE_PhaseI_WorkshopReport.pdf)

<sup>9</sup> American Chemical Society (2011) *Chemistry Education: Transforming the Human Elements*. [www.aacu.org/pkal/documents/ACS\\_000.pdf](http://www.aacu.org/pkal/documents/ACS_000.pdf)

<sup>10</sup> National Research Council (2013) *The Mathematical Sciences in 2025*. Washington, DC: National Academies Press. [www.nap.edu/catalog.php?record\\_id=15269](http://www.nap.edu/catalog.php?record_id=15269)

framework for IUSE that addresses immediate challenges and opportunities facing undergraduate STEM education, and provides guidance for how NSF’s investments, across education and the disciplinary areas, can potentially have the most strategic impact.

The IUSE framework is built upon a knowledge base accumulated from decades of research, development, and best practice across the Nation in STEM undergraduate education, and it integrates theories and findings from education research with attention to the needs and directions of frontier science and engineering research. IUSE is based on four guiding principles for NSF’s undergraduate portfolio:

- *NSF investments in undergraduate education will be focused, strategic investments centered on addressing the greatest challenges in U.S. undergraduate STEM education.* The greatest obstacle relative to the development of U.S. STEM talent is student retention. The U.S. lags behind much of the world in college degree attainment and production of STEM scientists and engineers as only 40 percent<sup>11</sup> of U.S. students who start in STEM majors complete those majors.
- *The IUSE framework portfolio represents coordination among all directorates.* Creating and maintaining this unified portfolio entails reviewing new programs for alignment with the IUSE framework, increasing NSF-wide planning, and developing common metrics and expectations for outcomes.
- *IUSE has been informed by input from multiple sources, including the STEM disciplines and education research.* Input from experts and leaders in the STEM fields is integral to the ongoing development and refinement of IUSE and will improve the NSF undergraduate investment.
- *Development and future growth of the IUSE portfolio will be based on demonstrated impact and effectiveness of NSF investments.* Evaluation and assessment of NSF’s investments in undergraduate education is essential and will inform decisions aimed at increasing the net funding available for improvement of undergraduate education.

**Total Funding for IUSE**

(Dollars in Millions)		
FY 2013	FY 2014	FY 2015
Actual	Estimate	Request
-	<b>\$88.98</b>	<b>\$118.48</b>

**Goals**

To maximize impact of NSF investment on STEM undergraduate education, a research and development-based planning matrix will be used to build coherence and complementarity in education investments across NSF and to inform strategic planning. IUSE investments will align with the following three goals:

- Improve STEM learning and learning environments;
- Broaden participation in STEM; and
- Build the STEM workforce of tomorrow.

**Approach**

The goals of IUSE will be pursued through three investment strategies, aligned with the *Common Guidelines for Education Research and Development*<sup>12</sup> developed jointly by NSF and the U.S. Department of Education’s Institute of Education Sciences:

<sup>11</sup> President’s Council of Advisors on Science and Technology (2012) *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*, [www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final\\_feb.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf)

<sup>12</sup> Institute of Education Sciences, U.S. Department of Education and the NSF (2013) *Common Guidelines for Education Research and Development*. [www.nsf.gov/pubs/2013/nsf13126/nsf13126.pdf](http://www.nsf.gov/pubs/2013/nsf13126/nsf13126.pdf)

## *Improving Undergraduate STEM Education*

- *Foundational and exploratory research.* These investments focus on core research questions—such as how learners move towards expertise in a discipline, or best learn about concepts that are interdisciplinary – that are foundational for the improvement of teaching, learning, engagement, and retention and for serving as a basis for development, adoption/adaptation, and implementation of models, prototypes, and innovations.
- *Design and development research.* These investments support iterative approaches to design, implementation, analysis, and revision, including prototyping and building and refining models.
- *Impact research.* Effectiveness impact studies focus on leveraging NSF’s investments in foundational, design, and development research. Key goals include the scaling of successful efforts on learning and learning environments, broadening participation, workforce preparation, and employing emerging technologies.

These funding strategies clarify the unique federal role in research and development in undergraduate STEM education and underscore the importance of leveraging these investments.

### **Scope**

IUSE is an NSF-wide investment that incorporates funding from established programs in the EHR directorate and other NSF directorates funded through the Research and Related Activities (R&RA) account. The IUSE Framework will eventually accommodate all NSF investments in undergraduate education and will be aligned with agreed-upon, cross-directorate goals and outcomes. A common system of assessing the impact of the collective investment will be implemented, based on the *Common Guidelines for Education Research and Development*.

NSF will fund a range of project types from foundational research to scale-up and effectiveness studies. Funding will be available for individual investigators and research teams with expertise cutting across one or more STEM disciplines and STEM education research, including discipline-based education research, cognitive science, and the social and behavioral sciences. The intent of IUSE is to build on NSF’s unique strengths across the STEM disciplines and STEM education to focus on sustained improvements towards the goals described above. Such research is inherently interdisciplinary in nature. Aligned with the funding strategy will be the development of robust, common indicators and metrics to gauge progress towards the goals of IUSE.

