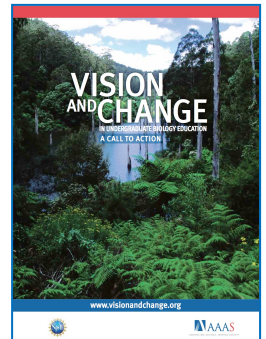




Course-based Undergraduate Research Experiences: A Scalable and Sustainable Approach for Advancing the Integration of Teaching and Research for Student Success

AGEP California - Summer Teaching Institute 2019
Christopher R Meyer, College of Science and Mathematics
California State University Fresno

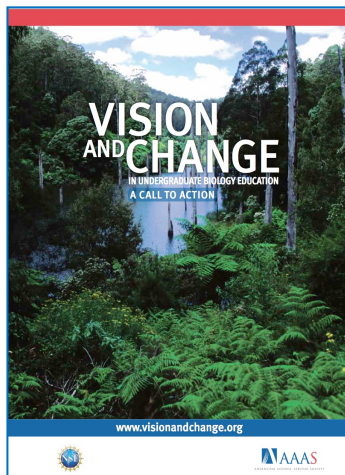


Course-based Undergraduate Research Experiences (CUREs): A Scalable and Sustainable Approach for Advancing the Integration of Teaching and Research for Student Success*

Christopher R. Meyer, Dean

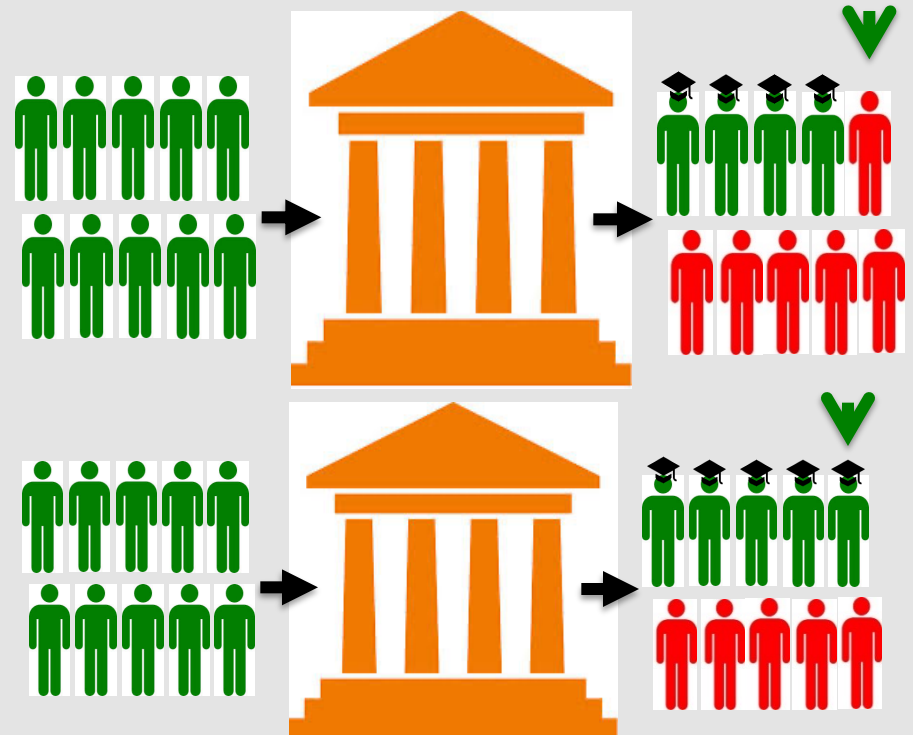
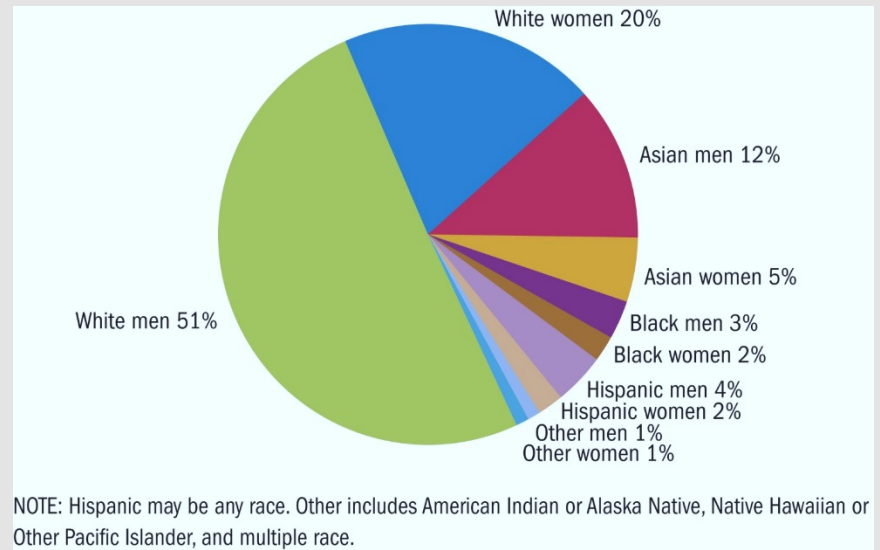
College of Science and Mathematics

*Special thanks to Erin Dolan, University of Georgia, and Sarah Simmons, HHMI



Challenges and Opportunities

- Critical shortage of US students being trained in STEM disciplines
- NAS Report: US ranked 27th among developed nations in producing undergraduate degrees in STEM
- State and federal budget limitations with the need to train large numbers of underserved students
- Need for interdisciplinary and team science training for complex problems
- Fewer than 40% of students entering college intent on majoring in STEM complete a STEM degree
- Increasing retention from 40% to 50% would generate 75% of the targeted 1 million additional STEM graduates over the next decade



POCKET NOTES

GREAT IDEAS



GREAT IDEA No. _____

DATE: _____

GREATNESS: 1 2 3 4 5

PROJECT: _____

NEXT STEP: _____

Lined writing area for notes.

