

## IMPROVING UNDERGRADUATE STEM EDUCATION (IUSE)

**\$109,000,000**  
**+\$4,000,000 / 3.8%**

### Overview

The National Science Foundation (NSF) Improving Undergraduate STEM Education (IUSE) initiative is a Foundation-wide integrated framework for the agency's investments in undergraduate science, technology, engineering, and mathematics (STEM) education. In order to prepare a diverse and innovative workforce<sup>1</sup> and a STEM-literate public, NSF has a leadership role in accelerating the quality and effectiveness of the education of undergraduates in all STEM fields. NSF investments in undergraduate STEM education are coordinated through the IUSE framework to enhance coherence and impact and to use shared metrics and evaluation approaches where appropriate. NSF investment in undergraduates and their education occurs across all directorates and addresses both general trends such as the use of approaches to promote "active" learning in undergraduate STEM instruction, the increase of undergraduate research courses, and attention to undergraduate degree completion; as well as specific disciplinary needs, such as the need to reform the "middle years" in the undergraduate preparation of professional engineers, the need to recruit more women and minorities into majors in computer science, and the data science preparation of undergraduates in the geosciences and the biological sciences.

IUSE ideas are informing cross-agency implementation of the undergraduate strategic objectives in the National Science and Technology Council's *Federal STEM Education 5-Year Strategic Plan*,<sup>2</sup> an effort co-led by NSF and the Department of Energy. The importance of the undergraduate experience for preparing a diverse STEM and STEM-capable workforce equipped for innovation, and a STEM-literate public ready to support and benefit from the progress of science, is described in a number of key reports and documents.<sup>3,4</sup> NSF, with its mission to advance science, engineering, and education, plans to invest \$109.0 million in FY 2017 through coordinated investments both across and within directorates, aligned with the IUSE framework for improving undergraduate STEM learning.

### Total Funding for IUSE

(Dollars in Millions)

FY 2015	FY 2016	FY 2017
Actual	Estimate	Request
<b>\$102.82</b>	<b>\$105.00</b>	<b>\$109.00</b>

### Goal

NSF investments are catalyzing improvement in undergraduate STEM education to achieve high quality STEM learning for all undergraduates and to build talent to increase degree completion for all STEM majors. NSF undergraduate investments map to one or more of the three IUSE goals:

- **Improve STEM learning and learning environments.** Improve the knowledge base for defining, identifying, and implementing innovative undergraduate instruction in all NSF-supported disciplines in order to improve student learning and foster widespread use of evidence-based resources and pedagogies in undergraduate STEM education.

<sup>1</sup> National Science Board (2015). *Revisiting the STEM Workforce*. Arlington, VA: National Science Board [www.nsf.gov/nsb/publications/2015/nsb201510.pdf](http://www.nsf.gov/nsb/publications/2015/nsb201510.pdf)

<sup>2</sup> [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>3</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>4</sup> Coalition for Reform of Undergraduate STEM Education (2014) *Achieving Systemic Change: A Sourcebook for Advancing and Funding Undergraduate STEM Education*. Washington, DC: Association of American Colleges and Universities.

- **Broaden participation and institutional capacity for STEM learning.** Increase the number and diversity of undergraduates recruited and retained in STEM fields and the number of available career pathways using successful, evidence-based strategies to broaden participation and by growing that evidence base.
- **Build the STEM workforce for tomorrow.** Improve the preparation of undergraduate students so that they can succeed as productive members of the future STEM and STEM-capable workforce, regardless of career path, and be engaged as members of a STEM-literate society.

