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Preface

Each year, U.S. colleges and universities prepare tens of thousands of talented individuals who wish to pursue careers in engineering. In 2006 alone, over 68,000 students earned a bachelor's degree in engineering; another 33,000, a master's degree; and 7,100, a doctorate.[1] As in other technical professions, great care is taken by the engineering community to assure that degree recipients receive their training at programs accredited by peers.[2] Nonetheless, educators have come to recognize that improvements are needed in engineering education to prepare future graduates for the opportunities and challenges facing the profession in the 21st Century – most notably the emergence of the global marketplace and the attendant demand for well-trained high-technology workers who will assure a continuing, strong U.S. presence.[3]

The cadre of scientists who conduct research in engineering education have responded to this concern over the future of engineering education by turning their attention to needed improvements in the curriculum as well as instructional issues involving such topics as cooperative learning and teamwork, the timing of student exposure to new technologies, and characteristics of student learning strategies and styles – especially given the greater diversity of students now pursuing careers in engineering.[4]

The National Science Foundation (NSF) represents a significant source of support for research in engineering education,[5] and recently renewed its commitment to this area following the release of a report by the National Science Board outlining steps that might be taken to improve engineering education.[6] To assure the efficient investment of public funds in the coming years, the NSF Engineering Education and Centers Division (EEC) of the Directorate for Engineering asked the IDA Science and Technology Policy Institute (STPI) to examine a sample of NSF grants programs in engineering education, while also developing a master plan for longer term support for research in engineering education. STPI launched a six-month study in April 2008 to provide the NSF's Engineering Education program with a systematic review of the outcomes and impacts of active grants in three engineering education program areas:

Subtask 1: How People Learn Engineering (HPLE)

[1] National Science Foundation, Science and Engineering Degrees: 1966 – 2006 Detailed Statistical Tables, NSF 08-321, Arlington, VA.

[2] ABET, Inc. is the recognized national accreditation body for colleges and universities providing training in applied science, computing, engineering, and technology. ABET currently accredits 2,800 programs at more than 600 US colleges and universities. See: www.abet.org.

[3] See, for example, the National Academy of Engineering, Educating the Engineer of 2020, Washington DC: National Academies Press, 2005.

[4] J. Heywood, Engineering Education: Research and Development in Curriculum and Instruction, Hoboken, NJ: John Wiley & Sons, Inc., 2005, provides a useful overview of research in engineering education.

[5] See, for example, program announcement NSF 08-610 "Innovations in Engineering Education, Curriculum and Infrastructure" available at www.nsf.gov/2008/pubs.

[6] National Science Board, Moving Forward to Improve Engineering Education NSB 07-122, Arlington, VA, 2007.

Subtask 2: Department-Level Reform of Undergraduate Engineering Education (DLR)
Subtask 3: International Research and Education in Engineering (IREE)

This report presents the results of the STPI's evaluation of the program addressing "How People Learn Engineering" (subtask 1).

Pamela Ebert Flattau, Ph.D.
Project Leader
IDA Science and Technology Policy Institute

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Executive Summary

The National Science Foundation's Division of Engineering Education and Centers has supported research for a number of years that explores "the aims and objectives of engineering education; the content and organization of the curriculum; how students learn problem-solving, creativity and design; new methods for assessment and evaluation of how students learn engineering; and research that helps us understand how to attract a more talented and diverse student body to all levels of engineering study." The Foundation is looking for "significant breakthroughs in understanding" so that "engineering education can be transformed to meet the needs of the changing economy and society."

In April 2008, the Foundation's Division of Engineering Education and Centers asked the IDA Science and Technology Policy Institute (STPI) to evaluate the early outcomes of 37 research grants active in fiscal year 2008 in the area of "How People Learn Engineering" (HPLE). The objective of the STPI analysis of the HPLE grants program was three-fold:

1. To characterize the portfolio of grants active in FY 2008,
2. To document selected outputs generated by these grantees as of FY 2008, and
3. To specify the types of indicators that would be needed to gauge the longer-term outcomes of the HPLE program in engineering education reform.

Using administrative files furnished by the agency, STPI developed a Logic Model to characterize the lifecycle of these projects and identified factors that could be evaluated at different points throughout the lifecycle using the model.

Through a combination of administrative file analysis and expert interviews, STPI found that the Foundation's HPLE program has been effective in supporting grants that treat the range of topics outlined in the program description.

- The typical HPLE grantee:
    - Explores a well-defined research agenda;
    - Clearly specifies the concepts to be studied and how they will be measured;
    - Pays close attention to data collection and analysis, and the potential for its application in the education setting; and
    - Produces curricular or other materials as a result of the research activity.
- The typical HPLE grantee communicates findings to colleagues in the research and education communities.

However, STPI's analysis of the outputs of HPLE grants yielded little evidence for active publication by the scientists in peer-reviewed journals – with several notable exceptions.

- By 2008, most HLPE grantees included in the analysis had chiefly presented research findings at meetings sponsored by the American Society for Engineering Education:
  - Few reported presenting findings at professional meetings outside the engineering community.
- Few grantees reported having published HPLE-funded results in peer-reviewed journals by 2008,
  - Nor did many report producing a book incorporating the results of their HPLE-supported work.

It is worth noting, however, that HPLE-grantees are quite prolific with respect to the development of education-related materials. Most grantees had developed tool kits, models to facilitate learning, or specific courses/curricula as a result of HLPE funding. Some established websites to make the results of their research available to educators, other researchers, and students.

- It was common for the grantees to report that curricular materials had been adopted in the parent or collaborating institution.
- Few HPLE grantees reported widespread adoption of HPLE-based education materials or practices by 2008, perhaps due in part to the limitations of the progress/final reports to document the outcomes and impacts of these grants.

More formal and longer-range assessments of the outcomes and impacts of these HPLE grants are needed.

- Publication and citation analyses would be useful to demonstrate that HPLE-supported grantees actively publish their results in peer-reviewed journals – and that their work is cited.
- Longitudinal outcome assessments are needed to track the extent to which HPLE-based ideas have been embraced by the engineering education community in the U.S. and abroad.

Many HPLE grantees expressed an interest in creating a more talented and diverse student body at all levels of engineering education through their NSF-funded research. To accurately gauge the impact of such research efforts, longitudinal assessments of the flow of talent into engineering would be needed. It is feasible to measure such outcomes locally through careful record keeping – and some HPLE grantees offered evidence in support of such efforts. However, given the limited size and scope of the NSF HPLE program, it would be difficult to demonstrate that the program is responsible wholly or in part for the changes that are observed in the size and composition of the entire U.S. engineering workforce at a later point in time.

A more effective strategy to gauge the benefits of the NSF HPLE program would be for the NSF to encourage HPLE grantees to document the local outcomes and impacts through improved annual reporting practices. Such information might be used by the

Foundation at a later stage to promote broader dissemination of certain of these education efforts.

Improving Engineering Education through Research

In 2007, the National Science Foundation's (NSF) National Science Board outlined steps that might be taken to improve engineering education in the face of current U.S. dependence on international students and workers, declining interest in engineering studies and careers among U.S. students, and demographic trends that are "unfavorable to increasing citizen participation rates in these fields."[7] Of course, any changes made to engineering education in the United States take place within the context of a rigorous accreditation process that drives much of the content if not the delivery of that education. Nonetheless, given the urgent need to improve engineering education, the National Academy of Engineering (NAE) has recommended that academic institutions "take advantage of the flexibility inherent" in the most recent ABET accreditation criteria[8] and support "research in engineering education as a valued and rewarded activity for engineering faculty."[9]

The NSF Division of Engineering Education and Centers (EEC) actively funds research in engineering education through a variety of grants programs. One program launched several years ago is "How People Learn Engineering" (HPLE).[10] According to the program description:

> *We are looking for significant breakthroughs in understanding so that our undergraduate and graduate engineering education can be transformed to meet the needs of the changing economy and society. We are interested in research that addresses: the aims and objectives of engineering education; the content and organization of the curriculum; how students learn problem-solving, creativity and design; new methods for assessment and evaluation of how students learn engineering; and research that helps us understand how to attract a more talented and diverse student body to all levels of engineering study.*
>
> *NSF EEC, Program Description, S. Kemnitzer (Personal Communication, 2008)*

The 37 awards active in April 2008 were included in the analysis that follows, totaling nearly $18 million in support to 31 institutions. (See Appendix A for details.)

An analysis of funding patterns by the "start date" of each award shows that program funding reached a peak of over $9 million in FY 2007:

- $375,000 in FY 2002 (1 grant)
- $643,000 in FY 2003 (1 grant)

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7 Moving Forward to Improve Engineering Education, National Science Board NSB 07-122, Arlington, VA, 2007.

8 ABET (formerly known as the Accreditation Board for Engineering and Technology) "serves the public through the promotion and advancement of education in applied science, computing, engineering, and technology"; it does so by issuing criteria for accrediting programs and providing assistance to programs seeking accreditation. See: http://www.abet.org/index.shtml.

9 Educating the Engineer of 2020: Adapting Engineering Education to the New Century, National Academies Press, Washington, DC, 2005.

10 In April 2008, NSF EEC announced another program of support, "Innovations in Engineering Education, Curriculum, and Infrastructure" (IEECI). See: PA 08-542 at www.nsf.gov/pubs/2008.

- $1,165,000 in FY 2004 (3 grants)
- $405,000 in FY 2005 (1 grant)
- $4,296,000 in FY 2006 (11 grants)
- $9,228,000 in FY 2007 (16 grants)
- $1,649,000 in FY 2008 (4 grants as of April 2008).

Earlier this year, NSF asked the IDA Science and Technology Policy Institute (STPI) to conduct a systematic review of the early outcomes from the HPLE program and to outline a strategy for the longer-range assessment of program outcomes. The report that follows summarizes the results of STPI's analysis that took place between April and August 2008.

Context

NSF's interest in the reform of engineering education through research occurs at a time of nation-wide interest in educational reform. According to the National Research Council, contemporary federal legislation such as the *No Child Left Behind Act of 2001* and the *Education Sciences Reform Act of 2002* "catapulted education research into the [national] spotlight"[11] owing to requirements for the improvement in educational delivery through "evidence-based"[12] research and analysis. As Shavelson and Towne[13] noted in their 2002 report:

> *No one would think of getting to the Moon or wiping out disease without research. Likewise, one cannot expect reform efforts in education to have significant effects without research-based knowledge to guide them.*

In other words, contemporary American society not only supports the goal of educational reform, it also values the research that makes such reform possible.[14]

Research in engineering education research is considered by many to be a rapidly growing specialty "…as evidenced by the recent emergence of the critical components of an infrastructure to sustain a community of scholars."[15] To facilitate the advancement of research in engineering education, a community of scholars organized

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11 Advancing Scientific Research in Education, L. Towne, L.L. Wise, and T.M. Winters (Eds.), National Research Council, National Academies Press, Washington DC, 2005.

12 "One type of such evidence is scientifically based research, which can focus on practices or on programs. The second type of empirical evidence is objective measures, which can consist of benchmarks or local data." See, G.J. Whitehurst, Assistant Secretary, Office of Educational Research and Improvement, U.S. Department of Education, "Evidence-based Education," December 18, 2001. *PowerPoint* presentation available at: http://www.ed.gov/offices/OERI/speeches.html.

13 Scientific Research in Education, R.J. Shavelson and L. Towne (Eds.), National Research Council, National Academies Press, Washington DC, 2002.

14 See: http://www.nsf.gov/statistics/seind08/c7/c7s3.htm. *Although support for federal research investment is at historically high levels, other kinds of federal spending generate even stronger public support. Support for increased spending is greater in numerous program areas, including education (73%), health care (72%), assistance to the poor (68%), environmental protection (67%), and Social Security (61%).*

15 See: http://www.asee.org/publications/jee/REES.cfm. Elements of the research infrastructure include annual meetings of researchers as well journal outlets for publishing research results.

the Engineering Education Research Colloquies (EERC) several years ago to "develop a national research framework and agenda to conduct rigorous research in engineering education." In October 2006, the Steering Committee of the National Engineering Education Research Colloquies announced five priority research areas to "ensure a coherent, rigorous and innovative foundation and sustained transformation of our engineering education system,"[16] an excerpt of which is reproduced in Figure 1.

It is within the context of these efforts to promote educational reform through research that the NSF introduced its program of research support in the furtherance of engineering education.

[16] The Steering Committee of the National Engineering Education Research Colloquies, "The National Engineering Education Colloquies," Journal of Engineering Education, pp. 257 – 261, October 2006.

Figure 1: Excerpt from the *Special Report* by the Steering Committee of the National Engineering Education Research Colloquies

Special Report

The Research Agenda for the New Discipline of Engineering Education

The five research areas for the new discipline of Engineering Education consist of one or more interrelated strands of research that can be investigated independently or integrated with other areas of inquiry. The research areas include:

- Engineering Epistemologies
- Engineering Learning Mechanisms
- Engineering Learning Systems
- Engineering Diversity and Inclusiveness
- Engineering Assessment

Area 1—Engineering Epistemologies: *Research on what constitutes engineering thinking and knowledge within social contexts now and into the future.*

Area 2—Engineering Learning Mechanisms: *Research on engineering learners' developing knowledge and competencies in context.*

Area 3—Engineering Learning Systems: *Research on the instructional culture, institutional infrastructure, and epistemology of engineering educators.*

Area 4—Engineering Diversity and Inclusiveness: *Research on how diverse human talents contribute solutions to the social and global challenges and relevance of our profession.*

Area 5—Engineering Assessment: *Research on, and the development of, assessment methods, instruments, and metrics to inform engineering education practice and learning.*

Journal of Engineering Education October 2006

Nature and Scope of the STPI Analysis

The objective of the STPI analysis of the HPLE grants program was three-fold:

1. To characterize the portfolio of grants active in FY 2008;
2. To document selected outputs generated by these grantees as of FY 2008; and
3. To specify the types of indicators that would be needed to gauge the longer-term outcomes and impacts of the HPLE program on engineering education reform.

