Who We Are

HHMI Professors

The Society of HHMI Professors
Promotes the integration of scientific research into every aspect of science education. The Society works through its members to help frame educational goals, create teaching methods and materials that are effective for a diverse group of students, and generate rigorous scientific analysis of these methods.

Survey of HHMI Projects
A qualitative survey of 52 current HHMI Professors as well as Program Directors of 85 HHMI-supported undergraduate research programs. Response demographics:

- ~ 50% public research-intensive universities
- ~ 10% other public institutions
- ~ 20% private research-intensive universities
- ~ 20% other private institutions
Survey results echo numerous studies on the benefits of knowledge-generating research experiences:¹⁻⁶

- improved persistence in STEM
- increased pursuit of graduate education
- helping underrepresented students succeed in STEM

Many projects report quantitative evidence of success

- typically attitudinal and external (grades, retention)
- cognitive and other internal measures are rare

¹Nagda et al. (1998); ²Hathaway et al. (2002); ³Bauer & Bennett (2003);
⁴Lopatto (2004; 2009; 2014); ⁵Hunter et al. (2007); ⁶Laursen et al. (2010)
We considered the surveyed programs through the lens of Auchincloss et al. (2014), who propose five elements that describe course-based undergraduate research experiences:

- Producing new knowledge
- Relevance/importance
- Scientific practices
- Collaboration
- Iteration

All of these elements were found in nearly all surveyed programs.
Undergraduate Research Experiences
Formulas for Success

A Diversity of Experiences

Platonic
The “perfect” apprentice
Not feasible or suitable

Common Reality
‘cookbook’ lab
Ideal for all

Feasible and Meaningful
Surveyed projects each include elements of instruction and application, described here as:

- **Research Preparation**: Students learn scientific thinking and reasoning skills, as well as specific laboratory or other skills.

- **Research Practice**: Students apply these skills to a specific research question, producing original knowledge.

These two elements may be sharply divided. They may also be combined. They may scale in different ways.
Survey results identified the following approaches:

- *Individual apprenticeship experiences* with faculty and their research groups
- *Course-based experiences* tackling authentic research questions using an authentic scientific process
- *Cohort-based experiences* combining research experiences with college-success training, near-peer mentoring, etc.

Some projects combine all three approaches (e.g., UCLA Pathways to Success)
Undergraduate Research Experiences
Success in Diverse Settings - Examples

Liberal Arts Colleges
- Smith College
  AEMES (Achieving Excellence in Mathematics, Engineering & Science)

Public Research Universities
- UCLA
  Biomedical Research Minor & Pathways to Success
- UT-Austin
  FRI (Freshman Research Initiative)

Multi-Institutional
- GEP
  Genomics Education Partnership
- SEA-PHAGES
  Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science
UCLA Biomedical Research Programs funded by HHMI

Introductory programs – 1st, 2nd-year and transfer students

- URCFG – “hands-on” research (>60 students/yr)
- Research Deconstruction (300 students/yr)
- Collaborative Undergraduate Research Lab (Yr. 1, 20 students)

Minor in Biomedical Research (since 2007)
- 215 enrolled; 241 alumni
- 180 labs across campus; >150 publications
- 80% enter advanced degree programs w/in 2 yrs

Advanced program for intensive research training

These programs have trained over 2,500 students since 2003.

HHMI Professor-U. Banerjee
HHMI Professor-T. Johnson
Intro lab courses – *Biomed Res 10H & MCDB 30H*

The Undergraduate Research Consortium in Functional Genomics (URCFG)

The Collaborative Undergraduate Research Lab (Freshmen only)

Highlighted in “Vision and Change”

Common features of both programs
Every student does original research.
Students contribute to one large group project.
Publication promotes “ownership” of work.
Students begin to “see themselves as scientists”
Intro course - *Biomedical Research 5HA*

Research Deconstruction (preparation for research)

"Deconstructing" Scientific Research: A Practical and Scalable Pedagogical Tool to Provide Evidence-Based Science Instruction

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Highlighted in "Vision and Change"
Outcome: high student retention in STEM retention regardless of whether they advance to the Minor.

STEM degree completion (6-year)

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*Even w/ small numbers, big impact

URCFG (n=312) research deconstruction (n=272)
"I consider myself a scientist."

“This class pushed us to think outside the box. Most of us came with no knowledge of the subject forcing us to do more research outside of class. This class also introduced us to research which no other class yet has been able to provide. It was an invaluable experience.” ~ Victor M.
How do faculty benefit?


134 undergraduate authors

Discovery-Based Science Education: Functional Genomic Dissection in Drosophila by Undergraduate Researchers


The excitement of scientific research and discovery cannot be fully conveyed by didactic lectures alone. Several recent initiatives and proposals, therefore, have supported a more participatory, discovery-based instruction for undergraduate science education [1,2]. In functional genomics, we have found an ideal platform to simultaneously benefit students and contribute to scientific discovery. The sequencing of entire genomes has facilitated the identification of complete sets of genes in human and model genetic organisms. This knowledge has enabled us to discover networks of transcriptional regulation and interactions of regulatory proteins and cell phenotypes. These interactions are essential for understanding the biology of complex organisms. However, one of the best tools to provide functional information about gene function is the study of genetic variation resulting from heritable loss of function, as demonstrated in this study.