IDEA TRASHED

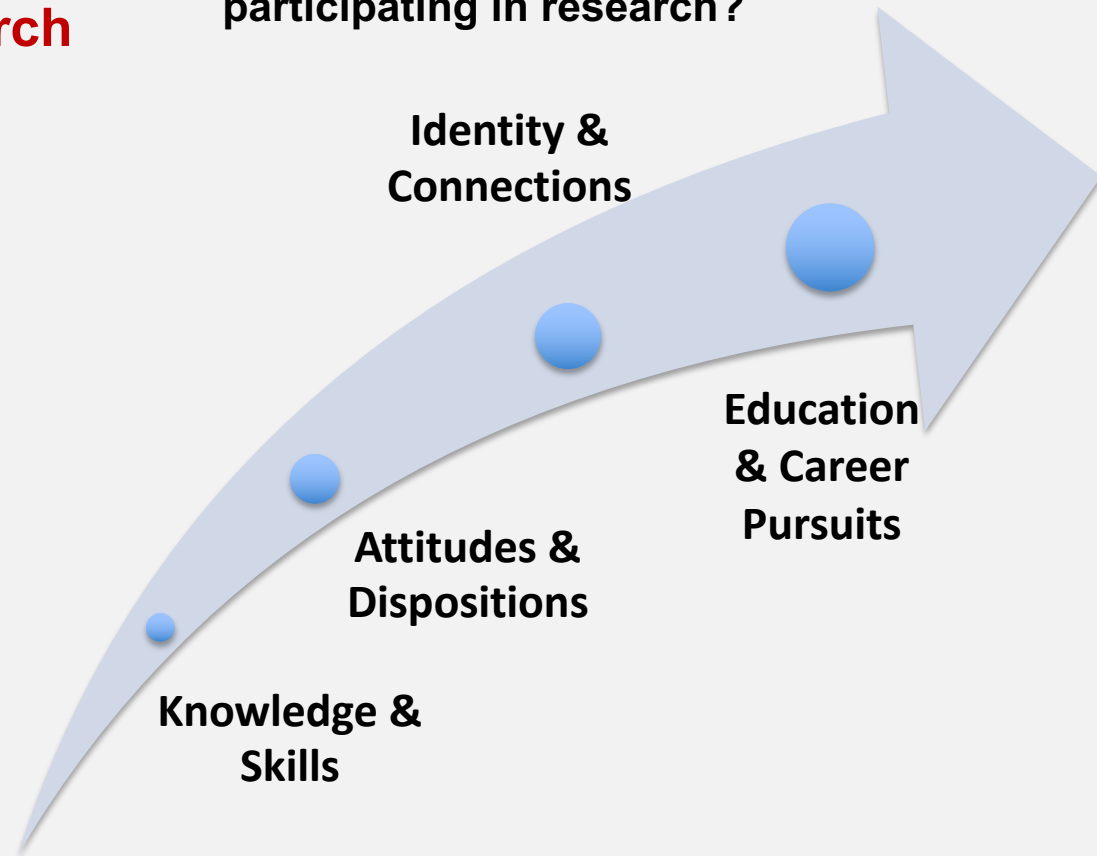
IDEA POSTPONED

IDEA ACTUALIZED

High Impact Practice of Research

- General Definition: Undertaking research is an inquiry or investigation conducted by an undergraduate that makes an original intellectual or creative contribution to the discipline (Wenzel 2010)
- NSF, AAAS, NIH, HHMI, Vision and Change (2011): Introduce research experiences as an integral component of biology education for all students...
- Undergraduates can investigate leads and take risks not practical for Ph.D. students and postdocs in exploring research projects

How do students benefit from participating in research?



Caveats: Indirect measures, measures that lack validity evidence, self-selecting populations (for critique see Linn, Palmer, Baranger, Gerard, & Stone, 2015)

Adapted from Erin Dolan, University of Georgia



Undergraduate research experiences

General Definition: “Undertaking research is an inquiry or investigation conducted by an undergraduate that makes an original intellectual or creative contribution to the discipline.”

<http://www.cur.org/ISSOTL/2010/Wenzel.pdf>

NSF, AAAS, NIH, HHMI Vision and Change (2011): **Introduce research experiences as an integral component of biology education for all students...**

AAC&U (2007): **Undergraduate Research is one of 10 “high impact educational practices.”**

Congressional Action: Funding for programs such as the NSF STEM Talent Expansion Program (STEP) and NSF REU, allowing for the engagement of more undergraduates in authentic research experiences.

Successful Undergraduate Research Projects:

THE CHALLENGE: Suitability for publication and grant awards while optimizing the learning experience of the undergraduates participating in the research. Some successful elements: (for faculty buy in...)

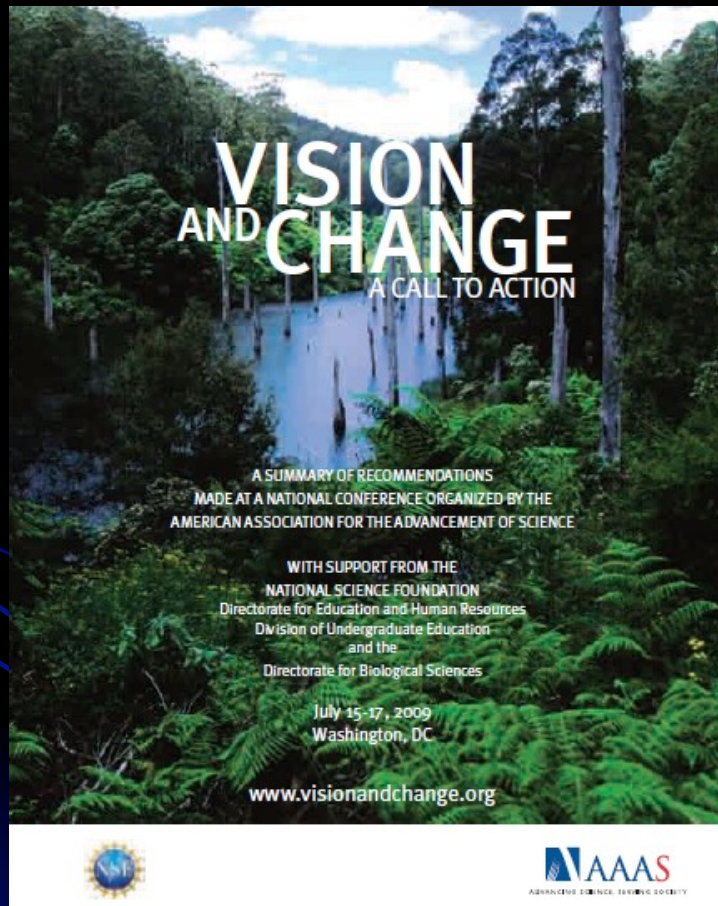
- having a reasonable scope - being feasible with the given resources
- generating data that a student can present and publish
- -avoiding cookbook experiments - being multifaceted
- able to be broken down into subprojects that individual students or student teams can complete
- allowing for manageable continuity in training and passing on information to new students

Undergraduates can investigate leads and take risks not practical for graduate students or postdocs in exploring even potentially transformative research projects.

-From Brad Goodner, Hiram College



Introduce Students to Research Early & Often



Challenges at a Comprehensive University...



