

The Genomics Education Partnership: Exploring best practices in implementation of a genomics CURE



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Abstract

Since 2006, the Genomics Education Partnership (GEP) has incorporated authentic genomics research experiences into the undergraduate curriculum, introducing thousands of students to eukaryotic gene annotation, comparative genomics, and the evolution of contrasting genome domains. Our 100+ participating institutions include community colleges, primarily undergraduate institutions, and research-intensive PhD-granting institutions. Using our shared resources and publicly accessible data bases, students have been able to contribute meaningfully to scientific investigations coordinated through the GEP.

A large consortium of faculty implementing a core course-based undergraduate research experience (CURE) in a variety of ways also provides opportunities to examine best practices for lab course design and implementation. Through use of faculty logs, assessment of student learning gains, and responses to surveys and focus groups, we have examined faculty actions and student attitudes that impact student learning. The data indicate that our research format encourages use of active learning strategies while promoting dialogue about science; student responses overall are positive, but those students with positive attitudes toward science benefit the most. We also looked for particular aspects of the GEP CURE that promote student learning. Our data suggest that students experience a beneficial process of "formative frustration" where they are initially allowed to fail in their analyses, followed by exploration, re-evaluation, adjustment, and re-analysis. Additionally, the relatively low-cost, low-stakes structure of a genomics CURE may make instructors more prone to give students leeway to experience this process.

To support the GEP's ongoing mission of conducting genomics research with undergraduates, we have partnered with Galaxy to develop G-OnRamp, a web-based platform for constructing genome browsers from assemblies. This is enabling us to initiate new collaborative annotation projects that harness the research power of the GEP collective. We are looking for additional "science partners" who have interesting projects for collaboration, and for new faculty members interested in incorporating GEP curriculum and projects into their classrooms. We provide fully-supported training for new GEP faculty members through online mentoring and in-person workshops. Those interested in joining can contact us at http://gep.wustl.edu/contact_us. Supported by NSF IUSE-1915544 and NIH IPERT-1R25GM130517-01 to LKR.

Biological Data Workflow & Overview of Educational Assessments

Biological data workflow: Report results in scientific Construct genome browsers for draft genomes data into public databases (e.g., using G-OnRamp Utilize reconciled gene set for Identify the genom Identify pathways of scaffolds of interest interests (e.g., insulir lownstream comparative an (e.g., Muller F elemer signaling, venom) pathway analyses Identify locations of **Experienced GEP students** Partition scaffolds from outative orthologs and selected regions into submitted gene models overlapping projects pathway-specific genes **1** ≥ 2x **1** GEP Faculty claim projects and students produce

Educational Assessments:

Student data:

- Pre- & post-course quizzes to assess scientific learning gains
- Pre- & post-course surveys assessing student attitudes and the research experience benefits
- Student focus groups comments
- Student demographics

The Genomics Education Partnership (GEP)

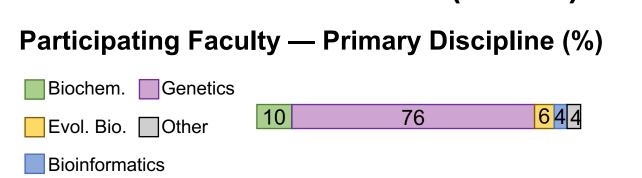
GEP Goals

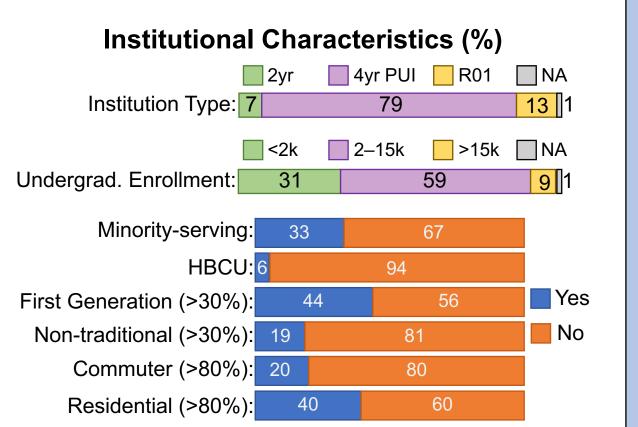
- Incorporate genomics and bioinformatics into the undergraduate curriculum
- Engage undergraduate students in authentic genomics research



- >100 faculty from >100 affiliated schools
- >1000 undergraduates participate annually

GEP Characteristics (n=124)