The overarching evaluative question asks whether the NSF HPLE program is accomplishing its goal of promoting *significant breakthroughs in understanding so that our undergraduate and graduate engineering education can be transformed to meet the needs of the changing economy and society.*[17] In other words, is the HPLE program effective?

To establish a baseline understanding of range and types of activities supported through the HPLE program portfolio, STPI examined each grant for evidence of those factors that could be evaluated at different points in the lifecycle of a project. These include:

- Inputs (funding from the National Science Foundation, principal investigator [PI] leadership and management, collaborations within and among institutions);
- Activities (key components of the research and development process as described by the PIs in their grant proposals and/or annual reports to NSF);
- Outputs (in terms of research and development products generated by HPLE-funded activities);
- Outcomes (in terms of the quality of the HPLE-funded research and/or changes in engineering education curriculum or teaching practices); and
- Impacts (in terms of a larger, more diverse, and competitive U.S. engineering workforce through local changes).

STPI developed an HPLE "Logic Model" to guide STPI thinking about the relationship among these variables. (See Figure 2.)

Method

To conduct its analysis, STPI reviewed administrative files furnished by the National Science Foundation, including research proposals, budgetary information, and annual reports filed by HPLE grantees. STPI next generated a set of "Study Questions" for purposes of analyzing the HPLE portfolio of grants. Appendix B provides a detailed listing of the study questions that guided the work of the STPI project team.

STPI also interviewed a sample of principal investigators to gain further insights into the nature of their research activities, outputs, and anticipated outcomes and impacts. The interviews were especially helpful in gathering supplementary information about the

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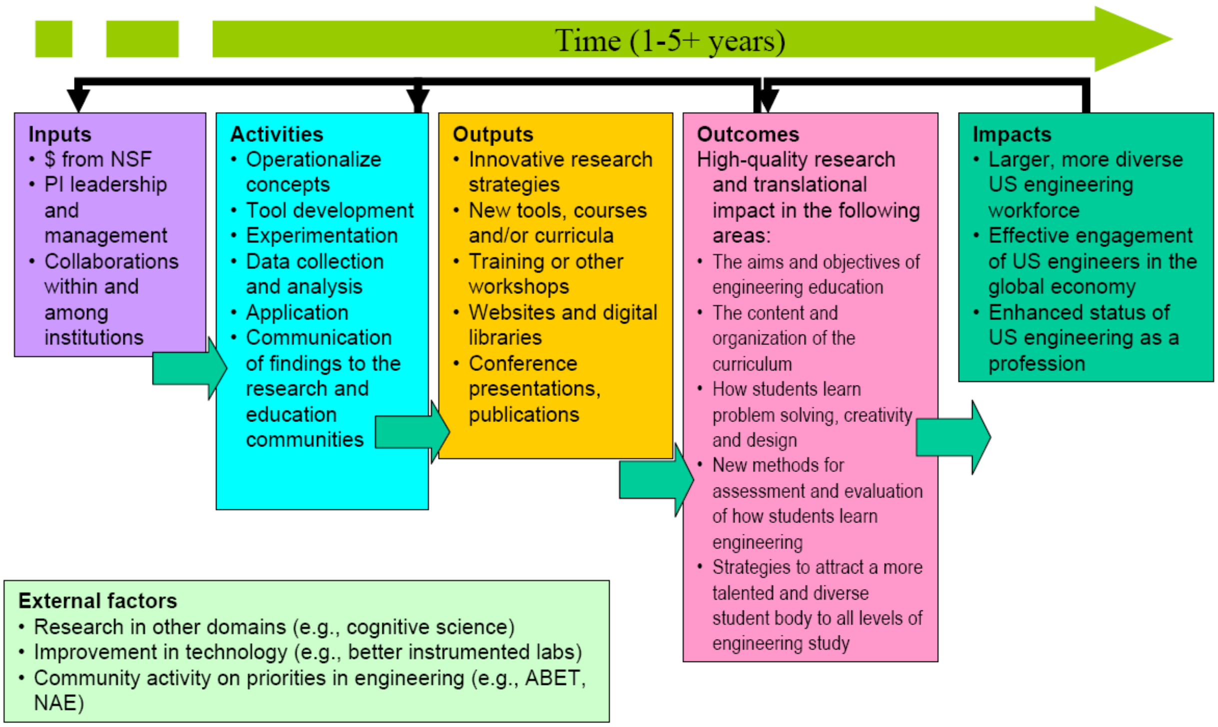
[17] NSF EEC, Program Description, S. Kemnitzer, Personal Communication, 2008.

research activities, outputs and anticipated outcomes of a subset of the HPLE grants. Appendix C describes the STPI sampling strategy and the types of questions posed to grantees. Together with the information generated by the administrative file analyses, information emanating from the interviews informed the preparation of the report that follows.

Figure 2: "How People Learn Engineering" Logic Model



SOURCE: IDA Science and Technology Policy Institute, 2008.

Organization of the Report

In the pages that follow, STPI presents the results of its analyses using the project lifecycle categories appearing in Figure 2, namely, "Inputs," "Activities," "Outputs," "Outcomes" and "Impacts." Within each category descriptive statistics are presented, supplemented with examples drawn from the work of the grantees or as a result of STPI discussions with HPLE Principal Investigators. Each section concludes with a summary of key findings.

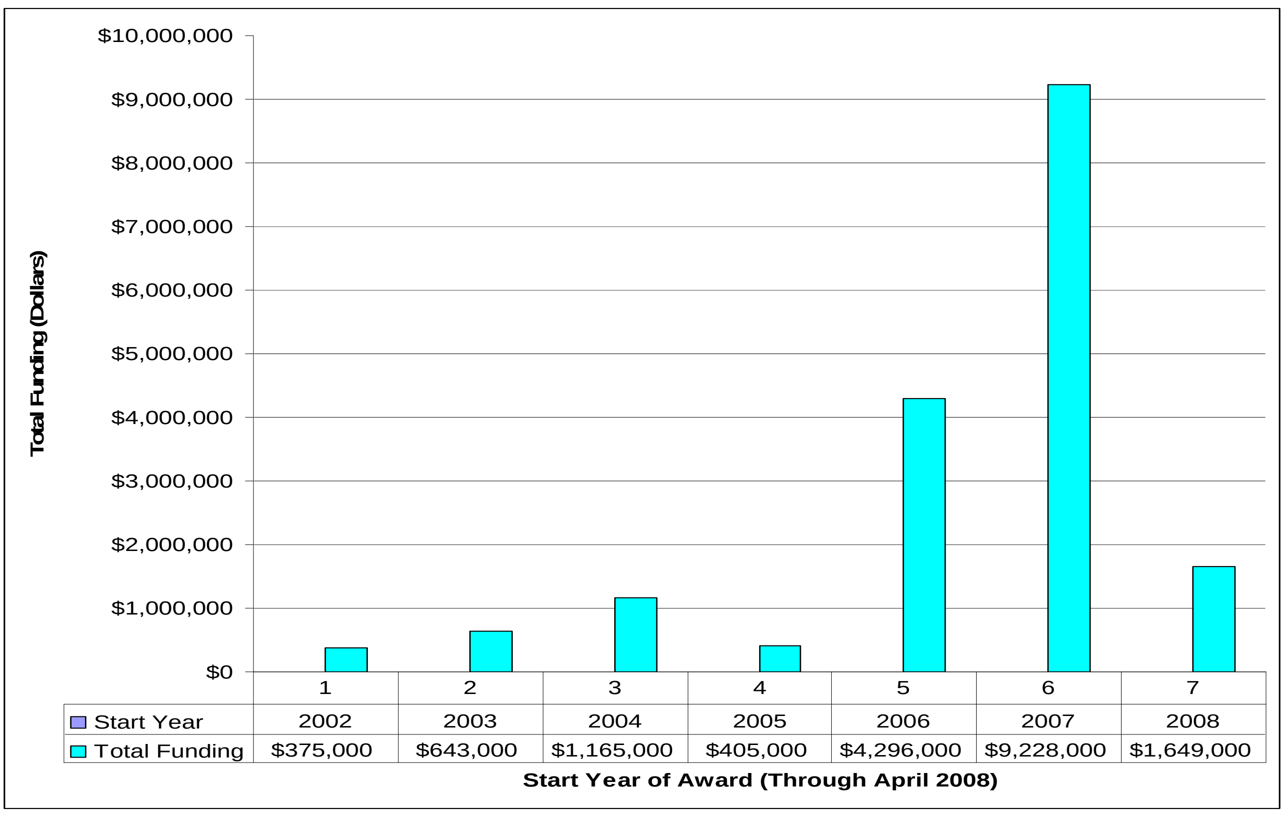
Inputs

STPI defines “inputs” into the HPLE grants program to include the combination of NSF grant support, coupled with PI leadership and grants management, as well as the nature and breadth of collaborations of scientists, engineers and educators within the grant infrastructure. In this section, STPI describes these inputs for the 37 HPLE grants active in FY 2008. Appendix A presents much of the information that serves as the basis for this analysis.

NSF Support

In April 2008, thirty-seven active grants were included in the Foundation’s HPLE portfolio. (See Appendix A.) Analyzing the funding pattern by “Start Date” of the award, FY 2007 represents the peak year of funding for awards made under this program, as shown in Figure 3.

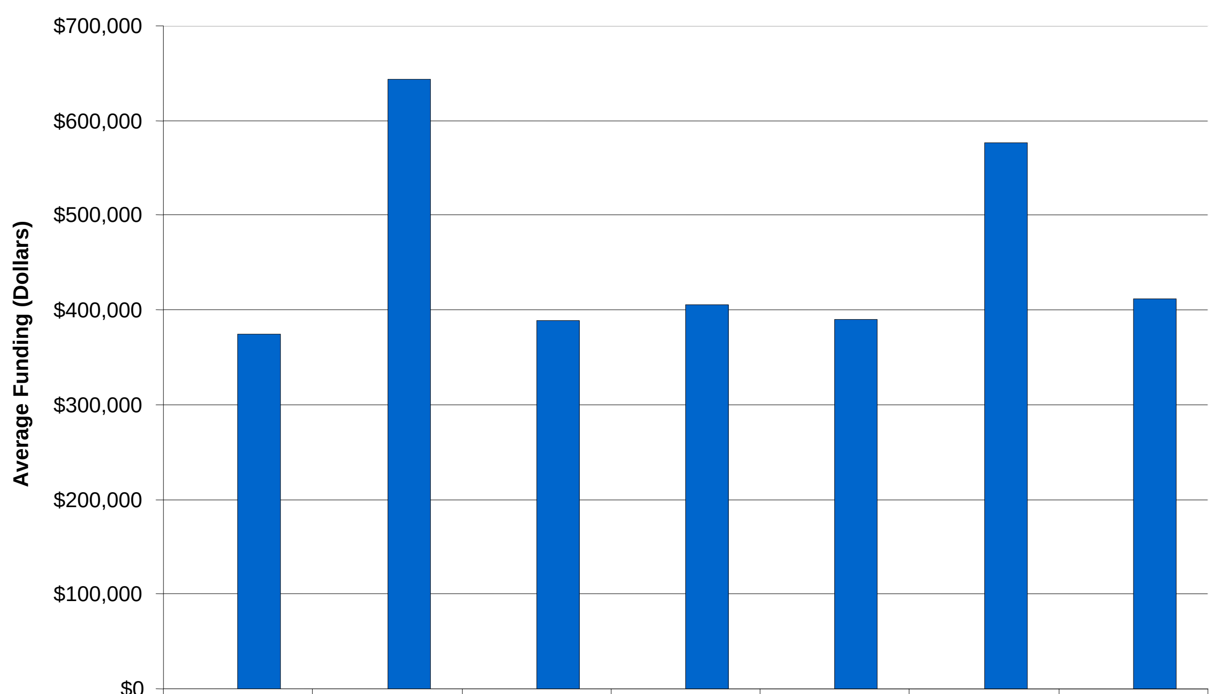
Figure 3: Distribution of Awards Funding for HPLE Grants: 2002 – 2008



SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

There is some evidence for recent growth in the average size of an HPLE grant, as shown in Figure 4. Nonetheless, most of the 37 grants active in FY 2008 averaged around – but not more than – $500,000 in total support. As Appendix A reveals, HPLE grants active in FY 2008 ranged in cost from a low of $99,964 dollars for 2 years of support (grant number 743223, Huband) to a high of $1.6 million dollars for 3 years of support (grant number 550710, Benyo).

Figure 4: Average HPLE Award by Start Year: 2002 – 2008



	1	2	3	4	5	6	7
Fiscal Year	2002	2003	2004	2005	2006	2007	2008
Average	375,000	643,000	388,300	405,000	390,500	576,800	412,300

Start Year of Award (Through April 2008)

SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

NSF Career Awards

Ten of the 37 active grants were supported as CAREER awards. (See Table 1, below.) NSF CAREER awards are made to assistant professors without tenure; associate professors with or without tenure are not eligible for these awards.[18] While there is some evidence of more frequent use of CAREER awards by the HPLE program in recent years, the use of these funds for HPLE research support is also evident earlier in the program. The average award for HPLE research through the CAREER awards program is about $510,000 – slightly more than the average HPLE grant.

18 "FAQs about the Faculty Early Career Development (CAREER) Program," NSF 08-557. Available at: www.nsf.gov.