SOLVING THE SPLIT BRAIN PROBLEM FOR FACULTY

Adapted from Brad
Goodner, Hiram College

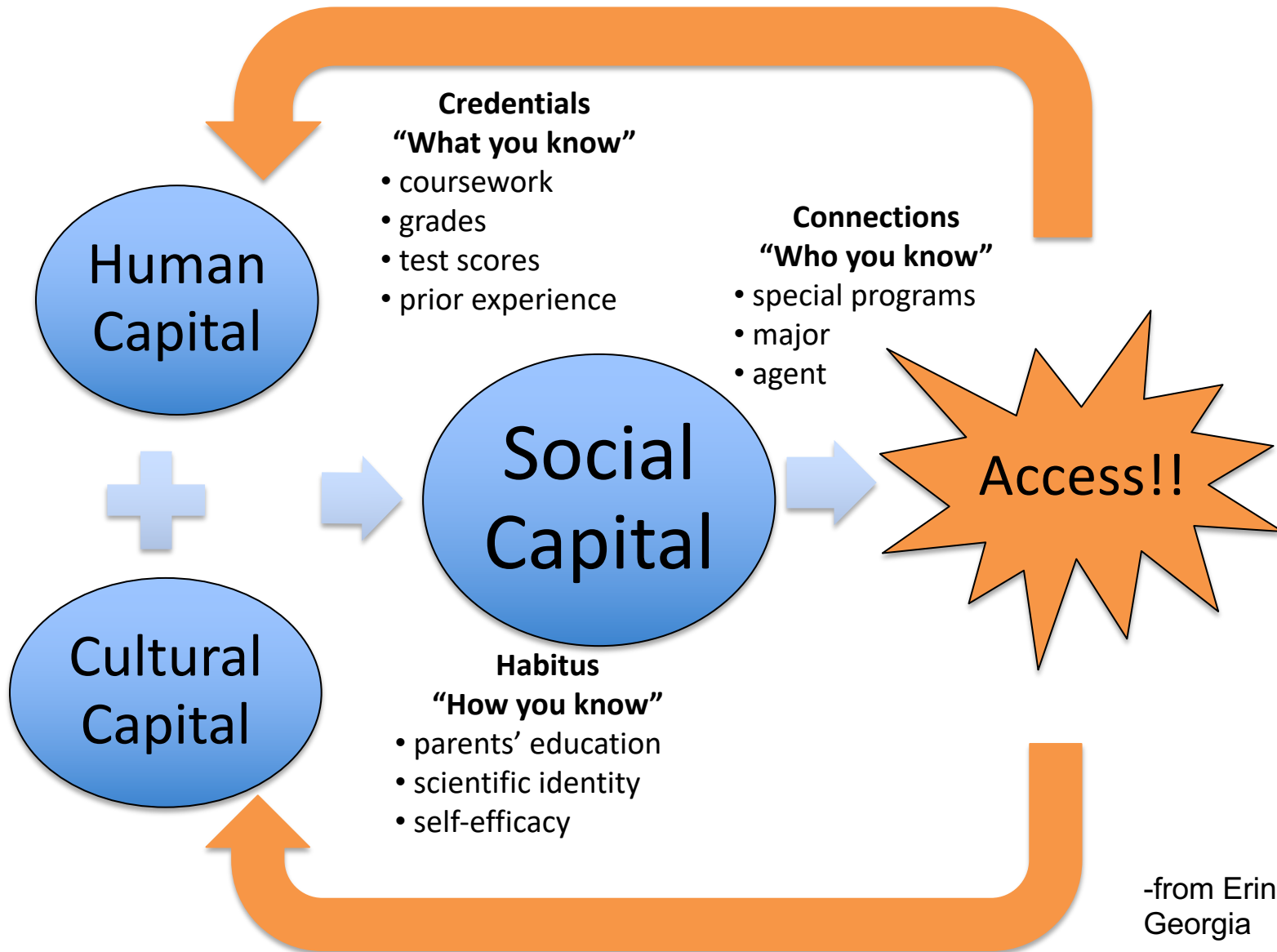
At Fresno State, we have recently received support from several donors for Course-based Undergraduate Research Experiences (CUREs) that will allow us to more efficiently integrate, scale our teaching and research efforts and *democratize exposure to this high impact practice.*

Which students get access to research experiences?

We considered how we find undergraduate researchers...

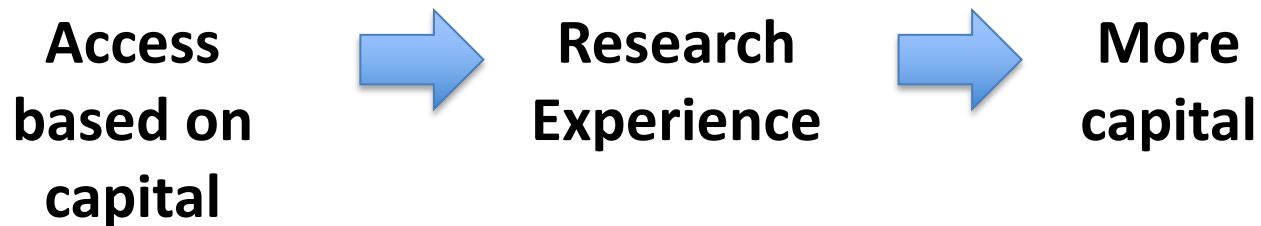
- Students who are performing well in class
- Asking a lot of questions
- Having the knowledge that research is important to do
- Having the confidence and persistence to seek out faculty to ask
- Being part of a program that includes a research requirement

Theory: Bourdieu's "Capital"



-from Erin Dolan, U of Georgia

This suggests that students who come to college primed for careers in science are most likely to persist and succeed



Recapitulates the status quo: Not enough, not everyone

How to achieve these outcomes for everyone?
How to broaden access?

Course-based Undergraduate Research Experiences



When whole classes of students address a research question or problem that is of interest to the scientific community

CUREs versus Research Independent Study

	CURE	Research internship
Scale	Many students	Few students
Structure	One to many	One to one
Enrollment	Open to all students in a course	Open to a selected or self-selecting few
Timing	Students invest time primarily in class	Students invest time primarily outside of class
Setting	Teaching lab	Faculty research lab
Mentoring	Consistent / Structured	Varied

(Auchincloss et al., 2014)

Anatomy of a CURE: Involves students in the following 5 Dimensions:

- **Use of scientific practices:** asking questions, building and evaluating models, proposing hypotheses, designing studies, selecting methods, gathering and analyzing data, identifying meaningful variation, navigating “real-world” (messy) data, developing interpretations, communicating findings...
- **Discovery:** New knowledge and insights (outcome of an investigation is not known to both the students and instructor)
- **Broadly relevant or important work:** Opportunities for impact and action beyond the classroom: science research publication, reports of interest to the local community, evidence-based recommendations for community action
- **Collaboration:** Group work is an important pedagogical element of CUREs – bringing many minds together to tackle a problem (as is necessary for “real life” complex problems). Students can improve their work in response to peer feedback
- **Iteration:** This can occur at multiple levels: students may design, conduct, and interpret an investigation, and, based on their results, repeat or revise/ “troubleshoot” the work to address issues, gather additional data; they can also build on and revise aspect of other students’ work to accumulate a large data set for analyses

Examples of the Diverse CUREs Landscape

- **National programs with a common research goal.**

- The Genomics Education Partnership (GEP; <http://gep.wustl.edu/>; Shaffer et al., 2010) upper division, national CURE program (Washington University in St. Louis).

- ~1000 GEP students/year enrolled in genomics and bioinformatics courses at diverse institutions annotate gene models in *Drosophila* to understand genome evolution.

- The Science Education Alliance-Phage Hunters program (SEA-Phages; <http://seaphages.org/>; <http://phagesdb.org/phagehunters/>), University of Pittsburgh, involves thousands of introductory biology students at diverse institutions in identifying and characterizing soil bacteriophage with the collective aim of studying their genetic diversity and evolutionary mechanisms

- **National programs with a common technology framework.**

- Includes microarray gene expression analysis, high throughput sequencing (GCAT-SEEK supported by NSF RCN-UBE), crowd-sourcing for the discovery of antibiotics (Small World Initiative <http://www.smallworldinitiative.org/>)