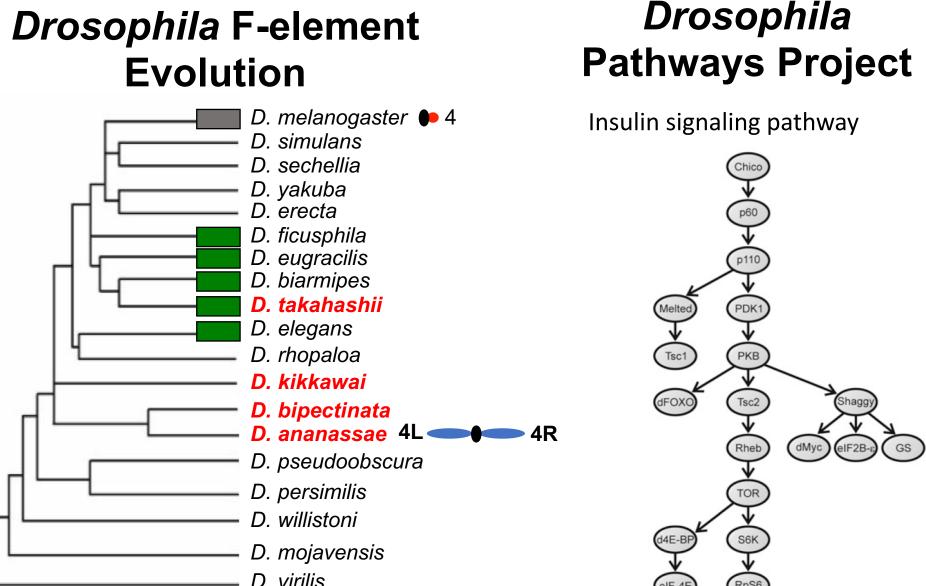


- One-third of the faculty teach at minority-serving
- The characteristics of GEP students generally reflect those majoring in science at the institutions

Assessment of student attitudes

toward science:

Current Biological Projects



Expanded F-element projects: What are the

expansion, and what is the impact on gene

mechanisms driving chromosomal

Annotation projects: Conserved motifs

structure and expression?

impacting gene expression?

- How does network structure determine robustness of function in response to perturbation (withinspecies timescales)?
- How does network structure influence and reflect the process of evolution (between-species timescales)?

Wasp Annotation **Project**

Annotation of genomes from parasitoid wasp species



Focus on venom proteins that modulate host physiology & signaling:

- Venom gene evolution? · Venom gene structure and
- function?
- Venom protein mimics?
- Venom gene/protein motifs?

GEP Courses Contribute to Biological Knowledge & **Enhance Student Attitudes Toward Science**

Biological publications with GEP student coauthors:

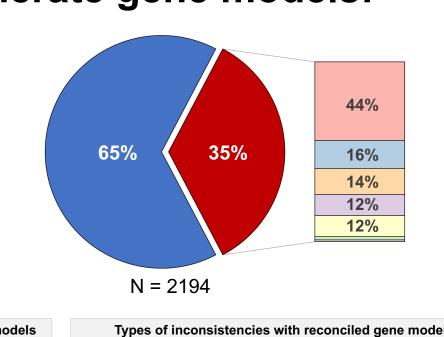
Evolution of genes & repeats in Drosophila Muller F-elements:

• Leung et al. (2010) Genetics • Leung et al. (2016) G3

Identification of factors contributing to D. ananassae F-element expansion:

• Leung et al. (2017) G3

GEP students accurately generate gene models:



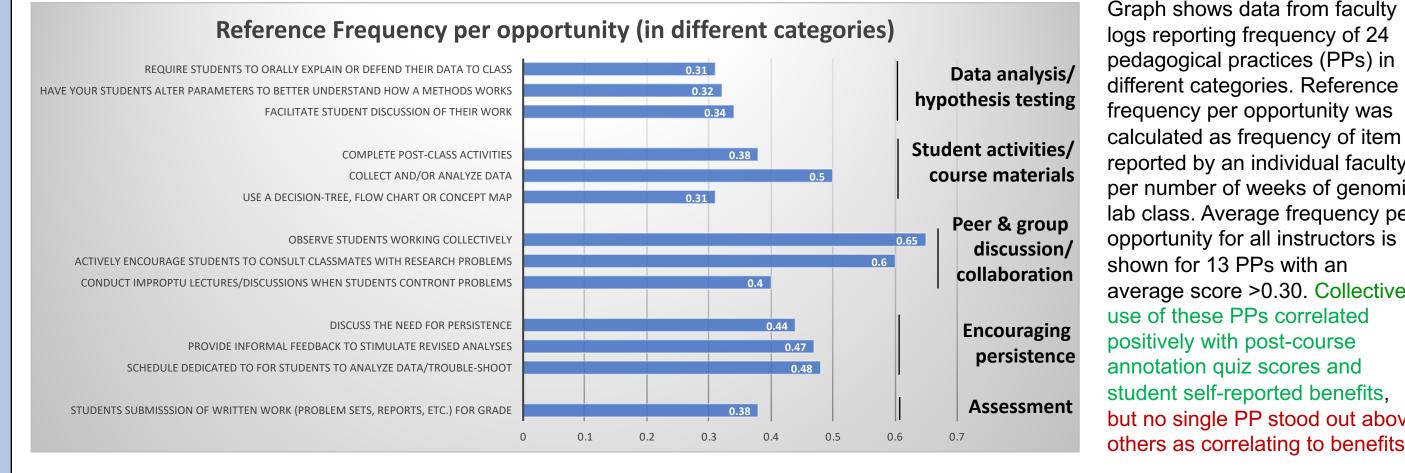
Gene model missing

Above: GEP student survey data collected over 2 years (2015-2017; green triangles) shows similar gains in student attitudes toward science as students engaging in a summer undergraduate research experience (SURE) as assessed by the 2017 SURE survey (red boxes).

Left: Submissions from 2 or more GEP-student annotators were examined by experienced annotators. 65% of gene models submitted were congruent with available data while 35% showed inconsistencies; the most common being differences in predicted splice-site boundaries.

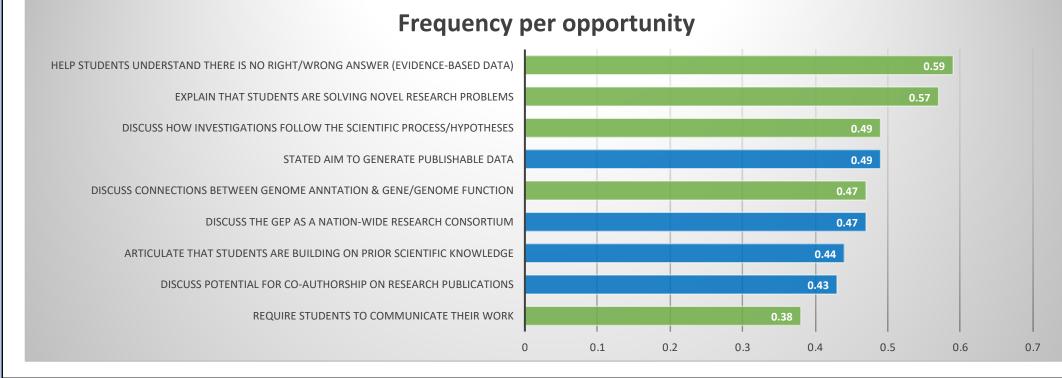
GEP CURES Promote Active Learning & Dialogue About the Research Process

Active learning practices employed with higher frequency:



Graph shows data from faculty logs reporting frequency of 24 pedagogical practices (PPs) in different categories. Reference frequency per opportunity was calculated as frequency of item reported by an individual faculty per number of weeks of genomics lab class. Average frequency per opportunity for all instructors is shown for 13 PPs with an average score >0.30. Collective use of these PPs correlated annotation guiz scores and student self-reported benefits. but no single PP stood out above

Frequency or practices emphasizing research process:



Graph shows data from faculty logs reporting frequency of 9 practices utilized for emphasizing the research process. Reference frequency per opportunity was calculated as noted above. To determine which practices resonated most with students comments during student focus groups were scored for references to the 9 practices Green bars indicate practices references most frequently by students (>22 times), while blue bars indicate items referenced less frequently (<11 times).

Formative Frustration: Student Setbacks Contribute to Learning Gains

Correlation between student setbacks and learning benefits: ■ Positive ■ Negative ■ No Effect

30 — 20 — 10 — Faculty were asked to comment on connections between setbacks in course structure (course setbacks) and setbacks in the research process (student setbacks) and

the perceived effect of each setback on student learning.

Faculty comments analyzed by *NVivo* term analysis and

negative (orange), or no effect (grey) shown. Data show a

clear correlation between student setbacks and perceived

percentage of references indicating positive (blue),

learning gains.

Likelihood of allowing students to experience setbacks:

GEP Annotation Workflow

(CDS) to contig

coordinates (workflow)

Faculty data:

Faculty survey

NCBI BLAST (bl2seq)