Table 1: HPLE Grants Funded as NSF CAREER Awards

CAREER Award Number	Title	Principal Investigator	Institution	Start Date	End Date	Amount
237135	Designing Effective Teams in the Engineering Classroom for the Enhancement of Learning	Stephanie Adams	University of Nebraska, Lincoln	2/15/2003	1/1/2009	$643,418
448240	Liberative Pedagogies in Engineering Education	Donna Riley	Smith College	2/1/2005	1/31/2010	$404,813
547599	Achieving Diversity in Engineering Education: Cultivating Student Self-Efficacy	Deborah Follman	Purdue University	3/1/2006	2/28/2011	$529,624
643107	Interdisciplinary Graduate Education in Engineering	Maura Borrego	Virginia Polytechnic Institute	9/15/2006	8/31/2011	$525,412
644796	Colleges of Engineering as Learning Organizations: Implications for Student Intellectual Development	Jennifer Karlin	South Dakota School of Mines	9/15/2006	8/31/2011	$531,739
644917	Development and Evaluation of Portable, Computationally Intelligent Team Training	Ray Luechtefeld	University of Missouri, Rolla	9/15/2006	8/31/2011	$554,624
747795	Advancing Engineering Education through Learner-centric, Adaptive Cyber-tools and Cyber-environments	Krishna Madhavan	Clemson University	2/1/2008	1/31/2013	$511,824
747803	An Examination of Graduate Education's Role in Preparing Engineering Students for Careers in Academia and Industry	Monica Cox	Purdue University	8/1/2008	7/31/2013	$541,507
748005	Intentional Seredipity, Cognitive Flexibility, and Fluid Identities: Cross-disciplinary Ways of Thinking, Acting and Being in Engineering	Robin Adams	Purdue University	9/15/2008	8/31/2013	$495,830
748186	Advancing Adaptive Expertise in Engineering Education	Helen Martin	University of Texas at Austin	9/15/2007	8/31/2012	$400,000
						$5,138,791

SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

NSF SGER Awards

NSF staff have also supported HPLE researchers through the program of “Small Grants for Exploratory Research: SGER.” SGER supports small-scale, exploratory, high-risk research in the sciences and engineering.[19] Of the 37 active HPLE grants, 3 have been supported with SGER funds. (See Table 2, below.) The NSF Division of Engineering Education and Centers appears to have used SGER support chiefly in FY 2006 for purposes of furthering research in engineering education.

[19] “Small Grants for Exploratory Research: Hurricane Katrina,” NSF 05-053. Available at: www.nsf.gov.

Table 2: HPLE Grants Funded as NSF SGER Awards

SGER Award Number	Title	Principal Investigator	Institution	Start Date	End Date	Amount
638762	Students' Perceptions of Value and Need for Mentors as They Progress Through Academic Studies in Engineering and Science	Carol Muller	MentorNet	9/15/2006	2/29/2008	$199,978
639895	Engineering in Context: An Investigation of How Experts and Students Incorporate Global and Scientific Issues in Their Engineering Design Processes	Cynthia Atman	University of Washington	9/1/2006	8/31/2008	$199,876
649914	Cooperative Education for Research Careers	Carlo Montemagno	University of Cincinnati	9/15/2006	8/31/2008	$200,000
						$599,854

SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

In summary, about one-third of the total support provided by the NSF for HPLE research in recent years was provided through the CAREER and SGER awards.

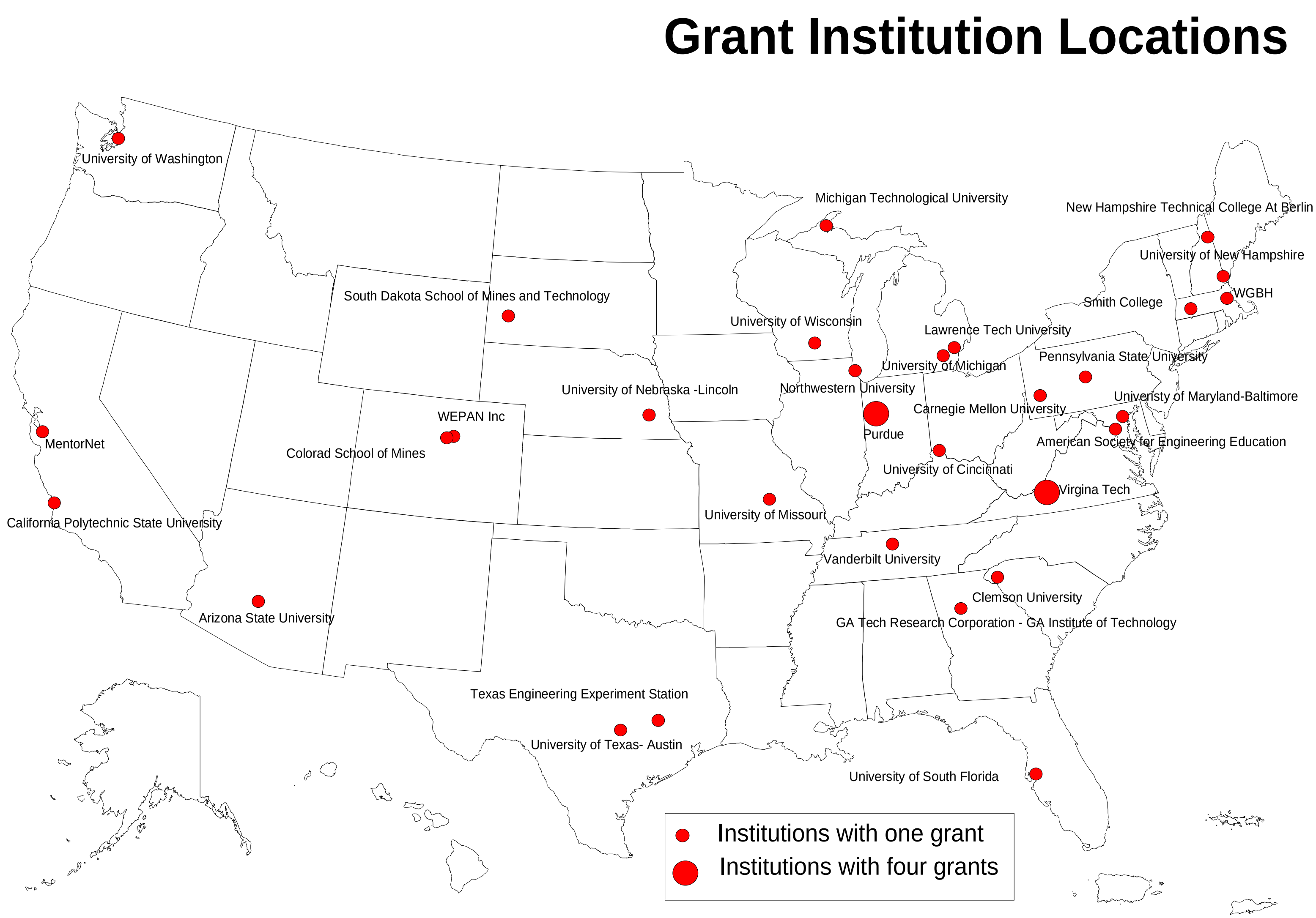
Project Leadership and Management

Another critical input to the research activities of grantees is the quality of the research infrastructure – in terms of the institutions where the research will take place and the principal investigators who oversee the research process.

Institutions

The National Science Foundation makes every effort to support high-quality research at a wide variety of institutions across America. Between 2002 and 2008, the HPLE program supported 37 research awards at 30 institutions, as shown in Figure 5. While the larger fraction of HPLE funding was awarded to institutions east of the Mississippi River, HPLE awards in the Western states were made – some of which participated in nation-wide collaborations as will be illustrated later in this section. It is worth noting that Virginia Polytechnic Institute and Purdue University are among those institutions sponsoring more than 1 HPLE research grant.

Figure 5: Geographic Distribution of NSF HPLE Grants Active in FY 2008

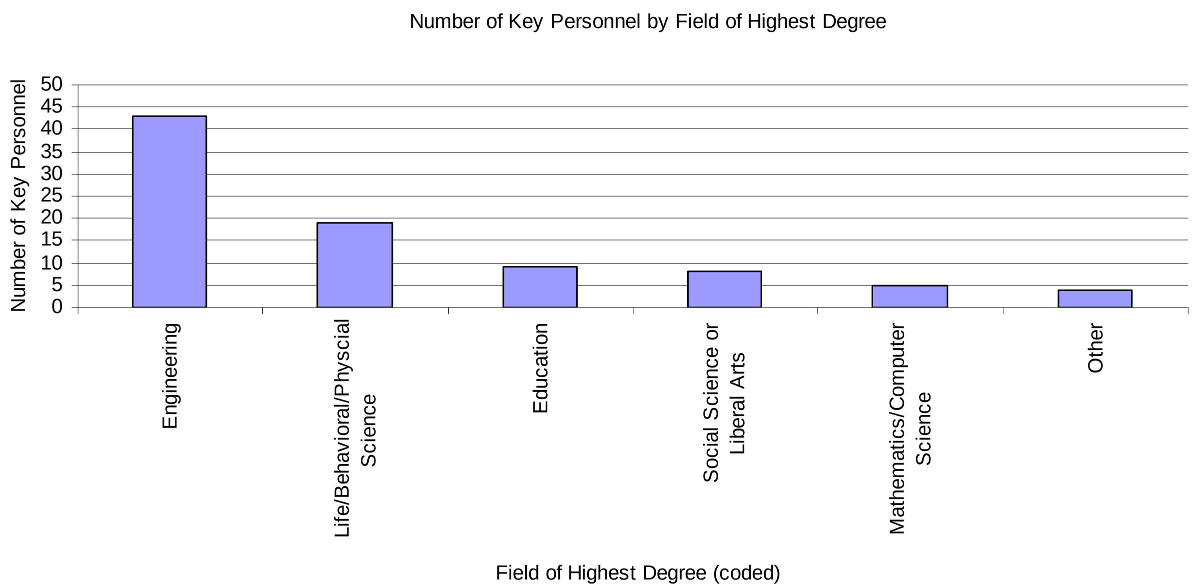


SOURCE: National Science Foundation, 2008. (Chart generated by IDA STPI.)

Selected Characteristics of HPLE Principal Investigators (PIs)

STPI examined the characteristics of the Principal Investigators managing these 37 active awards. Using the “bio-sketches” furnished by grant applicants, STPI observed that a majority of grantees earned degrees in engineering, as might be expected given the thrust of this research grants program. Nonetheless, it is interesting to note that at least four hold a doctorate in education and another three in non-science/non-engineering fields. This multidisciplinary mix of PIs is also reflected in the mix of disciplines which make up the 37 HPLE research teams. As illustrated in Figure 6 (below), taken together, the number of “key personnel” included in the HPLE grants who are not engineers essentially equals the number of engineers supported by these grants.

Figure 6: Distribution of HPLE Key Personnel by Highest Earned Degree



SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

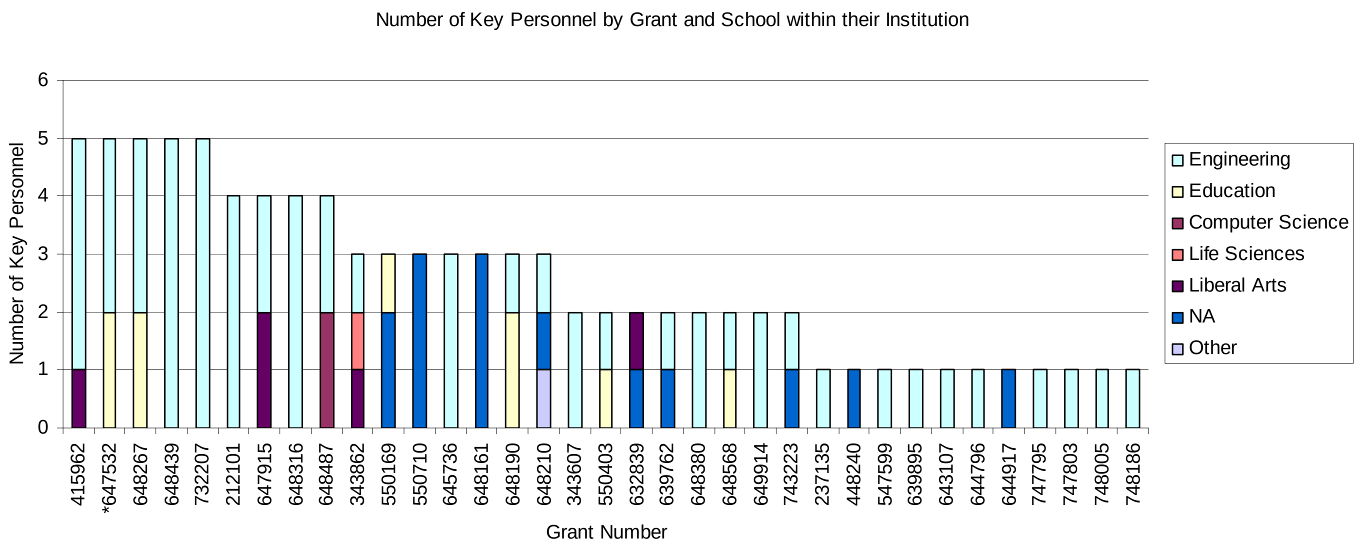
The ability of HPLE grantees to assemble multi-disciplinary teams may stem in part from the diverse work experiences of these PIs. Again, a review of the bio-sketches reveals that 15 of the 37 PIs worked in the industrial sector for some period following the baccalaureate; 6 worked in other types of settings – such as Argonne National Laboratory. Three HPLE grantees also had experience in the public policy arena as AAAS fellows.[20]

[20] For over 35 years the American Association for the Advancement of Science (AAAS) has supported a one-year fellowship program – often in conjunction with support from discipline-specific professional societies – to provide doctoral-level scientists and engineers with experience in public policy in the Executive Branch of the U.S. government or in the offices of the U.S. Congress. www.aaas.org.

In summary, the principal investigators who manage HPLE grants are located at a wide variety of institutions. Nonetheless, many share the common characteristic of working effectively with experts trained in other disciplines – perhaps owing to previous employment in non-academic settings.

Figure 7 provides further insights into the mix of disciplines within the HPLE program of support – on a grant-by-grant basis.

