

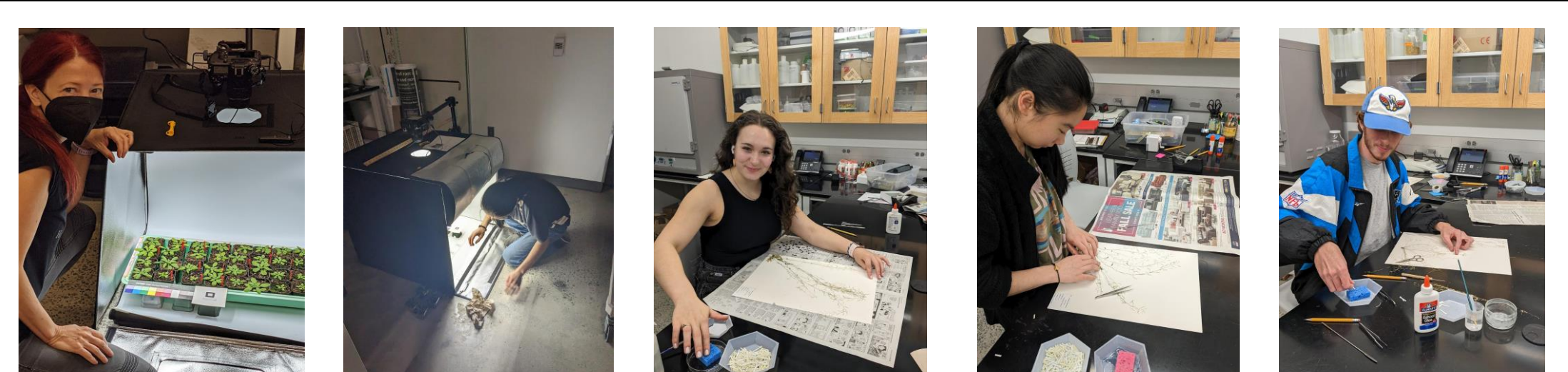
DCURE (Digital Course Based Undergraduate Research Experience): expanding student opportunities in research in quantitative plant biology

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INTRODUCTION

- Undergraduate students participating in research expand their understanding of science, gain transferable skills, and enhance their self-identification as scientists.
- One response to the call for enhanced opportunities for research in curricula is the expansion of CURE (course-based undergraduate research experiences).¹
- Benefits of the CURE include students gaining experience in the research process and scientific thinking^{2,3} and engage greater numbers of students than in one-on-one mentoring^{1,4}.
- The pandemic amplified the need for creative thinking in laboratory courses, particularly to include learners participating from a distance.
- Here we take a novel approach by modifying an experimental plant evolutionary ecology CURE to a digital CURE (DCURE) with the goal of increasing available research opportunities and examining plant biology questions on genotype by environment responses.



GUIDING QUESTIONS

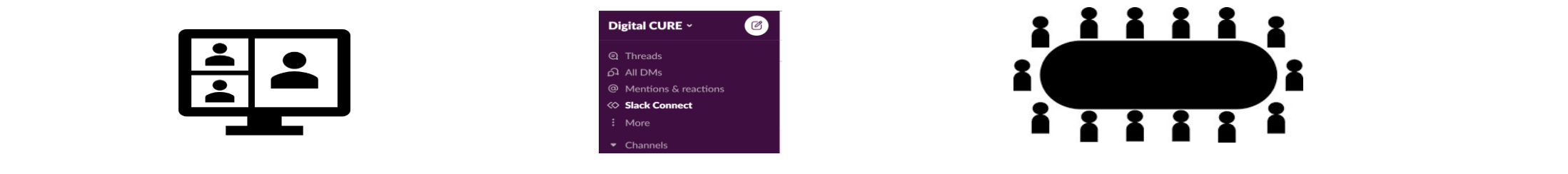
- Do students obtain learning and instructional gains in a digital CURE in quantitative experimental ecological genetics?
- Are digital CURE modules successful in expanding students' content knowledge, and metacognitive benefits as demonstrated for in-person CURES?

DCURE Biological Concepts

- Plants can respond to environmental variation by altering traits, in a process called phenotypic plasticity.
- Phenotypic plasticity of a trait has a genetic basis, and mutations can alter the action of these genes.
- Here, we investigate the influence of mutation in the study of genetic variation of phenotypic plasticity.