### **Organizational Structure**

EHR is charged with leading the coordination of the IUSE effort and working with internal and external program evaluation experts to help develop a set of metrics by which program progress can be evaluated over time. An NSF-wide IUSE Implementation Team comprising representatives from all directorates has been assembled to implement IUSE under the guidance of a charge developed by the Assistant Directors (ADs).

In FY 2015 all investments that are included within the framework will use a common name (e.g., “Improving Undergraduate STEM Education”), with a subtitle as appropriate to signify a more specific focus. Investments/program dollars will remain in home directorates, but solicitations and program announcements will incorporate or reference agreed-upon language describing the framework, and how the particular investment or program is situated within it. There is NSF-wide commitment to employing common goals and outcome measures, tailoring investments to address particular disciplinary challenges and understanding the differences, and increasing education investment in new and emerging areas of science.

**Investment Framework**

**IUSE Funding by Directorate**

(Dollars in Millions)

	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request
Biological Sciences	-	2.50	\$2.50
Education and Human Resources	-	74.08	99.08
Engineering	-	6.00	6.00
Geosciences	-	6.40	10.90
<b>Total</b>	-	<b>88.98</b>	<b>\$118.48</b>

Totals may not add due to rounding.

**FY 2014 Request**

The FY 2014 Estimate provides funding for awards in foundational and exploratory research, design and development implementation, and scale-up and effectiveness studies. The size and duration of the awards will be determined by the strength of the evidence behind the proposed intervention/project and resources necessary to achieve the desired outcomes. Proposals submitted to the IUSE Program Description<sup>13</sup> are currently going through the merit review process. Themed “Ideas Lab” efforts are underway through EHR partnerships with the Directorates for Biological Sciences (BIO), Geosciences (GEO), and Engineering (ENG), in an attempt to clarify discipline-specific needs and solution approaches.

This initial IUSE call attracted more than 1,000 proposals from across the disciplines in STEM education, and an additional 500 applications to participate in the themed Ideas Labs.

**FY 2015 and Beyond**

NSF will expand and refine the IUSE framework in a staged process over FY 2015 and FY 2016. In FY 2015, IUSE will provide the basis for coordinating all investments in research and development that are critical for curricular improvement in undergraduate STEM education, within formal and informal learning environments, including those that:

- Use and build evidence about improved STEM instructional practices, with a focus on increased retention and persistence;
- Design and study innovative learning opportunities, including cyberlearning;
- Create, implement, and test program, curricular, course, and technology-driven models;
- Develop, implement, and test creative approaches for adoption of education research into disciplinary teachings;
- Develop and validate assessments/metrics for undergraduate STEM learning and instructional practice; and
- Conduct fundamental research on issues of undergraduate STEM teaching and learning.

In FY 2016, IUSE will explore incorporating portfolio areas that support NSF’s direct investments in students through fellowships and scholarships, and investments in students’ participation in research experiences. All NSF directorates will fully participate in IUSE in FY 2016.

**Evaluation Framework**

The success of IUSE will depend upon the development of realistic and robust metrics and indicators for gauging progress toward the goals outlined above. These metrics and indicators will be tailored to the

<sup>13</sup> [www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=504976](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504976)

three investment strategies. While the specific metrics and indicators will need additional consideration, NSF’s recent experience in this area points to a number of promising approaches.

**Potential Assessment Framework: IUSE Investment**

<b>Investment Strategy</b>	<b>Potential Measure/Indicator</b>	<b>Relationship to Desired Outcome</b>
<b>Foundational and Exploratory Research</b>	<ul style="list-style-type: none"> <li>• Strategic monitoring of approaches and investment mechanisms, beginning with pre-award activities (development of logic models aligned with framework, issuance of announcements/solicitations; community response).</li> <li>• Identification of discipline-specific gaps in the literature and baseline evidence.</li> </ul>	<ul style="list-style-type: none"> <li>• Will enable strategic NSF investment to create knowledge underpinnings in areas of specific need (e.g., research on the teaching and learning of computer science at the undergraduate level), and complementary investment based in EHR or R&amp;RA directorates as appropriate that are aligned within the IUSE Framework.</li> </ul>
<b>Design and Development Research</b>	<ul style="list-style-type: none"> <li>• Evidence of activities that promote design of solutions to issues and discipline-specific STEM challenges and test those solutions under local or ideal conditions (e.g., implementation research).</li> </ul>	<ul style="list-style-type: none"> <li>• Creates a set of tested models and prototypes that allow for strategic investment in efforts at scale, as well as common outcome measures that can be applied across disciplines, as well as customized within disciplines.</li> </ul>
<b>Impact Studies</b>	<ul style="list-style-type: none"> <li>• Partnerships and leveraging activities that take effective design and development efforts to scale and look at impact on particular groups, in particular contexts, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Well-designed and evidence-based approaches are implemented at scale for direct impact on improving retention and broadening participation in undergraduate education.</li> </ul>