Figure 7: Mix of Key Personnel within HPLE Grants (2008)

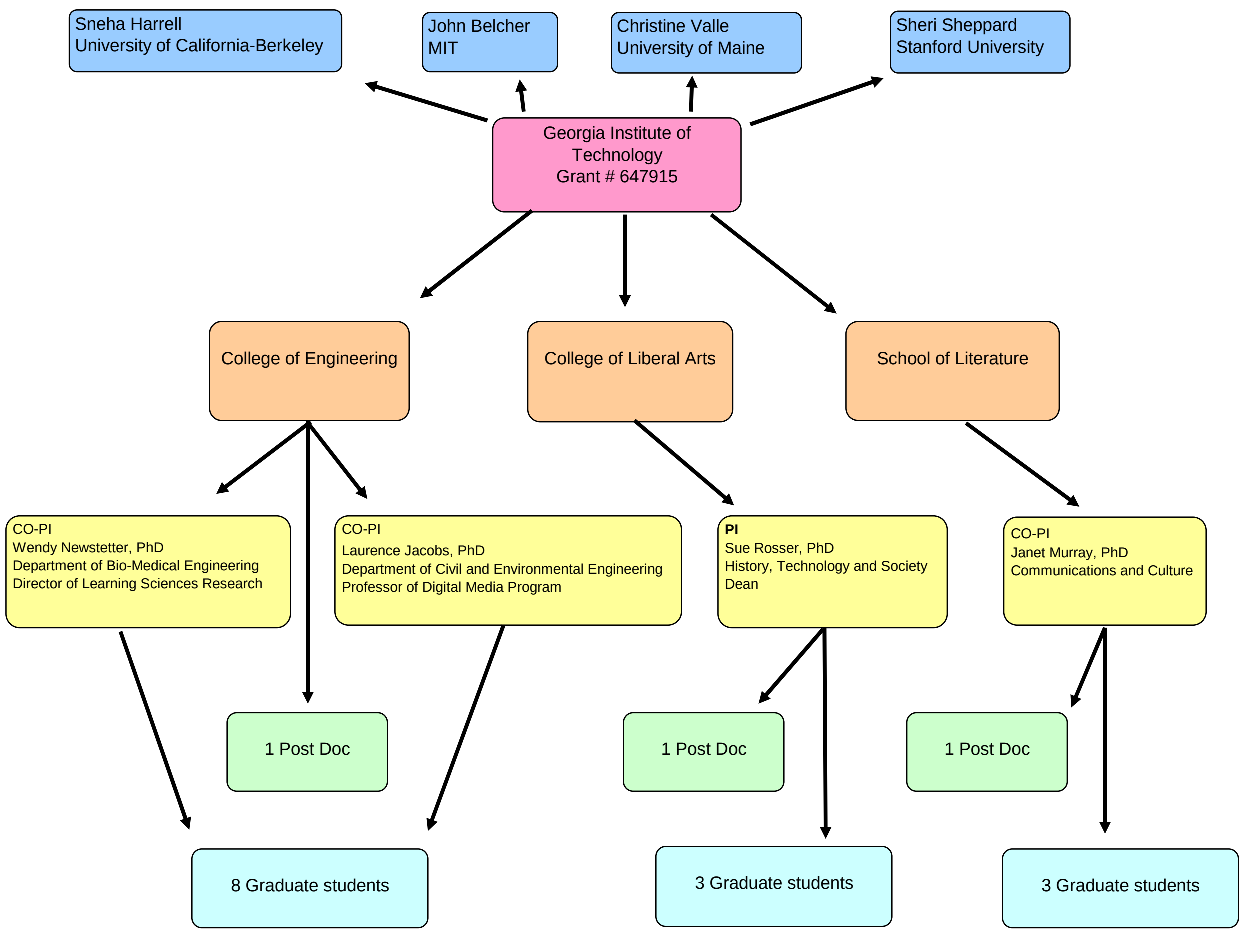


SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

Collaboration Within and Among Institutions

As we suggested earlier, in order to achieve the goals of the HPLE program, grantees frequently structure the grant to include cooperative research opportunities within the parent institution – as well as across institutions. While it is beyond the purview of this analysis to document the range of collaborations reported by these grantees, the example offered by Figure 8 is instructive. HPLE Grant Number 647915 to Sue Rosser at Georgia Tech “tests the efficacy of computer-based manipulable models within a foundational course in Statics.” The research questions focus on the ability of the software environment “to support the development of diagrammatic reasoning in introductory statics courses.” Owing both to the complexity of the subject matter (requiring a range of expertise) as well as the demand to test out the design solutions across a variety of student abilities, the PI assembled a project team involving faculty from the humanities and engineering within the parent institution as well as faculty drawn from academic institutions across the nation.

Figure 8: Illustrative Example of Intramural and Extramural Research Collaborations for HPLE Grantee (The Georgia Institute of Technology)



SOURCE: NSF HPLE Grant Number 647915, as analyzed by the IDA Science and Technology Policy Institute, 2008.

Activities

As we mentioned at the outset of this report, the educational research community has long discussed the challenges involved in introducing educational reforms – even if based on research. Professors Deborah Ball and Francesca Forzani have observed that delivering effective education remains a problem even in the face of research designed to improve and transform education:

> *Formal schooling and educational programs often fail. Students retain misconceptions even after instruction, basic academic skills are often underdeveloped, and many youth leave school unprepared to participate competently in a democratic and diverse society. Most troubling is that education is delivered unevenly and inequitably.*[21]

In the face of these challenges, the education community takes quite seriously its preparation of individuals to conduct education research. Over the years, training in social science and behavioral research methods has become fundamental in the preparation of educational researchers.

In reviewing the administrative files for the HPLE grants program, STPI became interested in identifying grants whose research design elements demonstrated certain aspects of "good" research design. The work of Earl Babbie[22] offers a handy framework for characterizing this element of the HPLE portfolio of support. The elements of the research design process selected for discussion in the pages that follow include:

- Operationalization of a concept
- Tool development
- Experimentation
- Data collection and analysis
- Application of research findings
- Communication of findings to the research and education communities.

STPI Characterization of HPLE "Research Foci"

Owing to the fact that the 37 active HPLE grants do not represent a homogenous pool of research topics or goals, STPI further sorted these grants on the basis of the general thrust of the grant as articulated in the research proposal. At first, STPI attempted to sort grants by the research agenda inherent in the 2006 colloquies (see page 11 of this report). But we soon abandoned the effort due to the fact that many of the active HPLE grants were awarded prior to the articulation of the colloquy goals. Furthermore, most HPLE grant proposals address more than one of the research goals inherent in the NSF HPLE program description and/or the colloquies listing.

Instead, STPI specified four categories of HPLE research for purposes of sorting the 37 active grants, largely reflecting an emphasis on the "unit of analysis." Nonetheless, the

21 "What Makes Education Research 'Educational'?" Educational Researcher, Vol. 36, 2007.
22 The Practice of Social Research, 9th Edition, 2001.

overlap between the STPI formulation of the HPLE research goals and those offered by the NSF program description and/or the research colloquies will be apparent:

- Grants focused on “problem-solving, creativity, design” processes (n = 8);
- Grants focused on “strengthening the engineering education system” (n = 15);
- Grants focused on “attracting and retaining a diversity of talented individuals in engineering” (n = 11); and
- Grants focused on “promoting the development of engineering education research as a specialty” (n = 3).

As we suggested earlier, most of the HPLE grants include one or more of these research foci in their proposals. STPI reviewed three elements of each proposal to determine a “primary” thrust – thus ignoring PI interest in or reference to other research thrusts. The proposal elements included: a statement of purpose; research method, including sampling plan; and expected outcomes.

The results of this sorting method appear in Appendix D of this report. The distribution of this set of active grants using these categories simply offers a convenient way to consider similarities or differences among grants relative to their outputs – a topic addressed later in this report.

The distribution of grants across these four research foci also allowed STPI to conduct a purposive sampling of grants for treatment in the sections that follow.

It is necessary to point out at this juncture that STPI elected not to include any description of the three grants occupying the final category, “Promoting the Development of Engineering Education Research as a Specialty.” This is due to the fact that these three grants largely represent support for convening groups of experts – much like “conference grants” – therefore, the analysis of their anticipated outputs and outcomes differs significantly from the 34 remaining HPLE research grants.

Operationalizing Concepts

Once a researcher specifies the concepts to be studied and has chosen a research method, the next step is to decide upon the appropriate measurement technique. “How will we actually measure the variables under study?”

The work by Ronald Miller (Grant Number 550169) is a particularly interesting example of the challenges facing the educational research and how they might be addressed. (See Figure 9.)

Miller and his colleagues decided to investigate the development of schema training strategies for helping engineering students develop “more fundamentally accurate mental models of dynamic processes which occur at small length scales.”

Figure 9: An Excerpt from HLPE Grant Number 550169

Developing Ontological Schema Training Modules to Help Students Develop Scientifically Accurate Mental Models of Engineering Concepts
R. Miller, Colorado School of Mines

Project Introduction, Vision, and Background

Engineering is a discipline that has historically and successfully relied upon a macroscopic and largely empirical description of how the physical world works. As we move into the 21st century, however, technological advances are being made at the microscopic, molecular, and atomic levels in many fields of engineering (e.g. microfluidics, biotechnology, genetic engineering, microelectronics, nanoscale machines, molecular computers, materials engineering, pharmaceutical design, catalyst design) that challenge engineering education to respond to these evolving disciplines. For example, the recent NSF report entitled "Societal Impacts of Nanoscience and Nanotechnology" (NSF, 2001) calls for introducing nanoscale scientific and technology concepts into all levels of engineering and science courses so that the next generation of engineering graduates possesses a strong conceptual understanding of dynamic engineering and scientific processes at small scales.

We will rely on Miller and Streveler's prior work on concept inventories to screen for students who show evidence of having particular robust misconceptions. As described in Miller et al. (2005), student responses on concept inventory questions reveal underlying misconceptions about important concepts in the thermal sciences. A set of 5 such questions will be used to screen potential participants. Students with fewer than 3 correct responses to this set of questions would be eligible for the study, and specific misconceptions will be captured by the screening.

We will also survey students concerning their prior instruction in (1) college biology, and (2) microfluidics. Stage 2 of our project requires that students are naïve in these two content areas. We anticipate that about 10 students will be involved in this phase of developing the screening inventory.

Study Phases	Experimental Group	Control Group
Pre-Test: Science Knowledge (repeated measure)	Pre-test	
Schema Training	Schema Text	Control Text
Training Post-test	Schema Post- Test	Control Post Test
Target Instruction	Emergent Process Instruction: Microfluidic Systems	
Post-test: Science Knowledge (repeated measure)	Post-test	
Transfer Instruction (remote concept)	Transfer Instruction	
Transfer Test of remote concept	Transfer Test	

Figure 2 – Design of Schema Training Study

Two fundamental questions of interest to Miller became: (1) why does the misconception exist, and (2) how can it be repaired?

To "seek to repair" student misconceptions, it became necessary to operationalize the concept of a "misconception." Miller turned to previous work on "concept inventories" to find a method to screen students relative to their misconceptions. Thus, it became possible to identify students who were "eligible" to participate in the study and to create both an experimental and a control group for purposes of analysis.

The operationalization of the concept of "robust misconception" was made possible through the adoption of a conceptual screening method.

Tool Development

HPLE researchers are involved in the development of many types of tools – teaching kits, course materials, curricula – but also models designed to convey new understandings to engineering students.

Knowing that "spatial ability" is an essential skill in science and engineering, Brad Kinsey (Grant Number 343862) became interested in the optimal training needed to develop visual spatial skills. (See Figure 10.) Kinsey proposed to design a computer integrated "Physical Rotator Model" and to study the effectiveness of the teaching tool in improving spatial ability, course achievement, and improvements in self-efficacy.

Over a three-year period, Kinsey proposed to:

- Build the Physical Rotator Model;
- Develop training materials;
- Conduct experiments using engineering students;
- Analyze data; and
- Disseminate information about the effectiveness of the tool and the training method for improving the spatial ability of engineering students.

In an interview with STPI staff, Kinsey described the process of using a standardized spatial abilities test at the beginning of freshman year to identify students with relative "poor" spatial abilities. Students were then invited to participate in the training sessions.

Kinsey has also produced a web-based tool for spatial ability assessment. He is encouraged by the fact that their research has shown that spatial ability can be developed. He has presented his findings in a variety of settings, and published results in engineering education journals as well as journals related to engineering design graphics.

Figure 10: An Excerpt from HLPE Grant Number 343862

Improving and Assessing the Spatial Ability of Engineering Students Using a CAD Integrated Physical Model Rotator

B. Kinsey, University of New Hampshire

Since the projective spatial abilities, i.e. being able to visualize an object from different perspectives, are crucial to engineering students, the part manipulation of interest here is that of rotation. The PMR will be integrated into a computer software package to allow an actual 3D object to rotate synchronously with the model rotating on the computer screen and in the same field of vision for the user. See Fig. 4 for a schematic of the system. The rationale for this device is that users of the computer software package may not be able to visualize the 3D representation of the object on the 2D computer screen thus becoming discouraged or confused. The PIs have anecdotally witnessed this while teaching mechanical engineering, civil technology, and civil engineering design courses which are used in the freshman and sophomore years to excite and retain students in engineering disciplines. As was shown by Sorby at Michigan Technological University [47], these introductory design courses represent a "gateway" course for students with poorly developed spatial ability, in the same way that calculus, chemistry and physics are typically considered "gateway" courses. By providing the user with an actual 3D object in the correct orientation, a perceptual connection will be made between the 3D object and the 2D representation, thereby improving the user's spatial ability skills. The goal is to assist the user in visualizing 3D objects in a 2D representation and develop the user's projective spatial skills, which are essential in creating, visualizing, and manipulating mental images of objects. These improvements will be assessed using spatial ability tests such as the MRT and the PSVT:R. Six of these devices will be fabricated to provide an efficient testing process.

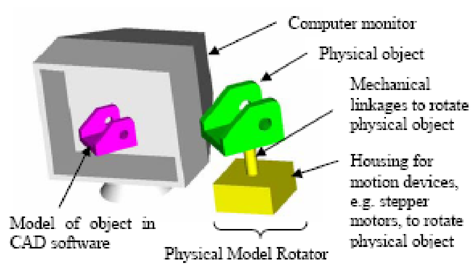


Figure 4. Schematic of CAD integrated Physical Model Rotator.

