A Curriculum-Wide, C. elegans-based "Pipeline CURE" Provides an Alternative to Apprentice-Style Research Experiences for Biology Student Cohorts at a Primarily Undergraduate Institution

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ABSTRACT:

STEM instruction in higher education increasingly relies on the learning opportunities afforded by authentic research experiences. By involving larger numbers of students than traditional apprentice-style research programs, Course-based Undergraduate Research Experiences (CUREs) improve STEM inclusivity. Most CUREs are offered within a single semester, and thus have limited capacity to support the deep learning afforded by long-term, iterative research. To explore the potential benefits of a multi-semester research program for larger student cohorts, we have embedded a five-stage "Pipeline CURE," featuring R1-level research on epigenetic reprogramming in *C. elegans*, within a four-year Biology curriculum at a primarily undergraduate institution (PUI). Novice students enter the Pipeline in an introductory biology course where they receive basic training on model husbandry and nematode behavioral assays (Stage 1); these skills are further elaborated in a second-year Genetics course where students perform a series of linkage mapping crosses (Stage 2). At this point, students are equipped to perform authentic epigenetics research on the chromatin modifying genes spr-5 and met-2 in a Developmental Biology elective (Stage 3) and/or in a capstone Epigenetics Research class (Stage 4); students emerging from these two Pipeline stages are well-trained for summer internships at the R1 partner lab (Stage 5). In 2017-2018, all five stages of the Pipeline were in place within the PUI curriculum. Attitudinal surveys and concept inventories were administered in a pre-/post-fashion at each stage of the Pipeline to assess their effects on students' scientific literacy and engagement; responses to open-ended questions regarding the benefits of long-term research projects were also coded for emergent themes. The cross-sectional data collected (n= 97 surveys) indicated that changes in student attitudes towards scientific research in the classroom were not evident in the first two stages of the Pipeline (where technical training is taking place), but that improved student attitudes emerged at Stages 3 and 4, with Stage 4 showing the largest gains in student attitudes and concept mastery. A preliminary longitudinal analysis of individual students progressing from Stage 2 to Stage 3 (n=9 students) confirmed these results, and provided a proof-of-principle that this approach, due to its inherent internal controls, will help determine the timing and nature of these positive attitudinal gains at higher resolution. Collectively, these initial findings indicate that a Pipeline CURE can help larger cohorts of students reflect deeply on the practice of authentic research and their role in it. As such, the Pipeline CURE may provide a useful alternative to traditional apprentice-style research experiences at PUIs.

1. RATIONALE:

Traditional Course-based Undergraduate Research Experiences (CUREs) support engaged and experiential learning

- Student work results in useful and/or publishable data
- Engage students during their normal class time
- Mitigate institutional barriers to research participation and increase access to research for all

However:

- Group-sourced CUREs do not always align with of PUI faculty training
- Novel CUREs can be hobbled by basic research infrastructure at PUIs
- Nationally sponsored CUREs do not allow students to engage in direct/reciprocal interactions with scientist-sponsors
- Semester-long CUREs do not allow for iterative training and mastery of experimental model

2. A SOLUTION:

- Develop a custom "Pipeline"-CURE at a PUI , sponsored by nearby R1 host lab
- Implement iterative, scaffolded research training across a 4-year Curriculum
- Expose all students to the nature of research: encourage grit and build confidence
- Generate "real" data for host lab
- Provide professional development for both students AND mentors

Katz Lab
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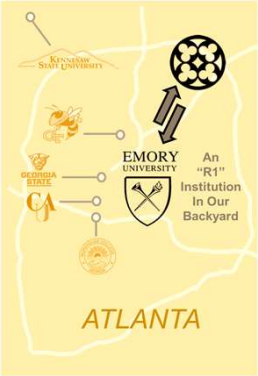


Oglethorpe University Biology Program

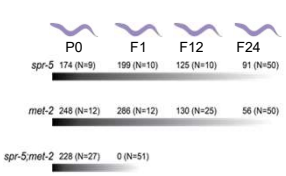
- 1,350 Students
- 30.8% UEM
- 37.9% First Gen.
- 29% Commuters
- 30.8 % STEM

3. THE SCIENCE BEHIND THE CURE:

Using *C. elegans* as a model to study the role of histone-based epigenetic reprogramming events in early development

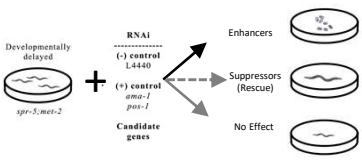
THE PHENOTYPE:

Worms that can't remove active marks on Histone 3 become progressively sterile



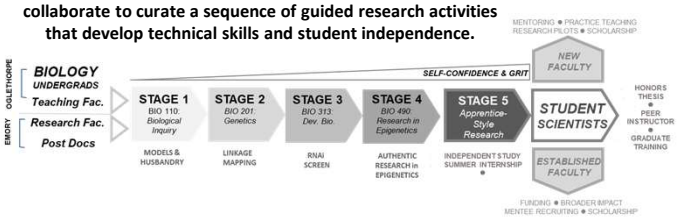
THE ASSAY:

Use RNAi to screen for suppressors/enhancers of the sterility/developmental delay defects



4. THE "PIPELINE":

Teaching-intensive and Research-intensive institutions collaborate to curate a sequence of guided research activities that develop technical skills and student independence.