### Approach

Six principles guided the development of the IUSE framework and continue to inform decision-making about strategic investments to achieve the three IUSE goals. The IUSE principles are listed below:

- Federal investment in undergraduate STEM education is critical to the development of the Nation's scientific workforce and NSF has a leading role in this area.
- NSF investments in undergraduate education will be focused, strategic investments that address the greatest challenges in U.S. undergraduate STEM education.
- The IUSE portfolio represents coordination among all directorates, while respecting distinct disciplinary opportunities, challenges, and needs.
- IUSE is informed by input from multiple sources, including the STEM disciplines and education research.
- Development and future growth of the IUSE portfolio will be based on demonstrated impact and effectiveness of NSF investments.
- The IUSE framework will accommodate all NSF investments in undergraduate education and will be aligned with agreed-upon, corresponding directorate goals.<sup>5</sup>

### Investment Framework

The IUSE framework uses findings from research and evaluation on STEM learning and education, as well as innovative models and approaches that have been developed in specific disciplines, to address challenges common across all undergraduate STEM education, as well as within specific disciplines. NSF IUSE core investments also serve as test beds for continued building of evidence for improvement across all IUSE investments. NSF IUSE-affiliated programs are positioned to connect to and benefit from, as well as inform, the core activities. The framework draws upon a knowledge base accumulated from decades of research, development, and best practices in STEM undergraduate education.<sup>6,7,8,9</sup> New and ongoing investments within the IUSE portfolio will integrate theories and findings from education research with attention to the needs and directions of frontier science and engineering research. New knowledge about learning and implementation of promising models will be valuable in improving the undergraduate preparation of a diverse STEM workforce.

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<sup>5</sup> All undergraduate programs have now been mapped to the framework and placed into two categories: 1) the IUSE core programs that were developed over the FY 2014 – FY 2016 period as part of the agency-wide initiative, and 2) affiliate programs that are aligned with the framework, both informing and being informed by the work across both program categories. All are connected by their commitment to the IUSE principles.

<sup>6</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>7</sup> National Research Council (2015) *Reaching students: What research says about effective instruction in undergraduate science and engineering*. Washington, DC: National Academies Press, [www.nap.edu/download.php?record\\_id=18687](http://www.nap.edu/download.php?record_id=18687)

<sup>8</sup> Bailey, T., S. S. Smith, & D. Jenkins (2015) *Redesigning America's community colleges: A Clearer path to student success*. Cambridge, MA: Harvard University Press

<sup>9</sup> Smith, D. (ed.) (2015) *Vision and change in undergraduate biology education: Chronicling change, inspiring the future*. Washington, DC: AAAS, [http://visionandchange.org/files/2015/07/VISchange2015\\_webFin.pdf](http://visionandchange.org/files/2015/07/VISchange2015_webFin.pdf)

The IUSE framework relies upon the following five investment strategies mapped onto the three goals, providing a tool to analyze and adjust the portfolio of programs in order to maximize the collective impact of the agency-wide effort:

- **Build core knowledge through research and development (R&D):** R&D investments through EHR core research will grow the evidence base about how to best improve undergraduate education through education research, including “discipline based education research.”<sup>10</sup>
- **Implement and scale evidence-based practices and tools:** These investments will allow for the execution of a program or activity, or the building of a discipline-specific, test-case model, based on core research knowledge; such programs and models can serve as sites for implementation research. Examples are IUSE: GEOPATHS and the Advanced Technological Education (ATE) programs.
- **Catalyze departmental and institutional transformation:** This funding supports design and implementation of models for systemic improvement, such as IUSE/Professional Formation of Engineers: REvolutionizing Engineering and Computer Science Departments (IUSE/PFE: RED).
- **Scholarship programs:** This is direct support to STEM students to encourage entry and retention. Examples of these programs are the Robert Noyce Teacher Scholarship (Noyce) and Scholarships in STEM (S-STEM) programs.
- **Disciplinary research experiences for students:** This funding engages students in research and is provided in programs such as Research Experiences for Undergraduates (REU) and International Research Experiences for Students (IRES).

The IUSE program is comprised of core and affiliate programs. These programs are connected by their commitment to the IUSE principles.

