Integrating Discovery-Based Research into the Undergraduate Curriculum:

Summary of a Convocation at the National Academies of Sciences, Engineering, and Medicine focusing on Course-based Research Experiences

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I hear and I forget.
    I see and I remember.
    I do and I understand.
    - Confucius

PCAST recommendation #2:
“Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.”

Translation: Opportunities for research experiences should be accessible for all undergraduates -- CREs can help us achieve that.
Organization of Session

1) Overview of Convocation and Report: 12 examples, discussion of common issues
2) Design features for Course-based Research Experiences
3) Will students develop an understanding of scientific inquiry? learn biology? YES - data from GEP
4) Can you create a CRE using a variety of topics? YES – example from U Texas FRI; see also REIL
5) Does a CRE have an impact on retention in science and graduation rates? YES – data from U Texas FRI
6) Questions and Discussion
Why now?

*Workforce, community needs in information-driven, global society.* (Jim Gates, Keynote Speaker)

**Feasibility:** “For the first time, students can work with the same data, at the same time, and with the same tools as research scientists” (Dave Micklos)

**Effectiveness:**
- increased retention in STEM & college
- teach analytical thinking, problem-solving skills

**Value:** “Undergraduate research is quality education” (Jim Gentile) – the ultimate active learning strategy
Convocation focused on CREs as a way to engage large numbers of students in the research process

Based on the examples presented....

Viable for all STEM disciplines? YES!
- many examples from life sciences, environmental studies, E&PS
- Increasing number of examples from chemistry, physics and math
- engineering “design studios”
- 12 examples in the report
- discussions of effective strategies, leveraging resources, scaling up

Freshman to senior? YES (emphasis may differ)

Participation by underrepresented students?
Effectiveness - similar results; need to develop students’ awareness of the value for them (including freshmen, community college students)
- HBCUs have greater infrastructure needs
- Need to align funding resources for CREs with UREs
A well-designed CRE incorporates evidence-based best practices

Factors thought to influence effectiveness and success:

- personal interest in the project → smorgasbord
- explicit instructional supports → parallel problems, group instruction
- decision making → individual responsibilities
- collaboration within lab → peer support → increased comfort level; allow for failure & troubleshooting – without failing the class!
- mentor support → challenge in scaling up; use peer-mentoring, hierarchical structure
- communication / reflection → first common, second often missing, easily added
- duration of research experiences → (many CREs one semester – integrate across curriculum)
Genomics Education Partnership
National collaboration with > 60 active schools

Our current research goal:
Use comparative genomics to investigate heterochromatic domains in Drosophila.

FlyBase: http://flybase.org
Strategy: divide and conquer!
The *D. mojavensis* dot chromosome

- Each student or pair is responsible for one chunk
- Each chunk done at least twice independently
- Whole reassembled for final analysis

Fosmid sequence matches consensus sequence

Putative polymorphisms

Finished sequences are made publically available; annotations are linked to Flybase.
Annotation challenge: Create gene models from evidence: sequence conservation, computational predictions, RNA-Seq, etc. (local UCSC Browser)
They do learn! GEP annotation quiz results ’10 – ‘12

Shaffer et al. CBE-LSE 2014
Gains in understanding research (self report) comparing av. 45 hr GEP courses (—) with summer-in-the-lab (—)

1. Understanding the research process
2. Knowledge construction
3. Readiness for research
4. Tolerance for obstacles
5. Skill interpreting results
6. Clarifying career choices
7. Integrating theory/practice
8. Tackling real problems
9. Assertions need evidence
10. Ability to analyze data
11. Reading/understanding Primary science literature
12. Understanding science
13. Ethical conduct
14. Lab techniques
15. Skill- oral presentation
16. Skill in scientific writing
17. Understanding how scientists think
18. Independence
19. Learning community
20. Teaching potential
Sue Wessler, University of California - Riverside

The Dynamic Genome Courses: Authentic Research Experiences for Freshmen
Plug-and-Play Model

• Four weeks introductory material
  • Molecular and computational skills
  • One week transition experiment
• Four weeks authentic research project offered by different faculty
• Currently > 300 students, ~20/section
• Other UC campuses looking at this model
An example CURE program: Freshman Research Initiative
What is a Research Stream?

Research Program:

• A faculty member’s body of work
• Interrelated, ongoing, usually with a common thread
• Sometime overlapping with other faculty
• Many different projects led by post-docs, grad students

Research Stream:

• Allows expansion of a subset of the research program by providing:
  • More minds and hands
  • Larger variable space
  • Lower risk

• Has its own potential to spawn other projects and research collaborations
FRI Timeline

Freshman

Fall
- Preparation
  - Research Methods
  - Other intro course
  - Stream Selection

Spring
- Research Stream
  - Lower division lab course
  - Intro to lab techniques
  - Begin Research
  - Summer Fellowships
  - Summer Volunteers
  - Summer School
  - Head start on Fall Research

Summer
- Summer School

Fall
- Head start on Fall Research

Sophomore

Spring
- Transition
  - Research Presentation
  - Peer Mentors
  - REUs, faculty labs, internships, etc.
  - Work towards publication

Fall
- Expand Projects
- Mentor Research Methods
- Summer Fellowships
- Summer Volunteers
- Summer School
- Head start on Fall Research

Class counts as credit towards degree
How does it work?

Traditional Model

- **Teaching**
  - Professor/Instructor
    - TA
    - Student
- **Research**
  - PI
    - Postdoc / GRA
    - Undergrad Researcher
- **Teaching**
  - Demonstration labs
  - More guidance
  - Basic Techniques
  - Predictable results
- **Research**
  - Research
  - Variable guidance
  - Advanced Techniques
  - Unknown outcomes

FRI Model

- **PI = Professor**
  - Postdoc = Research Educator
  - GRA = GTA
  - Undergraduate Student = Researcher

- **6-10 hour mentored research**
- **Basic → Advanced Techniques**
- **Known → Unknown**

**Up to 40 undergraduate researchers per stream**
FRI students more likely to graduate in 6 years and with a STEM degree than the matched non-FRI group

Hierarchical logistic regression analysis with propensity score matched control group ($n = 1,476$)

(Rodenbusch et al, in prep)

** $p<0.01$, *** $p<0.001$
Your Turn

comments for the on-going NAS/NRC Consensus Study:


Integrating Discovery-Based Research into the Undergraduate Curriculum: Report of a Convocation

http://www.nap.edu/catalog/21851

Copies available here and at the Round Table discussion

Tuesday 11 am