- **Local programs.**

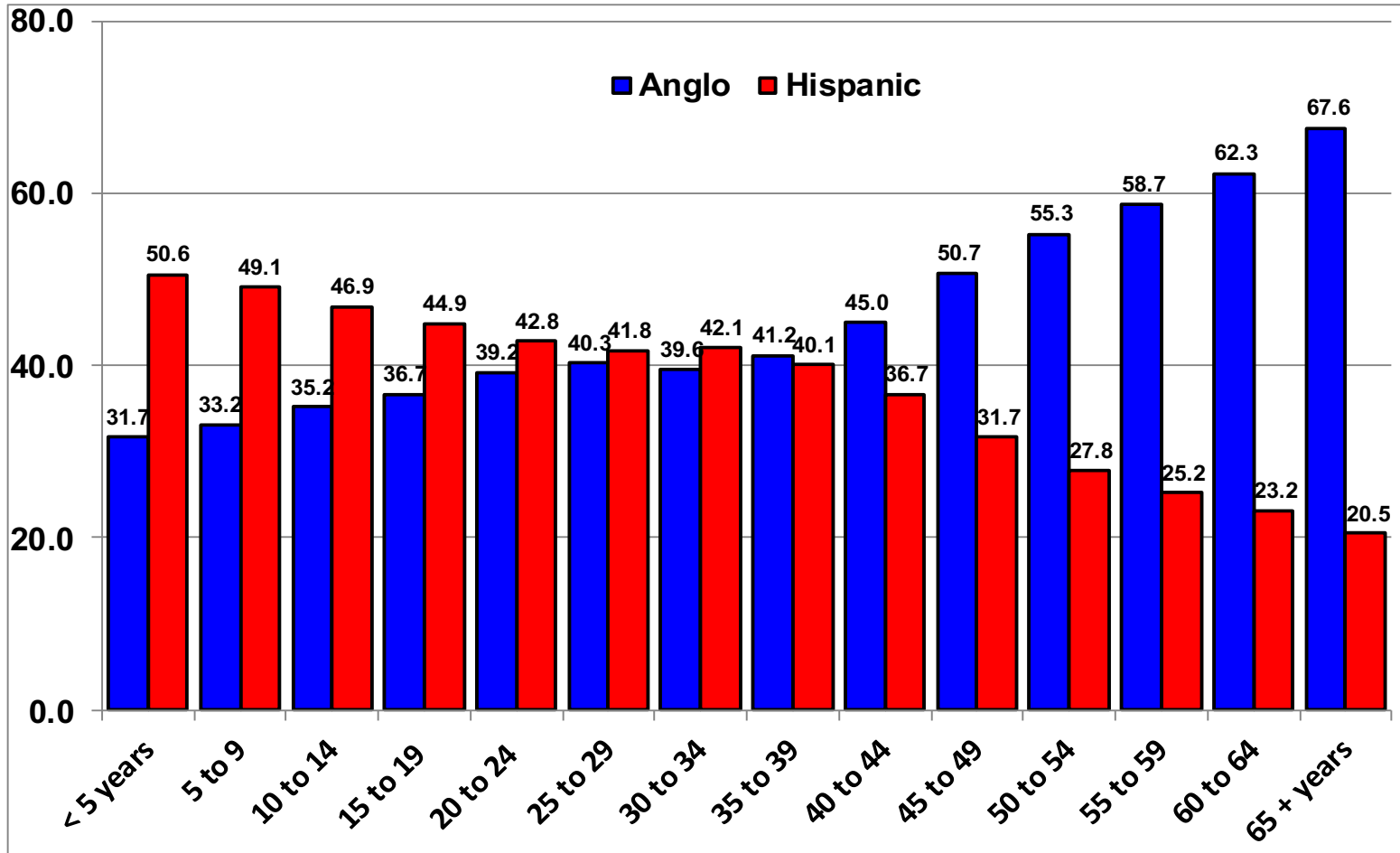
- Freshman Research Initiative UT-Austin (<https://cns.utexas.edu/fri>)

- Vertically-Integrated Projects Program at Georgia Tech (<http://www.vip.gatech.edu/>)

- **Specific courses.** Developed by faculty at their own institutions/departments related to their own research/research of collaborators



Percent of Texas Population by Age Group and Ethnicity, 2010



Source: Hobby Center for the Study of Texas at Rice University



Educational Attainment for the Texas Population Age 25 and Older by Race/Ethnicity, 2009

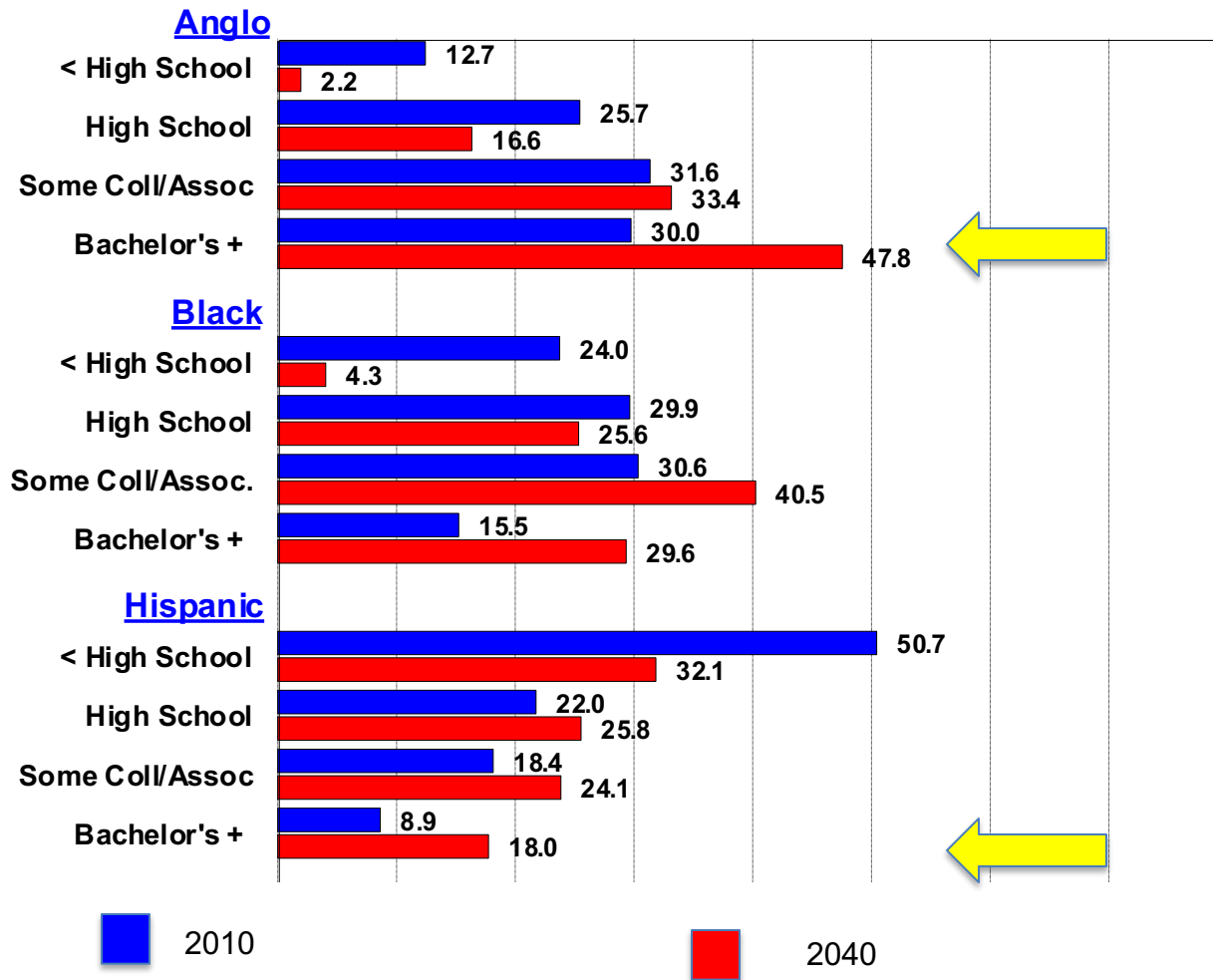
Race Ethnicity	Population Age 25 and Older	Less than high school	High school diploma	Some college or associates degree	Bachelor or more
Non-Hispanic White	8,026,049	8.3	25.3	32.5	33.9
Black	1,705,709	15.0	30.4	36.5	18.1
Hispanic*	4,876,517	42.5	25.2	21.4	10.9
Asian	580,159	14.2	15.4	17.2	53.2
Total	15,361,557	20.1	25.4	28.9	25.5

Source: U.S. Census, American Community Survey, 2009.

*Includes Hispanic persons of all races.



Percent of Persons 25 Years of Age or Older by Level of Educational Attainment and Race/Ethnicity in 2000 and Projected to 2040* Assuming 1990-2000 Trends in Educational Attainment Rates



Source: Hobby Center for the Study of Texas at Rice University



What can we do to change this prophecy?

Hundreds of programs with decades of data to support the impact undergraduate research experiences have on student attraction, retention and success



Why isn't the status quo sufficient?