Task Description	AY 2004-05			AY 2005-06			AY 2006-07		
	SU	F	SP	SU	F	SP	SU	F	SP
Task 1: Build Physical Model Rotator									
T.1.1 Improve on preliminary prototypes of PMR									
T.1.2 Evaluate and Redesign Physical Model Rotator									
Task 2: Produce primers and questionnaires for study									
T.2.1 Develop training materials									
T.2.2 Develop questionnaires									
T.2.3 Revise documents after initial studies									
Task 3: Conduct study on engineering students									
T.3.1 Conduct study of control groups									
T.3.2 Conduct preliminary study of training material									
T.3.3 Analyze data from control group									
T.3.4 Conduct study of experimental group									
T.3.5 Analyze data from experimental group									
Task 4: Write and disseminate information									
T.4.1 Write paper on Physical Model Rotator									
T.4.2 Write paper on preliminary study									
T.4.3 Write papers on studies									
T.4.4 Disseminate information on WWW	throughout project								

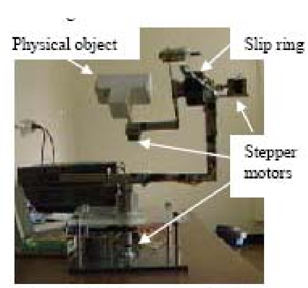


Figure 5. Initial prototype of PMR.

Experimentation

Collecting empirical data is at the heart of research. The choice of research method dictates the type of information that will be collected and how it will be collected.

Ray Luechtefeld (Grant Number 644917) tackled the complex problem of developing a training strategy to promote multi-disciplinary teams. The goals of the research project are:

- To characterize and model expert knowledge embedded in human dynamics research;
- To further develop the "virtual facilitator" as a means of helping engineering students learn effective team skills;
- To investigate a set of research questions evaluating the effects of the "virtual facilitator" as part of team education;
- To assist women and minorities in making their voices heard in teams; and
- To broadly disseminate the "virtual facilitator" for improving team skills in engineering education as well as in industry.

Luechtefeld's experimental method involves applying a set of "basic rules" embedded in a proof-of-concept virtual facilitator, interjecting (discourse) interventions into team conversations – referred to as "constructive controversy" – and then measuring the effects of these interventions on team performance.

The experimental method addresses two questions:

1. Do the behaviors of these experts promote greater shared understanding?
2. Do the behaviors of experts serve to reduce coercion among team members?

As Figure 11 indicates, Luechtefeld plans to explore these research questions over a five-year period. Experimentation involves the use of the virtual facilitator as part of engineering management and systems engineering course work. Wireless connectivity is a feature of the research environment.

Luechtefeld presented early findings not only to the engineer education research community (ASEE) but also to specialists involved in distance teaching and learning.

Figure 11: An Excerpt from HLPE Grant Number 644917

Development and Evaluation of Portable, Computationally Intelligent Team Training
R. Luechtefeld, University of Missouri, Rolla

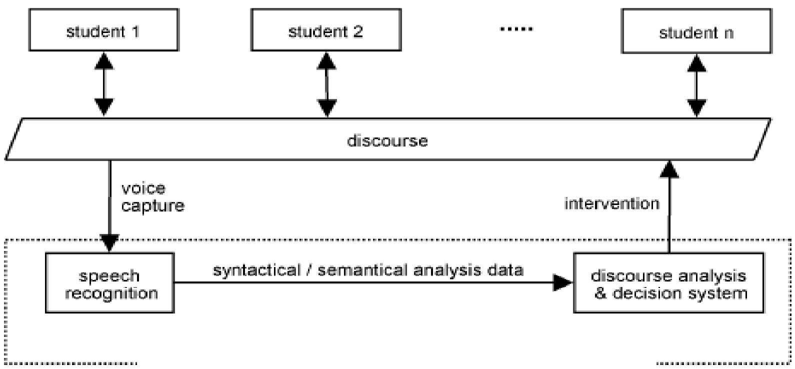


Figure 3. Block Diagram of the Virtual Facilitator

Academic Year	Development	Experimentation summary and Research Sites
2007/2008	Expert System Rule development Wireless Connectivity Website to deliver virtually facilitated Simulation Game	Simulation Game in ECE courses during Spring 2008 Preliminary evaluation and refinement of expert rules in sample of EMgt courses
2008/2009	Expert System rule refinement	Evaluation of wirelessly connected virtual facilitator during Fall 2008 to EMgt and ECE courses IDE course evaluation in two sections during Spring 2009.
2009/2010	Expert System rule refinement Possible computational analysis to unearth additional patterns of behavior by expert facilitators	Expansion of research into more sections of IDE course and into Stephens College students.
2010/2011	Additional refinement of rules and technology	Doctoral student dissertation completion targeted Invitations to expand collaboration to other institutions
2011/2012	Development of CD/DVD with virtual facilitator installer to ease dissemination of research to other educational institutions	Comparison of alternative rule sets for interventions as other expert facilitator approaches are considered. Broad dissemination

Figure 4. Key activities during the five-year research process.

Data Collection and Analysis

The collaborative research project involving the University of Michigan, Lawrence Technological University, and California Polytechnic State University presents an interesting example of the possibilities of coordinating the collection and analysis of data for purposes of improving engineering education. (See Figure 12.)

Focusing on the "highly publicized" ethical lapses in the sciences and engineering, Cynthia Finelli and her colleagues (Grant Number 647532) proposed to conduct a national assessment of educational experiences and student context "that positively influence the ethical development of engineering undergraduates." The HPLE-funding project has three objectives:

1. Validate an empirical model of the ethical development of engineering undergraduates;
2. Assess the impact of educational experiences and student context on ethical development; and
3. Identify and disseminate factors that have the most positive impact on ethical development.

To realize this goal of a national assessment, the collaborators have established relationships with a set of partner institutions. These 16 partner institutions (listed in Figure 12) have agreed to serve as sites for focus group visits, and have agreed that their engineering undergraduates can be surveyed during the research phase of this project.

Input variables of interest to the researchers include: curricular experiences, extracurricular experiences, student characteristics, and institutional culture.

During an interview with STPI staff, Finelli noted that the close cooperation of the collaborating PIs made it possible to anticipate the successful collection and analysis of data across this wide range and geographically disparate set of institutions. By 2008, the project team had conducted a series of focus groups and refined their skills in qualitative research data collection and analysis.

Figure 12: Excerpt from HLPE Grant Number 647532

A Holistic Assessment of the Ethic Development of Engineering Undergraduates
C. Finelli, University of Michigan
With D. Carpenter, Lawrence Technological University (HLPE Grant Number 647460) and
T. Harding, California Polytechnic State University (HLPE Grant Number 647929)

This importance of graduating more ethical engineers underscores the necessity to assess the current state of engineering undergraduates' ethical development and to identify factors that have a positive impact on this proficiency. Therefore, the PIs propose to conduct this critical investigation, and they will employ an empirical model for ethical development that consists of three components: *knowledge of ethics*, *ethical reasoning*, and *ethical behavior*. The first component, *knowledge of ethics*, is clearly an important aspect of ethical development and is included in some way by all engineering programs as required by ABET. However, the mode of delivery and effectiveness of these approaches vary widely, and the extent to which they promote *ethical reasoning ability* (the second component of ethical development) may be lacking [8, 9, 24]. Further, based on high rates of cheating among engineering undergraduates (described later in this proposal), students do not universally exhibit *ethical behavior*, the third component of ethical development. As such, the PIs are confident that current approaches to teaching engineering ethics are, on the whole, not adequate in influencing the ethical development of engineering undergraduates.

Figure 1. Empirical Model of the Ethical Development of Engineering Undergraduates

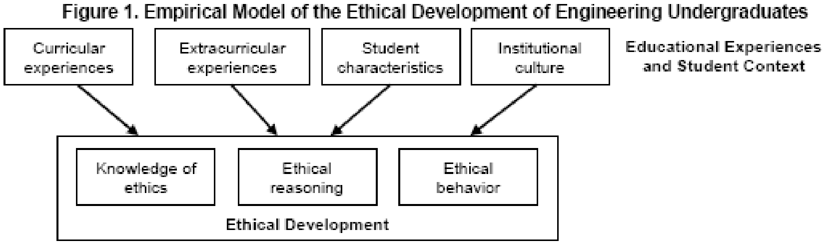


Table 1. Partner Institutions, Enrollment Data, and Information Pertaining to Student Recruitment

	Institution	Total engineering undergraduate population	Target number of participating students	Percent of eligible students to be recruited
DRE	Pennsylvania State University	5667	250	4.4%
	Iowa State University	4690	250	5.3%
	University of Florida	4454	250	5.6%
	University of California, San Diego	4273	250	5.9%
DRI	Michigan Technological University	3032	250	8.2%
	University of Missouri, Rolla	2766	250	9.0%
	University of Central Florida	2451	250	10.2%
	San Diego State University	1736	250	14.4%
MA	California Polytechnic State University	5079	250	4.9%
	FAMU-FSU College of Engineering	1987	250	12.6%
	University of North Carolina, Charlotte	1364	250	18.3%
	University of Texas at San Antonio	1168	250	21.4%
BAS	Rose Hulman Institute of Technology	1638	350	21.4%
	South Dakota School of Mines and Technology	1364	350	25.7%
	Cooper Union	476	150	31.5%
	West Virginia University Institute of Technology	456	150	32.9%
	Total	42,601	4000	9.4%

To enhance project dissemination, the PIs will maintain the E^3 Web site. The site (http://www.engin.umich.edu/research/e3/) currently contains biographical sketches for the project personnel, descriptions and summaries of results for previous projects, links to the team's publications,

Application

The results of education research often have profound implications for the actions that might be taken to improve instruction.

The work of Anne Spence (Grant Number 212101) to increase the enrollment and diversity of students in college engineering programs through more effective mathematics instruction at the high school level offers important insights into the challenges at this step in the research process. (See Figure 13.)

After devoting considerable attention to the design of a curriculum kit for use in Algebra classrooms, Spence conducted five-day summer workshops for in-service mathematics teachers. Spence worked with the Maryland State Department of Education (MSDE) to make certain that the content of the experimental curriculum conformed to MSDE Content Standards in mathematics.

Spence's proposal included after-school activities for six months for students interested in engineering, culminating in an annual competition. Annual reports filed by Spence indicate that the CD developed through this HPLE project was in use at over 20 schools in Maryland and that the PI had an opportunity to publish information about this approach in a publication of the National Council of Teachers of Mathematics.

The necessary involvement of the State Department of Education, teacher training, and opportunities for follow-up studies by the students demonstrates the need for education researchers to understand the system within which their research will be conducted – as well as negotiating with each partner in that educational infrastructure.

Communication of Findings to the Research and Education Communities

Perhaps one of the most critical features of scientific research is the communication of findings to peers. It is through dialogue with other researchers – and educators – that the research methods and findings undergo the scrutiny needed for the findings to gain acceptance in the community.

Cynthia Paschal (Grant Number 343607) became interested in exciting a broader range and greater number of learners in the field of biomedical imaging (BMI). She proposed three specific aims for the HPLE-funded research project:

1. To develop and test safe, inexpensive hands-on exercises and challenge-based learning activities designed to teach the principles of BMI to undergraduate biomedical engineers and high school science students;
2. To design, implement, and distribute these learning activities and exercises electronically with encapsulated video and still images of BMI experts, including many women and minorities, sharing their knowledge and experiences in the field of BMI; and

Figure 13: An Excerpt from HLPE Grant Number 212101

Introducing Engineering through Mathematics

A. Spence, University of Maryland, Baltimore County

Goal: This project seeks to increase student enrollment and student diversity in college engineering programs throughout the state.

Objectives relating to goal:

1. Develop four CD curriculum kits, each one targeting a different aspect of engineering (chemical, electrical, civil, and mechanical) that can be used in both middle and high school algebra classes.
2. Provide a five-day summer workshop for 30 in-service mathematics teachers and 10 undergraduate engineering Teaching Fellows. This workshop will give an introduction to engineering career opportunities and an overview of the curricula on the CDs prior to classroom use.
3. Develop an undergraduate engineering Teaching Fellows program targeting women and other underrepresented minorities to provide hands-on instructional classroom support for middle and high school algebra teachers to help them integrate the CD curricula into their courses. The Fellows program will also support the long-term retention of current engineering students, particularly underrepresented groups.
4. Maintain student interest in engineering at eight schools through the development and institutionalization of an after-school engineering program that culminates in a series of collaborative and competitive activities.
5. Increase the involvement of females and other underrepresented groups in engineering by providing female and minority engineering role models in the classroom and developing curricula that encourage interest and participation by all groups.

Simple algebraic formulas will be constructed around the activities. (Without electricity, you might be in the dark. What's the chance of selecting an AA battery that works from a drawer holding 15 batteries, only three of which are not dead on the first try?) Upon completion of these experiments, the undergraduate student would introduce an important algebraic concept used in engineering. In this case it would be Ohm's Law:

$\mathbf{V} = \mathbf{I} \cdot \mathbf{R}$ where **V** is voltage, **I** is current, **R** is resistance.

For more gifted students, the teacher may introduce Kirchhoff's voltage law.

$$\sum_{j=1}^{k} V_j = 0$$

The application of these equations to the set of experiments can be related to the Algebra/Data Analysis Content Standards sections 6.0, 7.0, 8.0, 9.0., and 10.0. This will be achieved by having the students analyze each of the experiments that were done, and identify how the Ohm's law (and Kirchhoff's law, if applicable) relates to each of the problems. All curricula will be developed to create a clear connection between the algebraic concepts and the engineering application as suggested below.