How do faculty benefit?

Also: Genetics (2007) – 264 undergraduate authors

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DOI: 10.1371/journal.pbio.0050059.g001

Figure 1. Representative Picture from the Laboratory Section of the Course
How do faculty benefit?

- Publications
- Well-trained researchers
- More commitment by students to understanding the material (ownership builds intellectual investment)
- Retention in STEM

Lessons learned…What does it take?

- Institutional commitment
  - Space
  - Time for faculty to develop new courses
  - Encourage collaborative teaching
- Funding agencies that support the notion of research & education being intricately tied (e.g. HHMI; NSF)
These projects share many features:

• In both projects, shared infrastructure and computer-based data analysis facilitate scaling across institutions:
  • The SEA-PHAGES network includes 81 active institutions and will reach 3184 students this year.
  • GEP includes students at ~ 100 institutions, reaching on the order of 1000 students per year.

• Both projects leverage advances in genomics to allow students to make novel discoveries and contribute to publications

• Both projects demonstrate improved graduation rates and skill growth comparable to a summer research experience
Internet Scaling

The Digital Domain

Only six mature HHMI projects reported using online approaches. 

*Examples of what might be done in the future:*

- Interactive, adaptive online research preparation experiences that tutor students in scientific thinking and reasoning, at scale
- Online research practice experiences built around authentic large-scale “citizen science” projects
- Scalable online mentoring and collaboration among and with social networks of scholars, near-peers, and peers

Several new HHMI projects explore some of the possibilities:
- Arizona State University: *Virtual Exploration of Earth Evolution*
- University of Arizona: *Astronomy - State of the Art*
- Boston University: *Research - Education - Communication - Science*
A non-profit science teaching network supported by a grant from the Bill and Melinda Gates Foundation to Smart Sparrow, with academic leadership provided by ASU’s Center for Education Through eXploration (ETX)
Findings
Practitioners’ Perspectives

• There is no one-size-fits-all recipe for successful undergraduate research programs, but the taxonomy described by Auchincloss et al. (2014) is a useful guide.

• Successful programs address both research preparation (i.e., instruction) and research practice (i.e., application).

• Success is possible across a variety of institutional and student contexts, through a variety of approaches appropriate to institutional context and scaling goals.

• Institutional support is essential for sustained success.

• Digital technologies offer underexplored potential for innovations in scaling, collaboration, and assessment, as well as appeal and reach to non-STEM and non-traditional students (“the new majority”).
Extra Slides…
Grand Canyon
Arizona, USA

Nearly two billion years of the Earth's geological history has been exposed as the Colorado River and its tributaries cut their channels through layer after layer of rock while the Colorado Plateau was uplifted. While the specific geologic processes and
Additional Frontiers

Target Audience: HHMI projects overwhelmingly aim at STEM majors. *Experiences for non-STEM majors are a frontier...*

• Likely a different balance of research preparation vs. practice
• Must align skills taught to student needs and expectations

Assessment Instruments: Today: typically attitudinal surveys and external metrics (e.g., grades). *Tomorrow: cognitive and other measures...*

• Digital technologies offer opportunities via clickstream analytics
• Next-generation instruments may answer the “why” of outcomes
Setting: Liberal Arts College
Program: Achieving Excellence in Mathematics, Engineering and Science (AEMES)
Emphases: faculty apprenticeship and mentoring

- The AEMES program seeks to improve the success of students of color in STEM through research support and peer mentoring
- AEMES Scholars work with a faculty member on individual research projects and are supported to become leaders in STEM
- The AEMES program also supports a broader peer mentoring program, designed to improve success of minorities in STEM
- Data collected before and after the start of the AEMES programs shows an increase in persistence for students of color in the life science major from 50 to 73%. In addition, the GPA gap in gateway biology/chemistry courses between students of color and majority students decreased from 0.30 to 0.07, a gap that is no longer statistically significant.
Setting: Large Public Research University
Program: Freshman Research Initiative (FRI)

**Emphases: course-based**

- FRI offers first year students the opportunity to initiate and engage in authentic research experiences with faculty and graduate students, sometimes resulting in publication.
- Spans three semesters of integrated coursework and laboratory research.
- Cohort-based for strong support and collaboration.
- Provides experience with experimental techniques, lab work, and a deep understanding of the scientific process.
- Reaches over 800 students per year, More than 6000 in total. 50% of students are women and close to 40% are from underrepresented groups.
- FRI students have higher overall GPAs. They have 35% higher graduation rate, and Hispanic FRI students have 43–51% higher retention than peers. 32% of students who entered FRI in 2006 went to graduate school, compared to 9% college-wide.