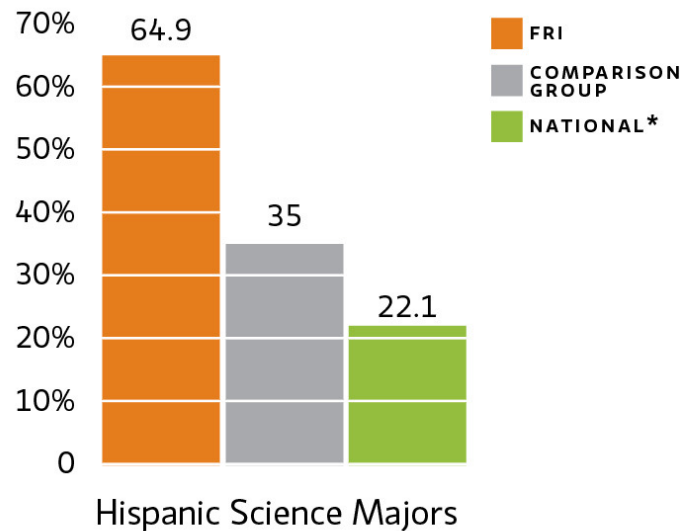
- Capacity maximum
 - Faculty time
 - Project options suitable for undergraduates
- Knocking on door approach
 - Favors students with characteristics not necessarily tied to research potential
 - Disproportionately daunting to students underrepresented in the sciences
- Too late
 - Traditional model involves junior/senior level work
 - Too late to impact retention or to take advantage of and effectively promote real stars
- Limits link between research and education
 - Keeps research and curriculum at odds with each other
 - Does not impact faculty within existing rewards structure (research progress, funding, publications)



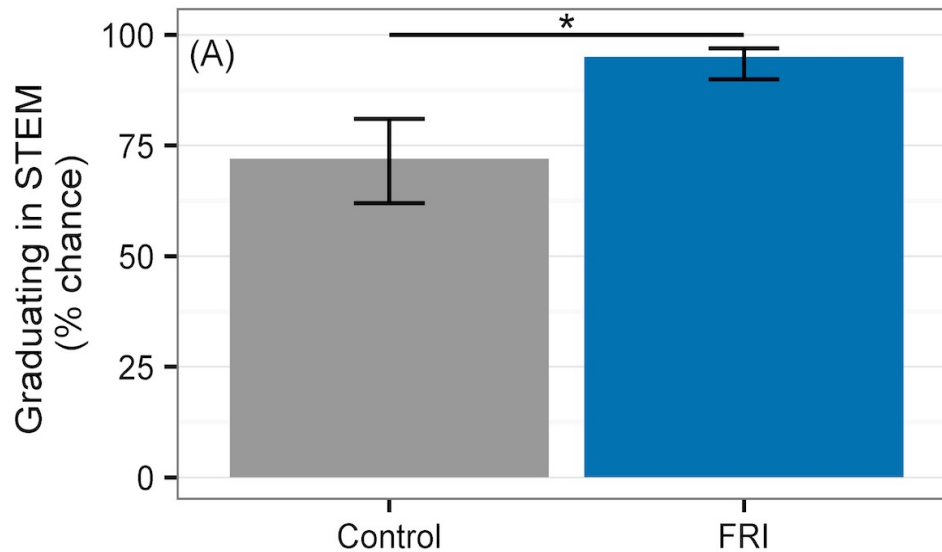
FRI Impact on STEM Retention for Hispanic students

- **Promotes success in Hispanic students**
 - FRI more than doubles the graduation rate for Hispanic students
 - 25% of students entering the program are first generation college students and 25% are Hispanic.
 - 35% more students (all) graduate with a science or math degree in FRI.

Hispanic 4 Year Retention Percentages



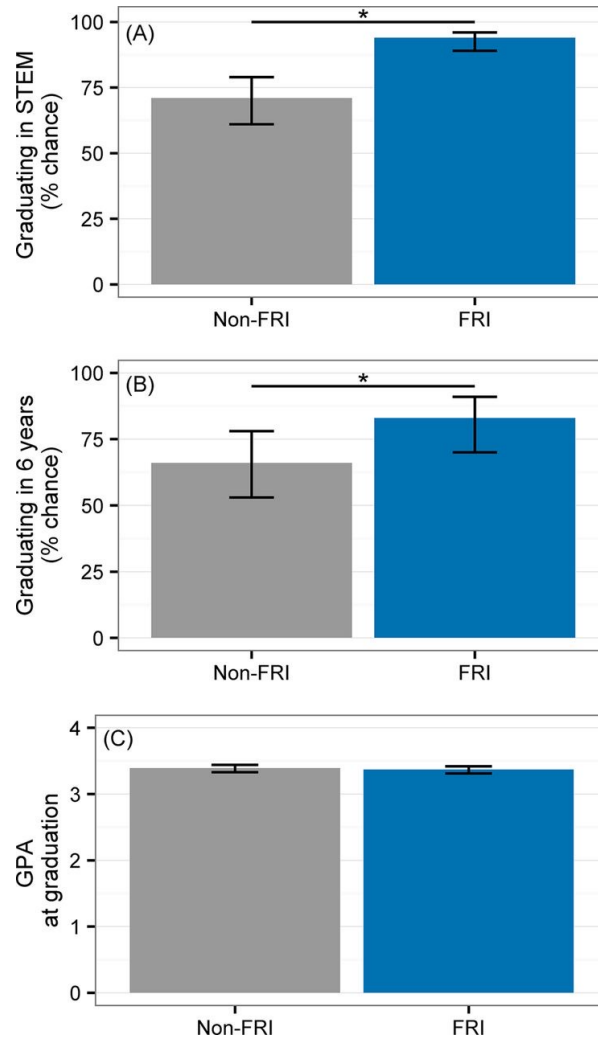
FRI students more likely to graduate with a STEM degree



Effect is the same for students from ALL backgrounds

* $p \leq 0.001$; error bars represent 98.7% confidence intervals
NOTE: 22.1% = National Hispanic STEM 6-year graduation rate

Participation in all three FRI courses significantly improves students' predicted probability of graduating with a STEM major (A) and graduating in 6 yr (B), but does not affect students' probability of earning a higher cumulative GPA at graduation (C).



Stacia E. Rodenbusch et al. CBE Life Sci Educ 2016;15:ar20





What is different about FRI?

- Freshman level
 - Chance to fly – with 4 years to be trained and groomed
 - Change early (major, field) and still be successful
- Large numbers
 - Exponential impact
 - Powerful force for change
- Not a select “honors” program
 - Allows students with interest to try research
 - Demonstrates that HS statistics aren’t only (or best) indicators for potential research aptitude
- “Cheap” for students
 - Course credit, tied to additional resources
 - Attractive even to students without an academic legacy



What particular issues regarding underrepresented groups does FRI address?

- Recruitment
 - Honors caliber program and resources
 - Meets with parents during orientation
 - Address “cost” of research
 - Not extracurricular
 - Credit in smaller classes
 - Connection to careers (parental pressure)
- Provide students language to talk to parents
 - Translate research experience into scholarships/fellowships
 - Industry internships
- Pipeline access to graduate/professional program
 - We know them early and well
 - Programs can come to us



Results in *better* STEM trained students

- Students learn science by doing science
- We argue that this kind of training better engages across all groups, but in particular, can level the playing field for groups underrepresented in the sciences.
- Better training as freshmen carries out over entire college career and beyond
- Freshmen courses become incubators for the production of **start-up scientists**.
- Students with these experiences are poised and sophisticated with a striking ability to problem solve and think critically.



*This research lab is a classroom,
this classroom is a research lab.*

Which of the Following Scenarios is a CURE?