MSDE Goal	Description	CD Kit	Learning Objective	Evaluation Method
6.0	Knowledge of Number Relationships and Computation	Electricity and Stored Energy	Calculation of terms in Ohm's (and Kirchhoff's) law; understanding the connection between and importance of a variable and a "real world" value.	Experimental observations, and lab assignment, assessment tool.
7.0	Process of Problem Solving	Electricity and Stored Energy	Determine information needed or missing to solve equations; look up values of relative charge. Acquire data, use a computational spreadsheet to generate voltage vs. resistance graphs; analyze results.	Experimental observations, use of reference materials, and lab assignment.
8.0	Process of Communication	Electricity and Stored Energy	Analysis of observed results of the experiments would be graphed to give a visual display of observations. Description of the reasoning process predict/analyze each successive experiment.	Experimental observations, lab assignment and pre-experiment prediction.
9.0	Process of Reasoning	Electricity and Stored Energy	Prediction of results of some experiments based on previous results. Give the students a flashlight to take apart and demonstrate their knowledge of the use and application of Ohm's (and Kirchhoff's) law in order to explain how a flashlight works.	Experimental observation, lab assignment, and post experiment analysis.
10.0	Process of Connections	Electricity and Stored Energy	Identify relationship between numbers and graphed data. Identify examples of electricity and how it works in their everyday life.	Experimental observations, lab assignments and post experiment analysis.

http://www.umbc.edu/engineering/me/engreducation/index.htm

To carefully assess the impact of these activities and exercises on learning and retention of engineering principles of BMI and on motivation for BMI/BME careers.

Figure 14 provides further details of the research design.

Annual reports filed by Paschal report a series of research and education activities characteristic of this HPLE grant. Specifically, Paschal and her colleagues presented the results of their research not only to the annual conference of the American Society of Engineering Education (2005 and 2006), but also to the annual meeting of the Biomedical Engineering Society (2004), and the regional convention of the National Science Teachers Association (2005) as well as the national conference that convened the same year (2005).

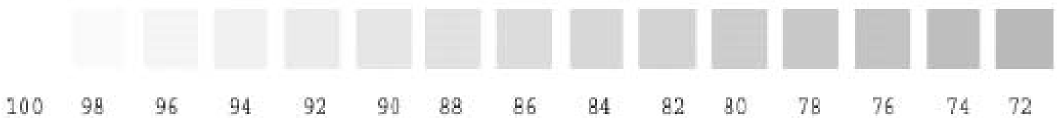
The diversity of professional societies where Paschal and her colleagues have presented their findings reflects the challenges faced by researchers conducting multidisciplinary research.

Figure 14: Excerpt from HLPE Grant Number 343607

Biomedical Imaging Education: Safe, Inexpensive Hands-on Learning

C. Paschal, Vanderbilt University

The use of actual biomedical imaging equipment for education, while desirable for real-life hands-on learning, is typically not feasible due to safety concerns, high cost, and lack of availability. It is possible to purchase for laboratory use small x-ray tubes and radiolabeled compounds similar to those used for x-ray based or radionuclide imaging techniques, respectively. However, exposure to such sources of ionizing radiation is associated with a number of safety risks including serious skin burns [3] and increased cancer risks [4]. Safety risks aside, the cost of biomedical imaging equipment prohibits its purchase solely for hands-on education with small x-ray tubes without detection systems starting at about $2,000, complete ultrasound systems running $80K to $200K, and MRI units on the order of a million dollars or more. These equipment costs, coupled with siting costs, are far greater than nearly any educational program can afford. While biomedical imaging equipment abounds in the radiology departments of any major medical center, the availability of such equipment for learning purposes is extremely limited due to the requisite priority patient examinations have for the machines. Also, while many undergraduate BME programs are housed next to a major medical center, many are not, and certainly very few high schools have close ties to medical centers.



The learner tapes the light intensity scale to a wall and sets up the lamp to shine on the scale. When ready, the learner takes a piece of foil with a hole the diameter of a thick pencil and places it over the lamp. (The learner is cautioned to not leave the foil on the lamp long while the lamp is on, as heat will be trapped and increase the risk of bulb breakage.) The learner then darkens the room, holds up a piece of transparency film, and matches the intensity of the resulting shadow with a square on the scale as shown in Figure 1. After recording this intensity in a data table (Table 1), the learner then repeats this process with two sheets of transparency film, then three, and so on.

Figure 1. Using visible light and transparency film to model attenuation of x-rays by an object.

Table 1. Light attenuation exercise

Thickness (# of sheets)	Light Intensity (% white)
0	100
1	
2	
3	
4	
5	
6	
7	

The learners are next asked to plot the natural logarithm of the shadow's light intensity versus the thickness of the attenuator for thicknesses 0 through 5 and to add a best fit line.

The learners are then asked to discuss several questions including the following:

- Do your data points fall along a relatively straight line? What does the equation of the fit line for your plot tell you about the relationship between attenuator thickness and the intensity of the shadow? (At some point during or after this discussion, learners conclusions are reinforced or corrected as needed by being informed of the basic relationship of Beer's law: $\frac{Intensity}{I_o} = e^{-\mu * Thickness}$)
- What is the attenuation coefficient, μ, of the transparency film? What are the units of μ?

Outputs

A final step in this early assessment of the HPLE program involves the specification of outputs – that is, the products of the research activities comprising the EEC HPLE portfolio. STPI identified five areas in which to examine the outputs of these HPLE grants:

1. Evidence for innovative research strategies;
2. The development of new tools, courses and/or curricula;
3. Training or other workshops;
4. Websites and digital libraries; and
5. Conference presentations, publications.

Unlike the previous section which presented exemplars of research in these categories, we will consider the sheer volume of outputs given the 34 active grants in the HPLE portfolio in 2008 – discounting the 3 “conference” grants mentioned earlier.

The basis for this characterization of outputs is two-fold, involving a careful analysis of each annual report filed by the HPLE PIs, supplemented further through discussions with a sample of grantees. The review simply yielded information on the “presence” or “absence” of certain outputs during the administrative file analysis and/or PI interview.

Appendix D presents a summary of STPI tabulations by grant and by output category.

The sections that follow highlight key findings.

Innovative Research Strategies

By 2008, thirty of the thirty-seven grantees had “operationalized” the concepts of interest to them – as recorded in the annual reports file by the PIs and/or discussions with STPI staff. STPI notes that several grants yielded especially “innovative” research strategies as evidenced by the interest of researchers within and outside the engineering research community. One example comes from the work of Donna Riley (Grant Number 448240) in the area of pedagogies that encourage all voices to be heard in a “democratic classroom.” This five-year project focuses on the development of research strategies to understand how women students conceptualize their identities as engineering students and/or future engineers. Riley utilizes a blog-based tool for self-reflection – and then uses a rubric style technique to analyze the narrative data. Riley has presented information about the tools for assessing “liberative pedagogies” to researchers within the field of engineering as well as to education researchers interested in gender and professional identities.

New Tools, Courses, and/or Curricula

By 2008, twelve HPLE grantees produced materials designed to advance engineering education and student learning. (See Appendix D.) Lisa McNair and her colleagues (Grant Number 648439) are working to discover patterns of interdisciplinary teaming that can inform engineering education pedagogy. Professor McNair holds a doctoral degree in Linguistics and has taken a specific interest in the role of “metaphor” and “analogy” to communicate concepts across disciplines.

Training or Other Workshops

A number of grantees have incorporated workshop activities into their HPLE research activities – whether for purposes of training or for disseminating research results. A total of 17 grantees reported on their workshop activities in the course of filing their annual reports (excluding the three conference grantees mentioned earlier). Maura Borrego (Grant Number 643107) is developing a theory “describing the circumstances under which engineers develop” awareness of truly interdisciplinary research. Motivated by the increasing globalization and international competition characteristic of contemporary society, Borrego utilizes interdisciplinary workshops as a way to integrate the results of her research with the educational application of her findings.

Websites and Digital Libraries

Several HPLE grantees report the establishment of a website for purposes of disseminating the results of their HPLE-funded research or as part of their educational research activities.

Carlos Montemagno (Grant Number 649914) has developed a brochure to make high school students aware of the undergraduate research opportunities at the University of Cincinnati – which he makes available at www.eng.uc.edu/coop/ResearchCoopRev.pdf. The brochure and the website are only incidental products of the larger effort to establish an Undergraduate Research Cooperative Education program modeled on a program with industry.

Conference Presentations, Publications

The STPI review of HPLE outputs included an analysis of patterns of research presentations – whether as poster sessions or as papers presented at national conferences. The vast majority of HPLE grantees who filed annual reports indicated that they routinely presented findings at ASEE conferences. Far fewer grantees reported publishing research findings in peer-reviewed journals or in book form.

A notable exception is the output from the grant to Julie Benyo (Grant Number 550710). This HPLE funding has enabled WGBH Boston to develop methods for introducing college-bound girls to young women engineers, who embody project messages. The results of these activities have been documented in part in a book published in 2006 entitled Changing Our World: True Stories of Women Engineers.

Outcomes and Impacts

The STPI review of the early outcomes of the HPLE grants program has yielded important insights into the characteristics of the grants portfolio – who receives support and how the grantees organize collaboratively to tackle the challenging research design and data collection efforts in engineering education research. STPI provided examples of the ways in which grantees approached specific research activities – how they introduced innovations into data collection and tool development. We have shown that the grantees actively communicate their findings to peers – but have concluded that there is little evidence for dissemination of research findings beyond the engineering research community with the exception of only a few cases.

To complete this assessment, STPI reviewed the stated project objectives – summarized in Appendix E of this report. These statements are useful for estimating near-term and longer-term outcomes and impacts of these research activities, as proposed by the principal investigators.

It is worth noting that HPLE grantees are quite prolific with respect to the development of education-related materials, which is in keeping with many of the stated project goals. By 2008, most grantees had developed tool kits, models to facilitate learning, or specific courses/curricula as a result of HLPE funding. Some established websites to make the results of their research available to educators, other researchers, and students.

- It was common for the grantees to report that curricular materials had been adopted in the parent or collaborating institution;
- Few HPLE grantees reported widespread adoption of HPLE-based education materials or practices by 2008, perhaps due in part to the limitations of the progress/final reports to document the outcomes and impacts of these grants.

In order to estimate the adoption of materials and/or curricula locally or nationally, more formal and longer-range assessments of the outcomes and impacts of these HPLE grants are needed.

- Publication and citation analyses would be useful to demonstrate that HPLE-supported grantees actively publish their results in peer-reviewed journals – and that their work is cited;
- Longitudinal outcome assessments are needed to track the extent to which HPLE-based ideas have been embraced by the engineering education community in the U.S. and abroad.

Many HPLE grantees expressed an interest in creating a more talented and diverse student body at all levels of engineering education through their NSF-funded research.

To accurately gauge the impact of such research efforts, longitudinal assessments of the flow of engineering talent nationally would be needed. It is feasible to measure such an impact locally through careful record keeping – and some HPLE grantees offered evidence in support of such efforts.

Given the limited size and scope of the NSF HPLE program, it would be difficult to demonstrate that the program is responsible wholly or in part for the changes that are observed in the size and composition of the entire U.S. engineering workforce at a later point in time. A more effective strategy to gauge the benefits of the NSF HPLE program would be for the NSF to encourage HPLE grantees to document the local outcomes and impacts through improved annual reporting practices. Such information might be used by the Foundation at a later stage to promote broader dissemination of certain of these education efforts.

> *At its core, scientific inquiry is the same in all fields. Scientific research, whether in education, physics, anthropology, molecular biology, or economics, is a continual process of rigorous reasoning supported by a dynamic interplay among methods, theories, and findings. It builds understandings in the form of models or theories that can be tested. Advances in scientific knowledge are achieved by the self-regulating norms of the scientific community over time, not, as sometimes believed, by the mechanistic application of a particular scientific method to a static set of questions.*
>
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Appendix A: Profile of NSF HPLE Grants Active in FY 2008

Award Number	Title	Principal Investigator	Institution	Start Date	End Date	Amount
212101	Introducing Engineering Through Mathematics	Anne Spence	University of Maryland, Baltimore County	9/1/2002	8/31/2008	$374,930
237135	Designing Effective Teams in the Engineering Classroom for the Enhancement of Learning	Stephanie Adams	University of Nebraska, Lincoln	2/15/2003	1/1/2009	$643,418
343607	Biomedical Imaging Education: Safe, Inexpensive Hands-on Learning	Cynthia Paschal	Vanderbilt University	12/1/2003	11/30/2008	$299,464
343862	Improving and Assessing the Spatial Ability of Engineering Students Using a CAD Integrated Physical Model Rotator	Brad Kinsey	University of New Hampshire	5/1/2004	4/30/2008	$311,110
415962	Optimizing the Interdisciplinary Course: Introduction to Electrical Engineering (EE) for Non-EE Majors	Seyed Zekavat	Michigan Technological University	9/1/2004	8/31/2008	$554,873
448240	Liberative Pedagogies in Engineering Education	Donna Riley	Smith College	2/1/2005	1/31/2010	$404,813
547599	Achieving Diversity in Engineering Education: Cultivating Student Self-Efficacy	Deborah Follman	Purdue University	3/1/2006	2/28/2011	$529,624
550169	Developing Ontological Schema Training Methods to Help Students Develop Scientifically Accurate Mental Models of Engineering Concepts	Ronald Miller	Colorado School of Mines	7/1/2006	6/30/2009	$755,163
550403	Teaching Sustainability in Engineering Through Public Scholarship	David Riley	Pennsylvania State University	6/15/2006	5/31/2009	$400,000
550710	Extraordinary Women Engineers	Julie Benyo	WGBH Educational Foundation	10/1/2006	9/30/2009	$1,600,000