- Core programs fund the IUSE investment and are as follows: IUSE: EHR, IUSE: GEOPATHS, Research Coordination Networks: Undergraduate Biology Education (RCN:UBE), IUSE/PFE: RED, and Research in the Formation of Engineers (RFE).
- Affiliate programs are aligned with the IUSE framework, both informing and being informed by the work across both program categories. The affiliate programs are: ATE, Broadening Participating in Engineering (BPE), CyberCorps<sup>®</sup>: Scholarship for Service (SFS), EHR core research (ECR), Historically Black Colleges and Universities Undergraduate Program (HBCU-UP), I-Corps for Learning, IRES, Louis Stokes Alliances for Minority Participation (LSAMP), REU, Noyce, and TCUP.<sup>11</sup>

#### IUSE Funding by Directorate

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	\$1.13	\$2.50	\$2.50
Computer and Information Science and Engineering	2.00	3.00	2.00
Education and Human Resources	83.84	87.00	92.50
Engineering	4.94	6.00	6.00
Geosciences	10.90	6.50	6.00
<b>Total</b>	<b>\$102.82</b>	<b>\$105.00</b>	<b>\$109.00</b>

<sup>10</sup> Op. cit., National Research Council (2012)

<sup>11</sup> ECR, I-Corps for Learning, RFE, BPE, and SFS are not specifically undergraduate programs; only portions of these are undergraduate investment. For LSAMP, Noyce, and S-STEM, the majority of the investment is at the undergraduate level with some support for other topics and students at other education levels.

## **FY 2015 – FY 2016**

- In FY 2015 and FY 2016, IUSE was implemented through four solicitations. IUSE: EHR had two main investment tracks: Engaged Student Learning and Institutional and Community Transformation. IUSE: GEOPATHS focused on broadening participation and workforce development. IUSE/PFE: RED funded systemic change in the second and third years of engineering and computer science majors to enable engineering and computer science departments to lead the Nation by successfully achieving significant sustainable changes necessary to overcome long-standing issues, including attracting and retaining more women and under-represented minorities, in their undergraduate programs. RCN: UBE scales effective practice through research networks.
- Affiliate programs were aligned with the IUSE framework. In FY 2015, the Directorate for Geosciences (GEO) collaborated with EHR/HRD to establish a new track for Partnerships in Geoscience Education (PAGE) within the TCUP solicitation. The research track of the ATE program was expanded to study retention and transfer in community college populations. EHR's S-STEM program solicitation reflects a program change to a guided-pathways program to support college completion for scholarship recipients in FY 2016.
- In FY 2015, Dear Colleague Letters (DCLs) were used across multiple programs to address specific needs, including further engaging Hispanic-serving community colleges (NSF 15-063 and NSF 15-064). Prospective applicants were invited to develop innovative approaches to increase college opportunity through increased mathematics success, resulting in 30 new awards (NSF 15-026). An I-Corps™ for Learning DCL offered training for grantees to support scaling of effective, evidence-based interventions, tools, resources, and models with an emphasis on reaching groups traditionally underrepresented in STEM fields (NSF 15-050). Hispanic Serving Institutions and I-Corps™ Learning DCLs continue in FY 2016, and EHR will issue a DCL to fund supplements for REU Sites from across directorates to pursue education research or assessment projects of interest to site leaders for improvement of their efforts.
- NSF funded a Maker Summit in FY 2015 and issued an Enabling the Future of Making to Catalyze New Approaches in STEM Learning and Innovation DCL (NSF 15-086).
- NSF-funded National Research Council (NRC) analyses build and spread the IUSE knowledge base. The report on *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and Engineering* was released and downloaded by more than 17,000 individuals.<sup>12</sup> A study on undergraduate authentic research experiences, including course-based research was funded by EHR.<sup>13</sup> Two additional studies were funded by EHR, one on indicators of successful undergraduate STEM education, and one study on measuring intrapersonal and interpersonal competencies associated with persistence in college and career satisfaction.<sup>14,15</sup> The Directorate for Computer and Information Science and Engineering (CISE) funded a study<sup>16</sup> to understand the growing enrollments in computer science and engineering, and the implications for computing education at the undergraduate level in the years ahead. GEO funded an NRC workshop to define best practices for using service learning in undergraduate geoscience.<sup>17</sup> The results of all of these efforts will help inform the continuing evolution of NSF's IUSE investments.
- Additional, discipline-specific efforts included the culmination of a decade-long collaboration between The Directorate for Biological Sciences (BIO) and EHR with the release of *Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future*.<sup>18</sup> GEO sponsored a