1. If the answer to the research question is unknown to the student but the scientific community knows the answer.
2. The research question is addressed by thought experiments by individual students.
3. The research involves characterizing the bacteria on shoes.
4. The research involves characterizing different forms of a novel protein.

Context and framing is important....

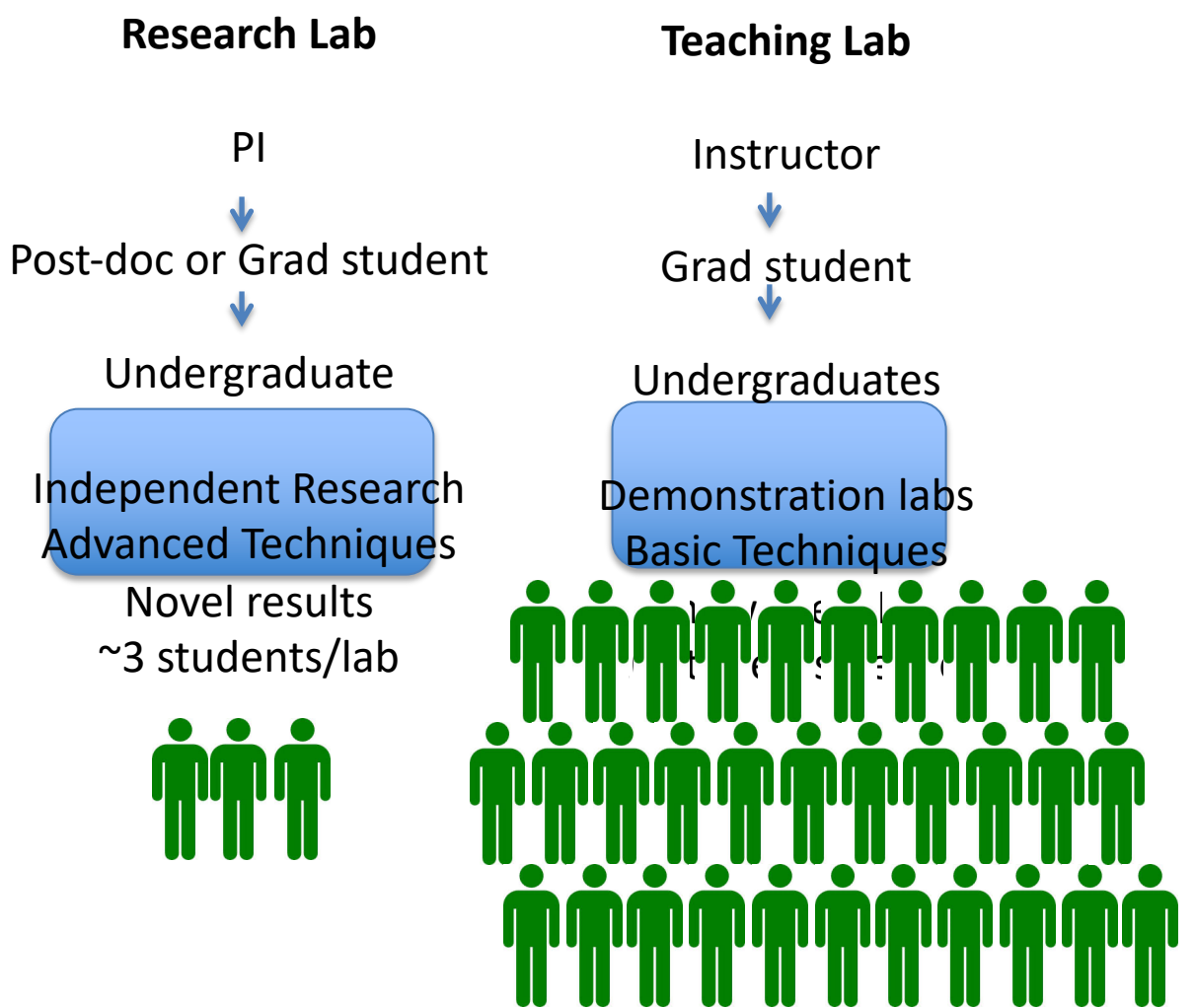


Example CURE program: UT Austin's *Freshman Research Initiative*:

-grown from 45 to ~900 students/year (~40% of incoming class of College of Natural Sciences); 3 course model: Research Methods course followed by 2 semesters of CUREs – all count toward graduation requirements