Faculty logs of educational practices

Faculty focus groups comments

Faculty formative frustration survey

Faculty and institutional demographics

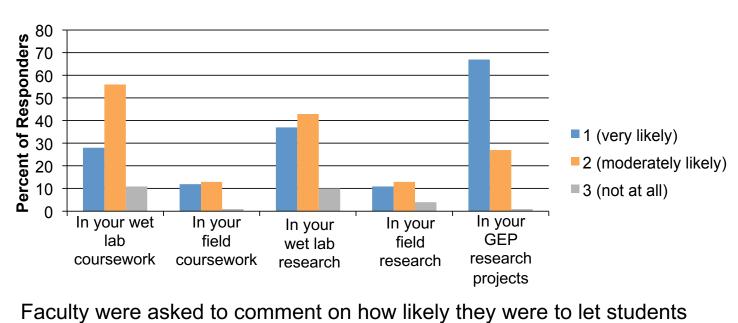
Click on gene prediction and the

protein against the D. melanogaste

Errors and warnings in checklis

Large gaps in dot plot

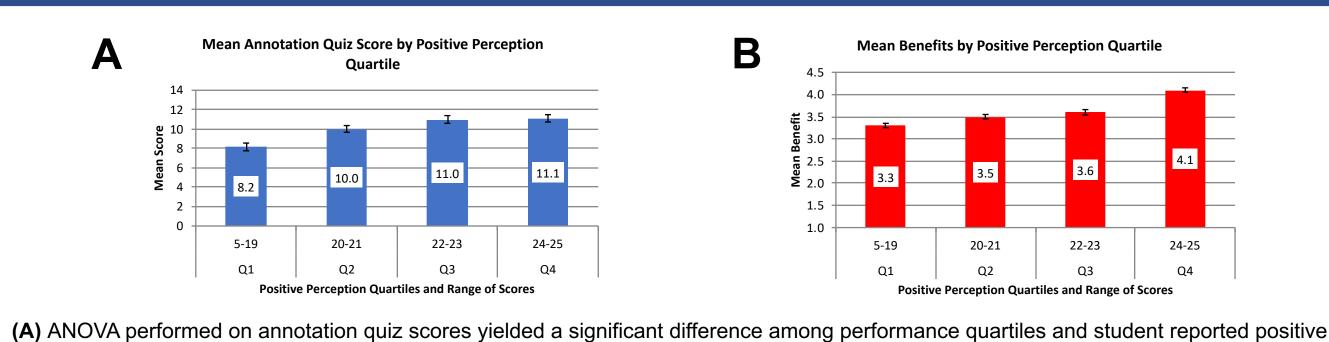
Gaps near splice sites



fail in different research situations. Degree of willingness to risk failure was evaluated as 1 (very likely), 2 (moderately likely) or 3 (not at all), and the percentage of responses in each category determined. Data suggest that the relative low-cost, low-stress conditions of a GEP research course make faculty more likely to let students experience the benefits of formative frustration.

Data from Lopatto et al. (2020) JMBE

Student Perceptions of Science Impact Course Benefits

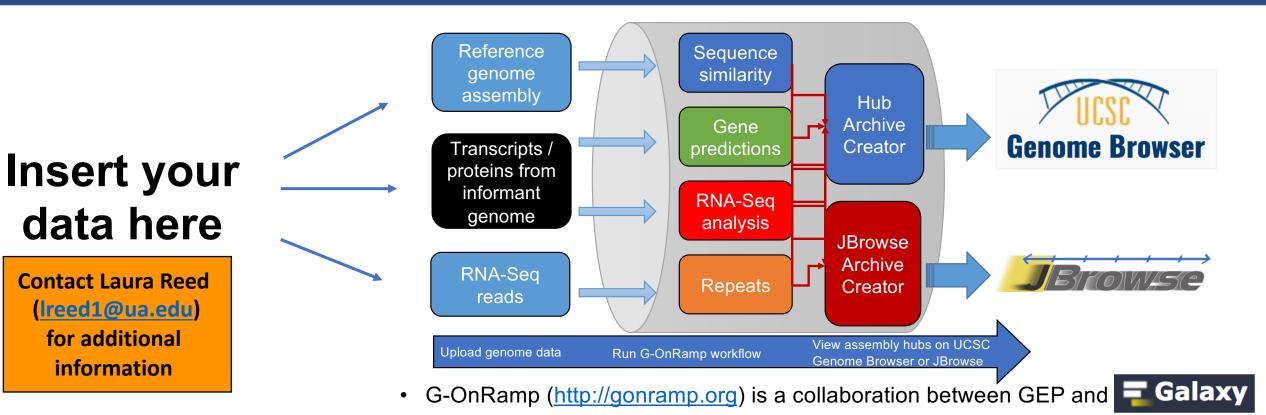


perceptions of science (F = 39.1, df =3,984, p<0.001), with high quiz-performers (Quartile 4) perceiving science significantly more positively than low performers (Quartile 1). (B) Analysis of student self-reported benefits also showed significant differences between groups (F=51.5, df=3,1010, p<0.001), with high performs (Quartile 4) reporting more benefits than low performers (Quartile 1). These data indicate the importance of finding ways to enhance student's perception of science in order to provide greater benefits during course instruction.

Faculty Training for online implementation

- Materials for online course implementation and project management
- Online training through the Quantitative Undergraduate Biology Education and Synthesis (QUBES) platform
- GEP is recruiting NEW MEMBERS. Contact Catherine Reinke (creinke@linfield.edu)

Recruiting New Science Partners through G-OnRamp



Extends Galaxy with tools and workflows for genome annotation

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