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<sup>12</sup> National Research Council (2015) *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and Engineering*. Washington, DC: National Academies Press, [www.nap.edu/download.php?record\\_id=18687](http://www.nap.edu/download.php?record_id=18687)

<sup>13</sup> [http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE\\_090473](http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE_090473)

<sup>14</sup> [http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE\\_167108](http://sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE_167108)

<sup>15</sup> [http://sites.nationalacademies.org/DBASSE/BOTA/CurrentProjects/DBASSE\\_160583](http://sites.nationalacademies.org/DBASSE/BOTA/CurrentProjects/DBASSE_160583)

<sup>16</sup> NSF award 1551227

<sup>17</sup> NSF award 1544268

<sup>18</sup> Op. cit., Smith, D. (ed.) (2015)

follow-on workshop<sup>19</sup> to a community summit<sup>20</sup> on the Future of Undergraduate Geoscience Education to identify critical competencies and skills required for the future geoscience workforce.

- Specific IUSE FY 2016 emphases include course-based research, scaling evidence-based practices, and broadening participation, specifically in computer science, engineering, and the geosciences.
- The inaugural Community College Innovation Challenge, including a boot camp for finalists and an event on Capitol Hill,<sup>21</sup> was launched in FY 2015 with a second challenge focused on the cross-Foundation priority Innovations at the Nexus of Food, Energy, and Water Systems issued in FY 2016.<sup>22</sup>

### **FY 2017 Request**

In FY 2017, both core and affiliate programs will work in the following IUSE priority areas:

- Develop the capability for gathering data on indicators as a part of IUSE core program monitoring and evaluation by: 1) developing and identifying indicators, metrics, and assessments to measure readiness for and progress toward widespread use of evidence-based resources in undergraduate STEM instruction; and 2) re-instituting the National Survey of Postsecondary Faculty in partnership with the National Center for Education Statistics (NCES).
- Address discipline-specific learning environment needs: 1) BIO will partner with EHR and other directorates to fund development of new curricula that enable 21<sup>st</sup> century biologists to have the skills to operate in a data-rich world; and 2) CISE will issue a DCL or solicitation focused on developing, prototyping, and implementing new strategies for undergraduate education in computer science, particularly in the face of growing enrollments and interest, and the increasing breath of disciplines from which students are coming to take computer science courses.
- Increase undergraduate research opportunities by: 1) developing research courses and course-based research across the STEM disciplines through the IUSE: EHR solicitation, informed by the NRC study on undergraduate research; and 2) increasing the STEM research and experiential learning opportunities available in NSF-funded large facilities, national laboratories, and centers through the S-STEM program in collaboration with the NSF Graduate Research Internship Program (GRIP).
- SFS funding will begin to lay the groundwork for SFS program scholarship holders to serve as a national resource over the course of their careers.
- Align affiliate programs as appropriate with the IUSE framework: 1) Noyce Teacher Scholarship Program (Noyce) and CyberCorps<sup>®</sup>: Scholarship for Service will consider guided pathways approaches for broadening participation; 2) Louis Stokes Alliances for Minority Participation (LSAMP), Historically Black Colleges and Universities Undergraduate Program (HBCU-UP), TCUP, ATE, and Noyce will align to support the broadening participation goals of the framework; and 3) a “New-to-IUSE” opportunity will be established in IUSE: EHR for investigators from minority-serving community colleges and investigators from two- and four- year institutions with prior funding from HBCU-UP and TCUP programs.
- Focus on broadening participation: 1) EHR will partner with GEO and CISE to support innovative proposals to increase the percentage of underrepresented racial and ethnic minorities completing geoscience bachelor’s degrees in geoscience and women completing bachelor’s degrees in computer science; 2) the IUSE: GEOPATHS program will create a broader and more inclusive pathway into careers in the geosciences via research experiences for undergraduates featuring active involvement in field campaigns and at high-level facilities, such as ships, airplanes, and data centers, with employer input about needed skills; and 3) the Directorate for Engineering’s (ENG) BPE program will continue to support projects that lead to the understanding of issues and challenges that impact the participation from underrepresented groups specifically in engineering. In FY 2017, IUSE will further advance the broadening participation goal by coordinating with the NSF Inclusion across the Nation of