Traditional Undergraduate Experience

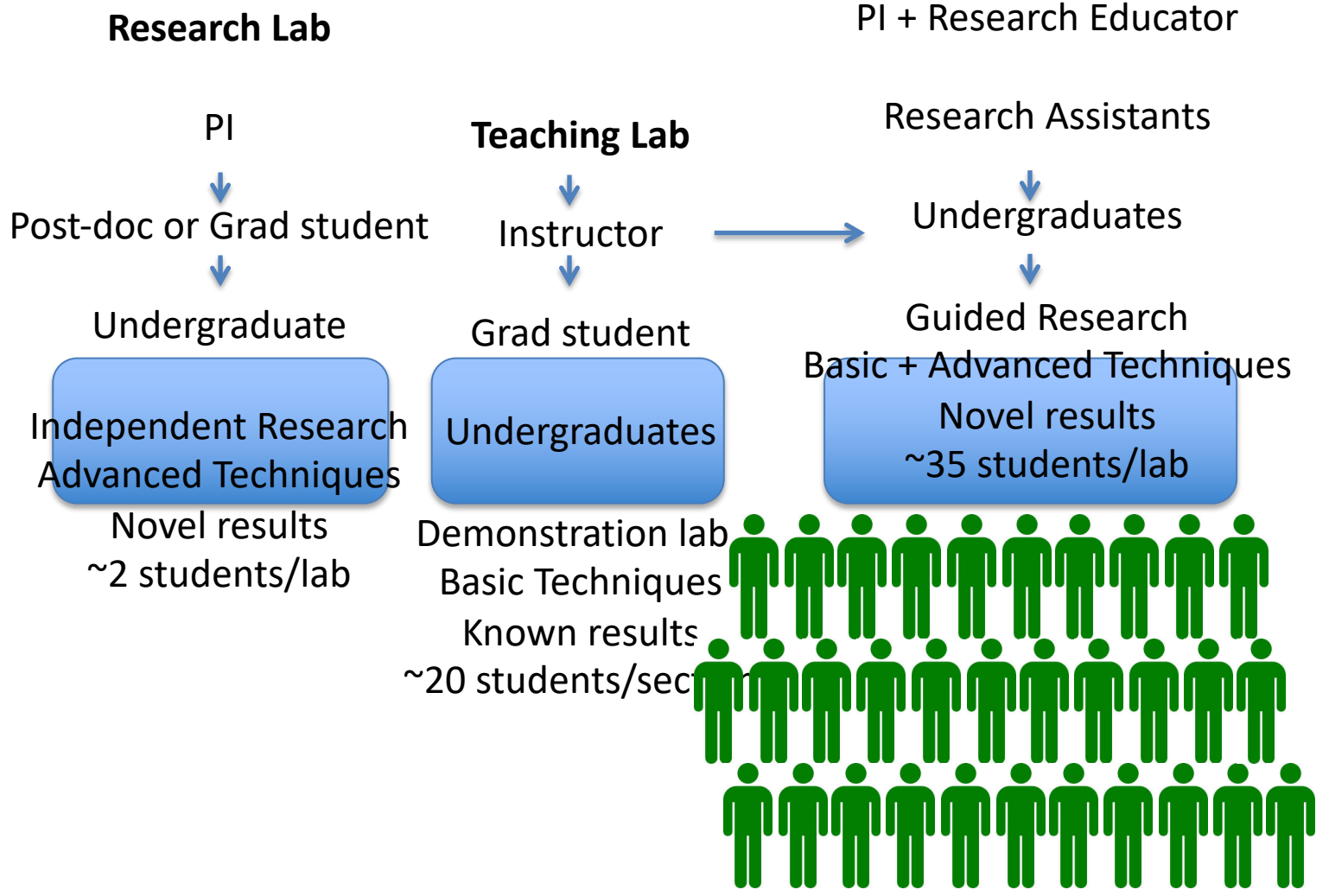




FRI Experience

Research Stream

PI + Research Educator

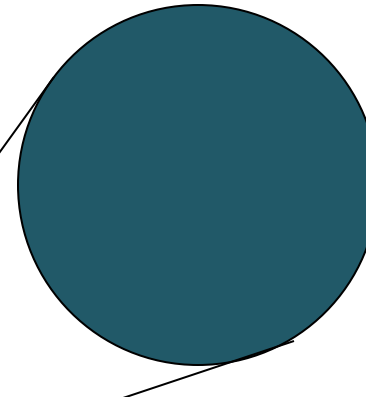
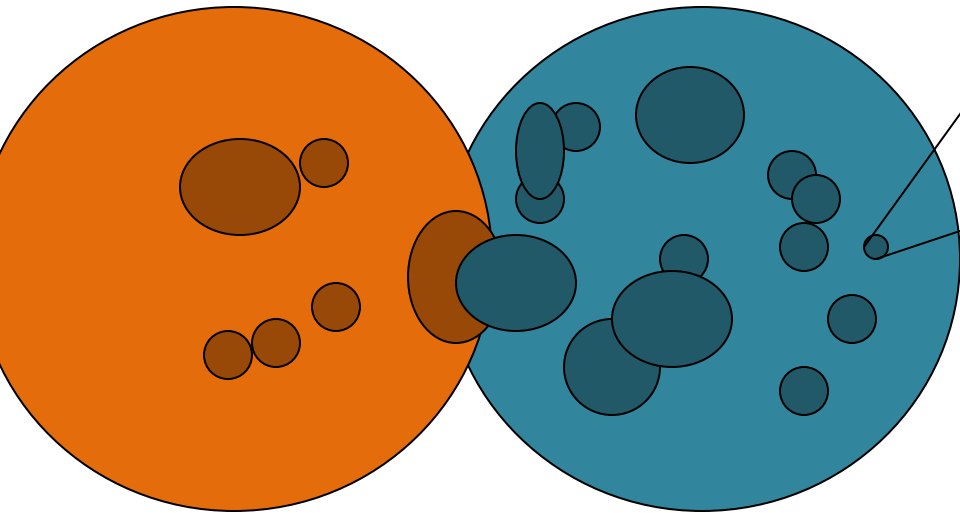




What is a *Research Stream*?

Research Program:

- A faculty member's body of work
- Interrelated, ongoing, usually with a common thread
- Sometime overlapping with other faculty collaborators
- **Many different projects led by post-docs, grad students and including FRI alumni as Near Peer Mentors**



Research Stream:

- Allows expansion of a subset of the research program by providing:
 - More minds and hands
 - Exploration of large variable space
 - Lower risk (a dissertation doesn't *have to* result)
- Has its own potential to spawn other projects and research collaborations



Can you define a “Research Stream” for a CURE class?

Initial steps to take in creating a CURE...

1. **Research goals** and **Student goals**
2. CURE design, including how you will **structure** the CURE to maximize **equity** and indicate who the **stakeholders** are
3. At least **1 set of objectives** aligning student and research goals
4. 1 example **lesson, assignment, guidelines** (Instructional Materials)
5. 1 example **rubric** or other assessment tool (Assessment)
6. **Instructional staffing** (if more than one person is involved in instruction)
7. And a title!



Goals Alignment Worksheet (see example handouts)

	Research Goal 1:	Research Goal 2:
Student Goal 1:		
Student Goal 2:		
Student Goal 3:		



Peer Feedback on your CURE:

- One strength
- One suggestion
- One question

Also:

- Does the CURE seem feasible for student to make research progress in a semester or two?
- How might you obtain funding for you CURE?



Instructional Staffing/Infrastructure

- **Make a list:** Who all will be or could be involved in helping your students with their CURE work?
- Now consider:
 - What **assets** does each bring to the table? How will their involvement be helpful?
 - What constraints or challenges might each have?
- What specific **roles/responsibilities** will they have?
- How will you make sure they are up to speed on these, especially if/when plans change?



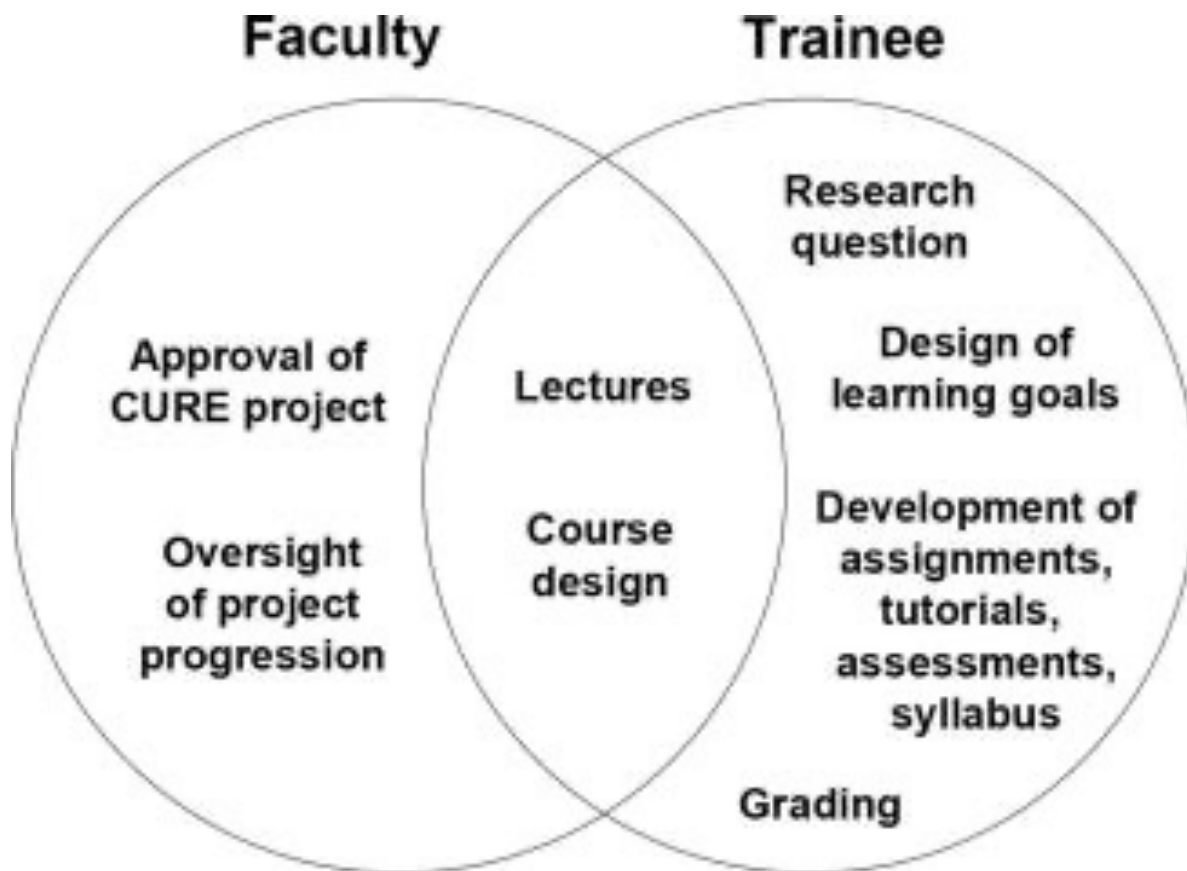
Problem- Solutions for CUREs:

How would you address:

- Different preparation/background of students
- Unpredictable nature of results
- Safety
- Time to complete tasks
- Intensity of mentoring needed
- Resistance/complaints about workload

(one poster/group)

Division of Responsibilities in the co taught CURE Model



-from Cascella, B. and Jez, J. M. (2018) Beyond the Teaching Assistantship: CURE Leadership as a Platform for Future Faculty. *J. Chem. Educ.* **95**, 3-6.