Award Number	Title	Principal Investigator	Institution	Start Date	End Date	Amount
632839	Engineering Leadership Through Problem Definition and Solution	Gary Downey	Virginia Polytechnic Institute and State University	7/1/2006	6/30/2008	$199,601
638762	Students' Perceptions of Value and Need for Mentors as They Progress Through Academic Studies in Engineering and Science	Carol Muller	MentorNet	9/15/2006	2/29/2008	$199,978
639895	Engineering in Context: An Investigation of How Experts and Students Incorporate Global and Scientific Issues in Their Engineering Design Processes	Cynthia Atman	University of Washington	9/1/2006	8/31/2008	$199,876
643107	Interdisciplinary Graduate Education in Engineering	Maura Borrego	Virginia Polytechnic Institute	9/15/2006	8/31/2011	$525,412
644796	Colleges of Engineering as Learning Organizations: Implications for Student Intellectual Development	Jennifer Karlin	South Dakota School of Mines	9/15/2006	8/31/2011	$531,739
644917	Development and Evaluation of Portable, Computationally Intelligent Team Training	Ray Luechtefeld	University of Missouri, Rolla	9/15/2006	8/31/2011	$554,624
645736	Accelerating Development of Engineering Education as a Discipline via Organized Dialogue	Jeffrey Froyd	Texas A&M University	9/15/2006	8/31/2008	$199,687
647460*	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Daniel Carpenter	Lawrence Technical University	3/1/2007	2/28/2011	$120,953
647532*	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Cynthia Finelli	University of Michigan	3/1/2007	2/28/2011	$548,181

Award Number	Title	Principal Investigator	Institution	Start Date	End Date	Amount
647915	InTEL: Interactive Toolkit for Engineering Education	Sue Rosser	Georgia Institute of Technology Research Corporation	3/1/2007	2/28/2010	$899,791
647929*	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Trevor Harding	California Polytechnic State University	3/1/2007	2/28/2011	$181,669
648161	Integrating Virtual Experiments and Hands-on Labs -- A Synergistic Approach to Enhance Engineering Education (Project IVEHOL)	Doyle Davis	New Hampshire Technical College at Berlin	3/1/2007	8/31/2009	$399,966
648190	Using Constructivist Teaching Strategies in Engineering Education : Gauging the Impact on Student Learning and Retention	Kingsley Reeves	University of South Florida	3/1/2007	2/28/2009	$411,996
648210	A Women in Engineering Knowledge Center: Informing Research, Practice and Institutional Change	C. Diane Matt	WEPAN, Inc.	6/15/2007	5/31/2010	$597,970
648267	Aligning Educational Experiences with Ways of Knowing Engineering: Improving Learning from Middle School Through Professional Practice	Sandra Courter	University of Wisconsin, Madison	7/1/2007	6/30/2010	$998,619
648316	Exploring the Role of Computational Adaptive Expertise in Design and Innovation	Ann McKenna	Northwestern University	6/1/2007	5/31/2010	$499,919
648380	Expansion of "How People Learn" Metrics in Engineering Classrooms	Monica Cox	Purdue University	3/1/2007	8/31/2009	$190,340
648439	Preparing Engineering Students for the Challenges of Interdisciplinary Team Design	Lisa McNair	Virginia Polytechnic Institute and State University	3/1/2007	2/28/2010	$475,475

Award Number	Title	Principal Investigator	Institution	Start Date	End Date	Amount
648487	ADEPT: Assessing Design Engineering Project Classes with Multi-Disciplinary Teams	Daniel Siewiorek	Carnegie-Mellon University	6/1/2007	5/31/2010	$500,000
648568	Empirically-based Instructional Tools for Fostering Engineering Problem Solving and Cognitive Flexibility in Precollege Students	Martin Reisslein	Arizona State University	3/1/2007	2/28/2011	$1,249,634
649914	Cooperative Education for Research Careers	Carlo Montemagno	University of Cincinnati	9/15/2006	8/31/2008	$200,000
732207	Building Connections Within the Engineering Education Research Community	Odis Griffin	Virginia Polytechnic Institute and State University	5/1/2007	4/30/2008	$153,691
743223	Engineering Education for the Global Economy: Research, Innovation, and Practice	Frank Huband	American Society for Engineering Education	10/1/2007	9/30/2009	$99,964
747795	Advancing Engineering Education through Learner-centric, Adaptive Cyber-tools and Cyber-environments	Krishna Madhavan	Clemson University	2/1/2008	1/31/2013	$511,824
747803	An Examination of Graduate Education's Role in Preparing Engineering Students for Careers in Academia and Industry	Monica Cox	Purdue University	8/1/2008	7/31/2013	$541,507
748005	Intentional Seredipity, Cognitive Flexibility, and Fluid Identities: Cross-disciplinary Ways of Thinking, Acting and Being in Engineering	Robin Adams	Purdue University	9/15/2008	8/31/20013	$495,830
748186	Advancing Adaptive Expertise in Engineering Education	Helen Martin	University of Texas at Austin	9/15/2007	8/31/2012	$400,000
						$17,761,641

* NSF grant numbers 647460 (Lawrence Technical University), 647532 (University of Michigan) and 647929 (California Polytechnic State University) represent a joint collaboration.

SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

Appendix B: Study Questions Guiding the STPI Analysis of the NSF HPLE Grants Program

1. Basic Characterization of Portfolio:	
1.1.	Investigators who receive EEC grants - Is this the right group of people?
	1.1.1. What institutions are they from?
	1.1.2. What departments are they in?
	1.1.3. What is their field of highest degree?
1.2.	Funding structure of the grant - Are they spending the funds well?
	1.2.1. Who/what does the grant support (faculty/students/other)
	1.2.2. General budget characterization
1.3.	Composition of the research team - Are there interdisciplinary teams of researchers and users?
	1.3.1. Undergraduate students at the school
	1.3.2 Graduate students at the school
	1.3.3. Other researchers/professors
	1.3.4. People from outside academia
	1.3.5. Is there an external evaluator for the award?
1.4.	Characterization of the schools receiving the awards
	1.4.1. Listing of schools, breakdown by type (research vs. teaching institutions, accepted rankings, schools with a history of leadership in engineering education vs. developing programs)
1.5. Other	
	1.5.1. General characterization by education level focus, type of pedagogical method, etc.
2. Portfolio Level: To what extent is the program contributing to the aims and objectives of engineering education research and practice, as articulated by the community?[1] To what extent do program goals map on to the goals of the community?	
2.1.	How do the individual grant goals and activities align with stated objectives of engineering education research and practice?
3. Portfolio Level: To what extent is the program-funded research producing new and relevant insights on how students learn problem solving, creativity, and design?	
3.1.	What suite of methods did the grant investigate (e.g., pedagogical methods; research-based, cooperative, or hands-on learning methods; team learning, etc.) to explore how students learn problem solving, creativity, and design?
3.2.	What insights has the grant produced on how students learn engineering?

4. Portfolio Level: To what extent is the program-funded research producing new and relevant insights in developing new methods for assessment and evaluation of how students learn engineering?	
4.1.	Has the grant developed (or is it developing) tools and other diagnostics to measure how students learn?
4.2.	Were they applied in classroom settings?
5. Portfolio Level: To what extent is the program-funded research producing new and relevant insights on how to attract a more diverse student body to all levels of engineering study?	
5.1.	Did the grant focus on examining diversity?
5.2.	(For the relevant grants) What insights did the research produce regarding attracting a diverse student body?
6. Portfolio Level: To what extent are the insights from the program being translated into classroom change?	
6.1.	What is the "footprint" of the grant in terms of traditional (e.g., publications) and non-traditional (e.g., classroom implementation, digital libraries) outputs and outcomes? What is the quality of the outputs of the grant to-date? How are they being used?
	6.1.1. Publications and citation frequency
	6.1.2. Workshops and conferences: dissemination/value of information
6.2.	In what way does the grant research team involve faculty members or teachers who teach engineering? Have there been translational impacts (such as improved student learning (how would we know))?
	6.2.1. Did the grant develop new a curriculum or improve the content of existing curricula?
	6.2.2. Did the grant develop a new class or revamp the teaching methods within a class?
	6.2.3. Are there other translational activities that have occurred?
6.3.	To what extent has the grantee developed new collaborations with other institutions, other departments within the institution, area K-12 education, or other community parties?
7. Portfolio Level: Outcomes and Impacts	
7.1	To what extent is the program developing/nurturing the emerging field/community of engineering education research?
7.2	How well-managed is the program? Are there deficiencies? What are they? How can program management be improved?
7.3	How big a player is NSF in the engineering education (research and implementation) community? Who are the other funders?
7.4	Is funding adequate? How much more would be better? Are there other things NSF can do (e.g., Mechanisms to create and collaborations)?
7.5	How would you suggest measuring the outcome of an HPL "insight"?
[1] Special Report: The National Engineering Education Research Colloquies. October 2006. Journal of Engineering Education.	

Appendix C: STPI Interview Partitioning Strategy and Questions for a Sample of NSF HPLE Grantees

Part of the STPI analysis of the HPLE program involved interviewing a sample of Principal Investigators (PIs). STPI utilized four categories for partitioning the population of 37 grantees:

- Educational focus of the HPLE grant;
- Department of the PI;
- Type of pedagogy, and
- Whether or not the grant focuses on increasing the diversity and talent of the engineering student body or workforce.

STPI also made an effort to interview PIs supported by “older” vs. “newer” awards, categorizing the awards as “old” if they started in or before 2005. Below are tables with the population (N) and sample (n) of awards for interviewing within each category.

Appendix Table C.1: Educational Focus of the HPLE Grant

	K-12	**Undergraduate**	**Graduate**
Older awards	N=2, n=1	N=6, n=1	N=1, n=1
Newer awards	N=3, n=3	N=22, n=4	N=7, n=4

Appendix Table C.2: Department of the PI

	Engineering	**Education or Other**	**Not Applicable**
Older awards	N=6, n=1	N=0, n=0	N=0, n=0
Newer awards	N=13, n=4	N=13, n=5	N=3, n=0

Appendix Table C.3: Type of Pedagogy

	Student-Centered	Teacher-Centered
Older awards	N=4, n=1	N=0, n=0
Newer awards	N=15, n=4	N=3, n=3

Appendix Table C.4: Focus on Attracting a More Diverse and Talented Student Body?

	Focus on Attracting Diversity/Talent?
Older awards	N=2, n=1
Newer awards	N=3, n=2

Appendix Table C.5: Partitioned Awards

Partition	Older Awards	Newer Awards
Educational focus: K-12	212101	550710; 648267; 648568
Educational focus: Undergraduate	343862	648316; 639762; 648161; 649914
Educational focus: Graduate	237135	550403; 644917; 643107; 747803
Department of PI: Engineering	415962	648487; 639895; 645736; 732207
Department of PI: Education or other discipline		632839; 647915; 648439; 748186; 743223
Type of pedagogy: Student-centered	448240	644796; 684190; 648380; 747795
Type of pedagogy: Teacher-centered		550169; 748005; 647460
Diversity focus	343607	648210; 547599

STPI developed a "Generic Interview Protocol" to guide discussions with this sample of PIs, probing for information in such areas as:

1. Research portfolio;
2. Program level goals;
3. How students learn engineering;
4. Assessment and evaluation methods for engineering education;

5. Diversity; and
6. Translational activities.

Questions asked of each PI were drawn from the following pool of potential questions. The mix of questions asked of any PI was determined by the type of information available to STPI through the HPLE proposal and/or annual reports. The purpose of this set of interviews was to supplement information not readily available in these sources.

What type of pedagogy does your research employ?

How did you choose this pedagogical method for your purpose?

What are the program goals you laid out for your award?

Probing: What outcome do you envision from your research? Similarly, what would be the ideal outcome of your work?

What methods did you/will you investigate during the course of the award?

What insights has the research produced on how students learn engineering?

Have you developed/do you plan to develop tools or diagnostics to measure how students learn?

Which assessment tools do you employ in your research?

Will your assessment strategy produce a replicable tool that others can use in the course of engineering education research?

Were these tools applied in classroom settings?

Have these tools been accepted by the engineering education community?

Which elements (if any) of your project focused on attraction and/or retention?

What conclusions did you/do you expect to draw from your attraction/retention methods? In effect, which methods did you find most effective in attracting underrepresented groups to engineering?

Were they different from the methods you used for retention?

(For PIs who have completed or plan to complete a workshop or conference as part of their award) Please describe the type of conference or workshop you have carried out under this award.

In your opinion, what are the most important outcomes of the conference? Probing: forging collaborations, presentation of results, dissemination of a new teaching method or tool?

Under this award, did you alter or add new curricula?

Have you had a chance to measure the outcomes? What are they? If not, what do you expect the outcomes to be?

Under this award, did you change the way a class was taught or add a new class to the curriculum?

Have you had a chance to measure the outcomes? What are they? If not, what do you expect the outcomes to be?

What collaborations have been forged over the course of this grant?

To what extent is the program developing/nurturing the emerging field/community of engineering education research?

How well-managed is the program? Are there deficiencies? What are they? How can program management be improved?

How big a player is NSF in the engineering education (research and implementation) community? Who are the other funders?

Was funding for your grant adequate? How much more would be better? Are there other things NSF can do (e.g., Mechanisms to create and collaborations)?

Could you have accomplished what the NSF funding allowed you to, without NSF funding (i.e., with other funding)? How?

How would you suggest measuring the outcome of an HPL "insight"?