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<sup>19</sup> [www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/](http://www.jsg.utexas.edu/events/future-of-geoscience-undergraduate-education/)

<sup>20</sup> [www.jsg.utexas.edu/events/files/Future\\_Undergrad\\_Geoscience\\_Summit\\_report.pdf](http://www.jsg.utexas.edu/events/files/Future_Undergrad_Geoscience_Summit_report.pdf)

<sup>21</sup> [www.nsf.gov/news/special\\_reports/communitycollege/](http://www.nsf.gov/news/special_reports/communitycollege/)

<sup>22</sup> [www.nsf.gov/news/special\\_reports/communitycollege/](http://www.nsf.gov/news/special_reports/communitycollege/)

Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) effort, particularly the Networks for STEM Excellence, and will incorporate the “collective impact” approach<sup>23</sup> that is underway in higher education efforts related to college access and improvement.

### **FY 2018 – FY 2020**

As NSF accumulates a broader and deeper set of findings and evidence-based practices for improving undergraduate STEM education, we anticipate increased emphasis in later years in several areas. These include increasing access to undergraduate STEM learning and research experiences through technology, citizen science approaches, and apprenticeship and internship models; transition from pre-college to undergraduate STEM education; and transitions from undergraduate STEM education to the workplace and to graduate school. IUSE will continue to coordinate with the NSF INCLUDES.

### **Evaluation Framework**

The success of IUSE is enhanced by 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 address progress towards the three IUSE goals: 1) improve STEM learning and learning environments, 2) broaden participation in and institutional capacity for STEM education, and 3) build the STEM workforce of tomorrow. Mapping the investment goals against the five investment strategies (i.e., build core knowledge through R&D, implement and scale evidence-based practices and tools, catalyze departmental and institutional transformation, provide scholarships, and promote disciplinary research experiences) will identify gaps and support analysis of whether or not NSF should invest in gap areas and/or decrease support in other areas. As the IUSE evaluation is planned, consideration will be given to how the different investment strategies – collectively, in combination, and individually – can be optimized to catalyze improvement in undergraduate STEM education. This approach to evaluation is centered on the IUSE framework and will directly inform and improve the collaborative initiative.

While the specific metrics and indicators will need additional consideration, NSF’s recent experience in this area points to a number of promising approaches. Specific metrics obtained through monitoring and evaluation can be complemented by metrics from the National Science Board *Science and Engineering Indicators*, including the number of STEM graduates in specific disciplines annually compared with the number of first-year students indicating a desire to major in STEM fields. Existing monitoring and evaluation plans propose to provide data regarding the number of two- to four-year articulation agreements for NSF-funded technician training programs and the relative number of first- and second-year students participating in NSF-funded undergraduate research. As new monitoring plans and evaluation frameworks are developed for IUSE core and affiliated programs, the IUSE AD Council will have responsibility for reaching agreement on any cross-cutting or common outcomes and objectives, and will support the development of discipline and program-specific outcomes. The IUSE Coordinating Committee will have a central role in proposing metrics that are appropriate for the IUSE framework. In addition, the REU Working Group will provide input to the Evaluation and Assessment Capability/EHR-based monitoring and evaluation planning in FY 2016. NSF’s efforts to participate in the revision of the National Study of Postsecondary Faculty with the National Center for Education Statistics (via EHR and the National Center for Science and Engineering Statistics) will lead eventually to availability of data on teaching practices, the evolving role of technology in education, and the rapidly changing nature of faculty work which can inform approaches to professional development. Developing and implementing shared metrics across federal agencies will inform IUSE.

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<sup>23</sup> [www.ssireview.org/articles/entry/collective\\_impact](http://www.ssireview.org/articles/entry/collective_impact)