-Opportunities for the enrichment of a graduate student or postdocs teaching/research portfolio – particularly valuable for PUIs/comprehensive universities

Future Work toward establishing CUREs “best practices”: Your work may help answer some of these questions!

- How will CUREs be integrated into the curriculum?
- How will research progress be balanced with student learning and development?
- To what extent will students have intellectual responsibility and opportunities to “own” aspects of the research?
- How will the research learning tasks be structured to focus beyond the development of project-specific knowledge and skills to foster students’ development as scientists?
- How will students’ progress be assessed?
- What are the roles of instructional staff?
- How will research learning tasks change as discoveries are made and initial research questions are answered?

-Adapted from “Course-based Undergraduate Research Experiences: Current knowledge and future directions”

EL Dolan, National Research Council Commissioned Paper, Washington, DC, USA

Possible Broad Scientific Discovery Goals in 1st or 2nd year CUREs

Information Literacy

- Distinguish between different types of information sources and develop skills for searching for primary literature.
- Begin to evaluate claims in scientific papers, popular science media, and other sources using evidence-based reasoning
- Provide background information about the scientific question or problem to be tested (Scientific content)

Scientific Process: Question Formulation

- Define the hallmarks of a good experiments and/or studies that would address specific hypotheses.
- Develop research questions based on your own or others' observations.
- Formulate testable hypotheses and state their predictions.

Scientific Process: Study Design

- Compare the strengths and limitations of various study designs.
 - Design controlled experiments, including plans Scientific Process: Study Design
 - Compare the strengths and limitations of various study designs.
 - Design controlled experiments, including plans for analyzing the data.
 - Execute protocols and accurately make and record measurements and observations (Organize, and annotate data sets)
 - Identify methodological problems and suggest how to troubleshoot them.
 - Evaluate and suggest best practices for responsible research conduct (e.g., lab safety, record keeping, proper citations).
- for analyzing the data.

Execute protocols and accurately make and record measurements and observations (Organize, and annotate data sets)

Identify methodological problems and suggest how to troubleshoot them.

Evaluate and suggest best practices for responsible research conduct (safety, record keeping, proper citation of sources).

Possible Broad Scientific Discovery Goals in 1st or 2nd year CUREs

Scientific Process: Data Interpretation and Evaluation

- Use observational skills to describe experimental outcomes.
- Analyze data related to the question or problem
- Use appropriate quantitative methods to evaluate results
- Create and interpret informative graphs or other data visualizations.
- Summarize patterns in the data
- Describe sources of error and uncertainty in data.
- Make evidence-based arguments using your own and others' findings and draw appropriate conclusions.
- Describe the iterative nature of science and how new evidence can lead to the revision of scientific knowledge
- Relate conclusions to original hypothesis, consider alternative hypotheses, and suggest future research directions based on findings.

Scientific communication **Develop a process for writing/communicating**

- Use appropriate language and style to communicate science effectively to targeted audiences (e.g., general public, biology experts, collaborators in other disciplines).
- Use a variety of modes to communicate science (e.g., oral, written, visual).
- Demonstrates conventional and proper use of sources in scientific writing.
- Relate concepts from more than one scientific area to interpret phenomena related to the question or problem.

Possible Pedagogical Goals in 1st or 2nd year CUREs

Science Identity

- Express increased confidence and enthusiasm in science and math
- Gain satisfaction in solving scientific problems
- Decrease stereotype threat
- Develop confidence that you can understand and do science
- Opportunities to reflect or work on things that you personally value or feel proud of
- Develop tolerance for obstacles faced in the research process
- Understand that failure is common to the process of science
- Understand how scientists work on real problems and that science is done by diverse teams

Metacognition

- Demonstrate willingness to seek help from others (teacher, peers, TA) when working on academic problems
- Know and use a variety of problem-solving strategies
- Evaluate your own understanding and skill level
- Learn strategies to plan, monitor, and evaluate your learning
- Embrace a growth mind-set with respect to intelligence and ability

Community

Develop a process for working in a group

- Become part of a collaborative group and develop a sense of belonging in the scientific community
- Value equity and inclusion practices in community engagement
- Work with teammates to establish and update group plans and expectations (e.g., team goals, project timeline, rules for group interactions, individual and collaborative tasks).
- Elicit, listen to, and incorporate ideas from teammates with different perspectives and backgrounds.
- Work effectively with teammates to complete projects.
- Evaluate feedback from others and revise work or behavior appropriately.
- Critique others' work and ideas constructively and respectfully.

Possible Pedagogical Goals in 1st or 2nd year CUREs

Ethics

- Identify and employ the characteristics of research integrity in experimental design, data collection, analysis, and communication.

Technical Skills

- These will likely be discipline specific...

Sources

Bioskills Guide. Clemmons A, Timbrook J, Herron J., Crowe A. (Draft document)

Classroom Undergraduate Research Experience (CURE) survey. Lopatto D. Grinnell College.

Cooper KM, Soneral PAG, Brownell SE. (2017) Define your goals before you design a CURE: A call to use backward design in planning course-based undergraduate research experiences. *Journal of Microbiology and Biology Education*. 18: 1-7.

Corwin LA, Graham MJ, Dolan EL. (2014) Modeling Course-Based Undergraduate Research Experiences: An Agenda for Future Research and Evaluation.

CBE - Life Sciences Education. 14: 1-13.



Keep Darwin's Words in mind:

**“ It is not the strongest
of the species that
survives, nor the most
intelligent that
survives;
it is the one that is the
MOST ADAPTABLE ! ”**

Some Useful Web Links

<http://home.sandiego.edu/~josephprovost/bmb20989-sup-0001-supinfo01.pdf>

<https://www.asbmb.org/asbmbtoday/201604/Education/CUREs/>

American Society for Biochemistry and Molecular Biology article

<https://serc.carleton.edu/curenet/index.html>

Welcome to CUREnet!

Research experiences are thought to be pivotal in the education and professional development of undergraduate science majors. Yet, there are many more undergraduates than can be accommodated through traditional research internships. In order to meet the demand for undergraduate research experiences, faculty have developed projects that engage whole classes of students in addressing a research question or problem that is of interest to the scientific community, dubbed "Course-based Undergraduate Research Experiences" or CUREs.

CUREs offer several advantages over research internships - they can enroll many more students and they are accessible to all students who enroll, not just the few who stand out in class, who are confident enough to approach faculty directly, or who have personal or programmatic connections that help them get access to research.

CUREnet was established in 2012 to support networking among faculty developing, teaching, and assessing CUREs, to share CURE projects and resources, and to develop new tools and strategies for CURE instruction and assessment.

<https://geni-act.org/>

Guiding Education through Novel Investigation
Academic Collaboration Toolkit

GENI-ACT brings authentic research into the classroom: enhancing student learning and engagement; supporting instructor scholarship and teaching; facilitating collaboration; and answering relevant scientific questions. Welcome to our educational community!