- Students completing the Pipeline at Oglethorpe will work between 175 -460 hrs in the lab (equal to 4 – 10 weeks working full-time at the bench)
- Implementation of the "Pipeline" has yielded unexpected professional benefits for both post-doc trainees and participating faculty (Teaching Training/Mentorship for Post-Docs and Grants/Promotions for Faculty)

5. ASSESSMENT:

Students at each stage of the "Pipeline" are surveyed for attitudes towards *C. elegans* as a model system and the degree to which students feel agency as scientists

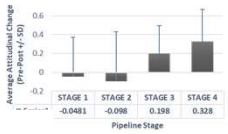
Attitudinal Survey: "Use the 5 point scale below (1=strongly disagree to 5=strongly agree) to indicate your attitudes regarding the following statements"

1. *Course-associated lab work helps me understand the scientific method. __*
2. *Course-associated lab work contributes to my mastery of biological concepts. . __*
3. *I am skillful in lab work. __*
4. *I enjoy doing lab work as part of my classes. __*
5. *When performing an experiment, I look forward to collecting my final data. __*
6. *When performing an experiment, I am skillful at representing raw data in tables, graphs and figures. __*
7. *When performing an experiment, I am skillful at making conclusions from my data. __*
8. *When performing an experiment, I find value in collaboration. __*
9. *When my experiments in lab are inconclusive, my first reaction is to repeat them. __*
10. *My lab work makes me feel confident in my ideas. __*
11. *I feel confident in my skills as a researcher. __*
12. *Doing lab work in my classes makes me feel like I am a scientist. __*
13. *The lab work I do in my classes will help me pursue future training/job opportunities. __*
14. *I have a strong understanding of what it means to do scientific research. __*
15. *I anticipate doing laboratory research in my future career. __*
16. *I understand why genetic model organisms are important in biological research __*

6. ATTITUDES OF STUDENTS IN THE PIPELINE

A. CROSS-SECTIONAL:

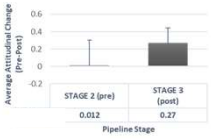
97 Student responses were collected in 2017-2018 from students enrolled in STAGES 1-4 of the Pipeline. Question-specific scores (Q1-16 right to left) reflect increases (green), decreases (red), or no change (white) in between pre- and post-semester survey scores



- **Aggregate data show that the early stages of the "Pipeline" fail to show notable gains in attitudes towards the practice of science and the utility of *C. elegans* training – this may be due to issues with "Beginner's Confidence"**
- **Improved student attitudes emerged at Stages 3 and 4, with Stage 4 showing the largest gains.**
- **Post-docs teaching in STAGE 4 find Pipeline students sufficiently prepared with respect to technical skills and work expectations**

B. LONGITUDINAL:

A Longitudinal analysis of 8 student responses collected during the 2017-2018 year from students progressing between STAGES 2-3 of the Pipeline. Scores reflect increases (green), decreases (red), or no change (white) in between pre- and post-semester survey scores



- **Longitudinal results confirm the trends seen in the cross-sectional data indicating improved attitudes between Stage 2 and Stage 3 of the Pipeline**
- **Variance in student responses may be reduced using this internally-controlled measure**
- **Provides proof-of-principle that Longitudinal analysis of Pipeline data can yield results with limited confounds**

7. QUALITATIVE RESPONSES - LONGITUDINAL:

Open responses to the statement: "I find research-based science interesting"

8 Longitudinal student responses were collected in 2017-2018 from students enrolled in STAGES 2-3 of the Pipeline.

THEME	STUDENT	STAGE 2 BIO 110 Biol. Inquiry (pre)	STAGE 2 BIO 201 Genetics (post)	STAGE 3 BIO 313 Dev. Bio. (post)
Theory Does Not Always Translate to Practice:	#1	Research based science is interesting because it provides a real experiment to go with the work in class	• I find research based science interesting when dealing with other types of model organisms and when the topic pertains to me specifically	• Only if I am working with group members who are able to carry their own weight.
	#2	• I completely agree. Working in the lab, especially with C.elegans has been one of my favorite parts of the bio department.	• I agree with this statement, and if I weren't being graded on my work, I would enjoy it so much more.	• I agree. I like outline in the effort and getting results, especially when the experiment hasn't been done before.
Experiential Learning is Impactful:	#3	• I agree. I think you can learn more from it also. You are applying skills and [knowledge] to the research.	• I think it's important to reinforce the concepts learned in this class. It's easier to understand when the process is taking place.	• I think this is an important tool to help understand concepts learned in class and try to [reinforce] them.
Increased attention to Detail:	#4	• I agree! Research based science has the potential to be very fun when looking at the process by which discoveries are made, as well as the discoveries themselves. And the best part is you can look through a paper and see the details of how and why discoveries and breakthroughs happened. • *(No voluntary response)*	• I think that being able to first-hand experience experiment and concepts discussed in class to be highly valuable. • *(No voluntary response)*	• Anything research based is interesting because it helps science because of the intricacies of performing experiments. • I find research based science interesting because it helps me understand the mechanism of the research

8. FUTURE DIRECTIONS:

- **Collect complete Pipeline-wide data set**
- **Add in direct measures of concept mastery**
- **Perform qualitative analysis of student focus group/exit interviews to further characterize the scope of Pipeline impact on student success**

9. REFERENCES:

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