Probing: e.g., years to completion of degree, grades, job placement, performance in workplace, percent going on to graduate study, retention

Appendix D: Selected Outputs of NSF HPLE Grantees by Research Focus as of 2008

Research Focus	Award Number	Title	Principal Investigator	Start Date	Operationalized Concepts	Poster Sessions	Presen-tations	Pubs**	Workshops	Website
Problem-Solving, Creativity, Design										
	343862	Improving and Assessing the Spatial Ability of Engineering Students Using a CAD Integrated Physical Model Rotator	Brad Kinsey	5/1/2004	Model		x		x	
	550169	Developing Ontological Schema Training Methods to Help Students Develop Scientifically Accurate Mental Models of Engineering Concepts	Ronald Miller	7/1/2006	Schema					
	639895	Engineering in Context: An Investigation of How Experts and Students Incorporate Global and Scientific Issues in Their Engineering Design Processes	Cynthia Atman	9/1/2006	x		x	x		
	643107	Interdisciplinary Graduate Education in Engineering	Maura Borrego	9/15/2006	x				x	
	647460*	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Daniel Carpenter	3/1/2007	x		x		x	
	647532*	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Cynthia Finelli	3/1/2007	x		x		x	x
	647929*	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Trevor Harding	3/1/2007	x		x		x	
	648316	Exploring the Role of Computational Adaptive Expertise in Design and Innovation	Ann McKenna	6/1/2007	n/a		x			

Research Focus	Award Number	Title	Principal Investigator	Start Date	Operationalized Concepts	Poster Sessions	Presen-tations	Pubs**	Workshops	Website
Strengthening the Engineering Education System										
	237135	Designing Effective Teams in the Engineering Classroom for the Enhancement of Learning	Stephanie Adams	2/15/2003	Model			x	x	
	343607	Biomedical Imaging Education: Safe, Inexpensive Hands-on Learning	Cynthia Paschal	12/1/2003	Curriculum		x		x	
	415962	Optimizing the Interdisciplinary Course: Introduction to Electrical Engineering (EE) for Non-EE Majors	Seyed Zekavat	9/1/2004	x		x	x	x	
	550403	Teaching Sustainability in Engineering Through Public Scholarship	David Riley	6/15/2006	Model			x		x
	632839	Engineering Leadership Through Problem Definition and Solution	Gary Downey	7/1/2006	x		x			
	644796	Colleges of Engineering as Learning Organizations: Implications for Student Intellectual Development	Jennifer Karlin	9/15/2006	x				x	x
	644917	Development and Evaluation of Portable, Computationally Intelligent Team Training	Ray Luechtefeld	9/15/2006	Model		x		x	
	648161	Integrating Virtual Experiments and Hands-on Labs -- A Synergistic Approach to Enhance Engineering Education (Project IVEHOL)	Doyle Davis	3/1/2007	x		x		x	
	648380	Expansion of "How People Learn" Metrics in Engineering Classrooms	Monica Cox	3/1/2007	x		x		x	
	648439	Preparing Engineering Students for the Challenges of Interdisciplinary Team Design	Lisa McNair	3/1/2007	Curriculum					
	648487	ADEPT: Assessing Design Engineering Project Classes with Multi-Disciplinary Teams	Daniel Siewiorek	6/1/2007	n/a					

Research Focus	Award Number	Title	Principal Investigator	Start Date	Operationalized Concepts	Poster Sessions	Presen-tations	Pubs**	Workshops	Website
Strengthening the Engineering Education System *(Continued)*										
	747795	Advancing Engineering Education through Learner-centric, Adaptive Cyber-tools and Cyber-environments	Krishna Madhavan	2/1/2008	n/a					
	747803	An Examination of Graduate Education's Role in Preparing Engineering Students for Careers in Academia and Industry	Monica Cox	8/1/2008	n/a					
	748005	Intentional Seredipity, Cognitive Flexibility, and Fluid Identities: Cross-disciplinary Ways of Thinking, Acting and Being in Engineering	Robin Adams	9/15/2008	n/a					
	748186	Advancing Adaptive Expertise in Engineering Education	Helen Martin	9/15/2007	n/a					
Attracting and Retaining a Diversity of Talented Individuals in Engineering										
	212101	Introducing Engineering Through Mathematics	Anne Spence	9/1/2002	Kits	x	x		x	x
	448240	Liberative Pedagogies in Engineering Education	Donna Riley	2/1/2005	Curriculum		x	x	x	
	547599	Achieving Diversity in Engineering Education: Cultivating Student Self-Efficacy	Deborah Follman	3/1/2006	n/a					
	550710	Extraordinary Women Engineers	Julie Benyo	10/1/2006	Outreach messages		x	x	x	x
	638762	Students' Perceptions of Value and Need for Mentors as They Progress Through Academic Studies in Engineering and Science	Carol Muller	9/15/2006	x		x			x
	647915	InTEL: Interactive Toolkit for Engineering Education	Sue Rosser	3/1/2007	Toolkit					x

Research Focus	Award Number	Title	Principal Investigator	Start Date	Operationalized Concepts	Poster Sessions	Presen-tations	Pubs**	Workshops	Website
Attracting and Retaining a Diversity of Talented Individuals in Engineering *(Continued)*										
	648190	Using Constructivist Teaching Strategies in Engineering Education : Gauging the Impact on Student Learning and Retention	Kingsley Reeves	3/1/2007	x				x	
	648210	A Women in Engineering Knowledge Center: Informing Research, Practice and Institutional Change	C. Diane Matt	6/15/2007	x	x			x	
	648267	Aligning Educational Experiences with Ways of Knowing Engineering: Improving Learning from Middle School Through Professional Practice	Sandra Courter	7/1/2007	x		x			
	648568	Empirically-based Instructional Tools for Fostering Engineering Problem Solving and Cognitive Flexibility in Precollege Students	Martin Reisslein	3/1/2007	x		x			
	649914	Cooperative Education for Research Careers	Carlo Montemagno	9/15/2006	Outreach brochure					x
Promoting the Development of Engineering Education Research as a Specialty										
	645736	Accelerating Development of Engineering Education as a Discipline via Organized Dialogue	Jeffrey Froyd	9/15/2006	x				x	
	732207	Building Connections Within the Engineering Education Research Community	Odis Griffin	5/1/2007	x				x	
	743223	Engineering Education for the Global Economy: Research, Innovation, and Practice	Frank Huband	10/1/2007	x				x	x

*Collaborative research award

****"Pubs"** include journal publications and books.

"n/a" refers to the fact that the grantee had not filed an Annual Report as of April 2008; in some cases, STPI gathered output information through PI interviews.

SOURCE: National Science Foundation, 2008. (Tabulations generated by IDA STPI.)

Appendix E: Stated Project Goals of NSF HPLE Grantees

Award Number	Title	Principal Investigator	Proposal: Stated Project Goal
212101	Introducing Engineering Through Mathematics	Anne Spence	This project seeks to increase student enrollment and student diversity in college engineering programs throughout the state.
237135	Designing Effective Teams in the Engineering Classroom for the Enhancement of Learning	Stephanie Adams	The research objective of this career-development plan is to develop, test, and validate a model of effective teaming for the engineering classroom.
343607	Biomedical Imaging Education: Safe, Inexpensive Hands-on Learning	Cynthia Paschal	The overall objectives of this project are (1) to excite the interest of a broader range and greater number of learners in the field of biomedical imaging (BMI), a strong and growing subdiscipline of biomedical engineering (BME) with applications in basic science research, medical diagnosis, and the guidance of therapeutic interventions, and (2) to improve the effectiveness of BMI education.
343862	Improving and Assessing the Spatial Ability of Engineering Students Using a CAD Integrated Physical Model Rotator	Brad Kinsey	In this research, a device will be developed and implemented, which will rotate a physical object synchronously with a model of the object in the computer software, for use in spatial ability training.
415962	Optimizing the Interdisciplinary Course: Introduction to Electrical Engineering (EE) for Non-EE Majors	Seyed Zekavat	The proposed research project will investigate the curricular requirements for multiple non-electrical engineering disciplines, and then develop, evaluate, and disseminate an optimally tailored curriculum to satisfy those requirements.
448240	Liberative Pedagogies in Engineering Education	Donna Riley	The objectives will be: (1) develop and implement curricular innovations based on liberative pedagogies and student input; (2) evaluate curricular and pedagogical changes based on liberative pedagogies using both conventional and critical assessment tools; (3) to understand how women students conceptualize their identities as engineering students and/or future engineers; (4) disseminate results on campus, in local preK-12 education, and throughout the engineering community; and (5) involve students in curricular development based on liberative pedagogies.
547599	Achieving Diversity in Engineering Education: Cultivating Student Self-Efficacy	Deborah Follman	Assess and describe undergraduate engineering student self-efficacy beliefs; measure correlations of self-efficacy beliefs with student achievement, interest, and retention; characterize how the engineering learning environment facilitates or undermines positive belief formation ... ; identify how student levels of self-efficacy...change as students progress through their undergraduate engineering programs...;develop, implement, assess, and refine course practices ...; disseminate findings and practices to faculty, faculty-in-training, advisors and administrators...

Award Number	Title	Principal Investigator	Proposal: Stated Project Goal
550169	Developing Ontological Schema Training Methods to Help Students Develop Scientifically Accurate Mental Models of Engineering Concepts	Ronald Miller	We propose to test Chi and Slotta's theory of emergent phenomena by creating effective schema training protocols and materials for helping engineering students create appropriate mental models of fundamentally important dynamic processes operating at small length scales.
550403	Teaching Sustainability in Engineering Through Public Scholarship	David Riley	This proposal seeks resources to understand more fully the contributions of Public Scholarship to sustainability education in engineering by broadening the assessment of student learning outcomes to three additional engineering courses focused on sustainable engineering design at two universities.
550710	Extraordinary Women Engineers	Julie Benyo	The ultimate goal of this project is to encourage academically prepared high school girls to consider engineering as an attractive option for post-secondary education and subsequent careers.
632839	Engineering Leadership Through Problem Definition and Solution	Gary Downey	The purpose of this project is to support longitudinal ethnographic research assessing the extent to which the problems of leadership, diversity, and globalization in engineering education can be understood and addressed as problems of knowledge and curriculum.
638762	Students' Perceptions of Value and Need for Mentors as They Progress Through Academic Studies in Engineering and Science	Carol Muller	MentorNet proposes a small grant for exploratory research in STEM education related to students' perceptions of the value and need for mentors as they progress through their academic students in engineering and science.
639895	Engineering in Context: An Investigation of How Experts and Students Incorporate Global and Scientific Issues in Their Engineering Design Processes	Cynthia Atman	The goal of the proposed work is to conduct research that can be used as the basis for developing these learning experiences and assessment instruments [related to global and societal issues].
643107	Interdisciplinary Graduate Education in Engineering	Maura Borrego	The motivation of this research is increasing globalization and international competition, which drive renewed efforts to prepare adaptable engineers who can work in interdisciplinary environments.
644796	Colleges of Engineering as Learning Organizations: Implications for Student Intellectual Development	Jennifer Karlin	The work proposed here looks at intellectual development of engineering students and organization effectiveness of colleges and departments as defined through learning organization literature. The two constructs will then be investigated for correlation.
644917	Development and Evaluation of Portable, Computationally Intelligent Team Training	Ray Luechtefeld	To characterize and model expert knowledge embedded in the approaches of Agyris and Rosenberg…, to further develop the virtual facilitator as a means to help engineering students learn effective team skills…

Award Number	Title	Principal Investigator	Proposal: Stated Project Goal
645736	Accelerating Development of Engineering Education as a Discipline via Organized Dialogue	Jeffrey Froyd	To what extent can external interventions catalyze and accelerate emergence of engineering education as a recognized discipline?
647460 *	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Daniel Carpenter	Validate an empirical model of the ethical development of engineering undergraduates; assess the impact of educational experiences and student context on ethical development; identify and disseminate factors that have the most positive impact on ethical development.
647532 *	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Cynthia Finelli	A purposeful examination of the factors affecting the ethical development of engineering undergraduates.
647915	InTEL: Interactive Toolkit for Engineering Education	Sue Rosser	This project will test the efficacy of computer-based manipulable models within a foundational course in Statics for learning the engineering approach to problem-solving.
647929 *	A Holistic Assessment of the Ethical Development of Engineering Undergraduates	Trevor Harding	A purposeful examination of the factors affecting the ethical development of engineering undergraduates.
648161	Integrating Virtual Experiments and Hands-on Labs - - A Synergistic Approach to Enhance Engineering Education (Project IVEHOL)	Doyle Davis	This project will focus on the research, testing and evaluation of the effectiveness of the use of hands-on and virtual experiments in undergraduate engineering curricula, as well as novel hyprid laboratories.
648190	Using Constructivist Teaching Strategies in Engineering Education: Gauging the Impact on Student Learning and Retention	Kingsley Reeves	Identify current problem solving and creativity related outcomes in core courses within the IMSE department of the University of South Florida; revamp these courses following constructivist learning principles; … disseminate project findings nationally.
648210	A Women in Engineering Knowledge Center: Informing Research, Practice and Institutional Change	C. Diane Matt	The WEPAn Knowledge Center will contribute to increasing the number of women in engineering at all levels by providing a unique, web-based resource for practice and research that synthesizes, targets and creates key information.
648267	Aligning Educational Experiences with Ways of Knowing Engineering: Improving Learning from Middle School Through Professional Practice	Sandra Courter	The AWAKEN Project will develop and test interventions to motivate, train and retain potential engineers from early experiences in middle school to those in professional practice.
648316	Exploring the Role of Computational Adaptive Expertise in Design and Innovation	Ann McKenna	To study the role that computational and analytical abilities play in innovation in the context of a conceptual framework that has recently emerged in the engineering education literature: adaptive expertise.
648380	Expansion of "How People Learn" Metrics in Engineering Classrooms	Monica Cox	The goal of this research project is to develop and to pilot the Observations of Pedogogy in Educational Environments (OPEE).
648439	Preparing Engineering Students for the Challenges of Interdisciplinary Team Design	Lisa McNair	The purpose of this mixed methods research is to identify factors that lead to successful interdisciplinary collaborations, and to determine how to bring those factors into undergraduate engineering curricula in ways that more effectively prepare students for interdisciplinary work.

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14. ABSTRACT
In April 2008, the Foundation’s Division of Engineering Education and Centers asked the IDA Science and Policy Institute (STPI) to evaluate the early outcomes and anticipated impacts of 37 research grants active in fiscal year 2008 in the area of “How People Learn Engineering.” The objective of the STPI analysis of the HPLE grants program was three-fold: (1) to characterize the portfolio of grants active in FY 2008, (2) to document selected outputs generated by these grantees as of FY 2008, and (3) to specify the types of indicators that would be needed to gauge the longer term outcomes and impacts of the HPLE program on engineering education reform. Using administrative files furnished by the agency, STPI developed a Logic Model to characterize the lifecycle of these projects and identified factors that could be evaluated at different points throughout the lifecycle using the model. Most grantees had developed tool kits, models to facilitate learning, specific courses/curricula as a result of HLPE funding. Some established websites to make the results of their research available to educators, other researchers, and students. However, STPI’s analysis of the outputs of HPLE grants yielded little evidence for active publication by the scientists in peer-reviewed journals.

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