METHODS: Evaluating Student Learning & Faculty Networking

- Pre-post student focus groups for each course and section.
- Faculty pre-semester workshop, during semester Slack, post-semester round tables.
- Code and categorize emerging themes.
- Outline elements for iterative refinement.



Plant Methods: Genotype by Environment

Arabidopsis thaliana

- Model plant system.
- Life cycle <1 semester
- Well defined quantitative measurements
 - early life size = rosette diameter
 - reproductive fitness = fruit number
- Natural populations for study.⁵
- Seeds from stock center: single gene mutants & wildtype controls.⁵



Plant Experimental Research Themes

- Do groups of mutant lines from distinct genetic functional categories vary in phenotypic plasticity to flood and temperature treatments?
- Is there genetic variation in phenotypic plasticity across genotypes leading to novel discovery of connections between genotype and trait?

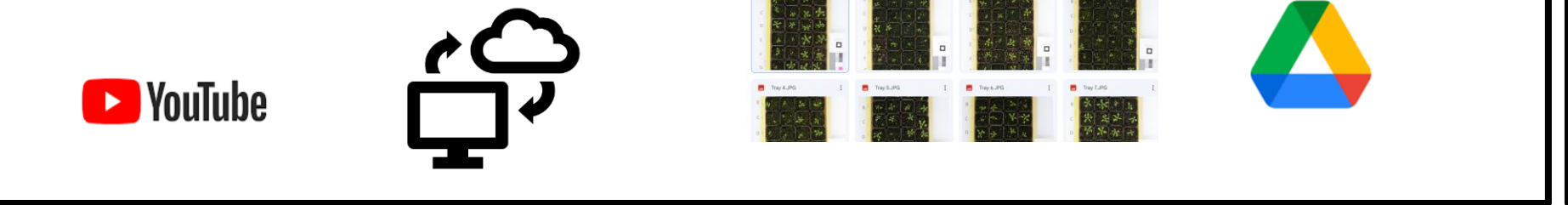
METHODS: Module Materials

Design and share instructional materials: research plant images, measurement protocols, "behind the scenes" details and instructional videos

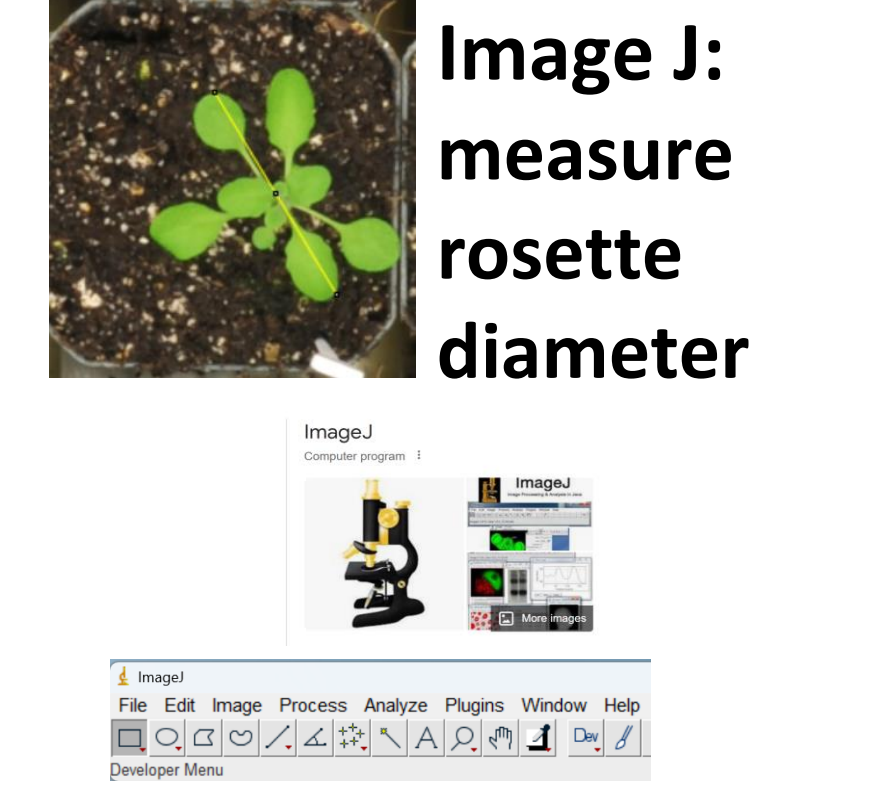
Student learning objectives:

- developing questions, refining hypotheses
- measurements with software tools
- data curation and data management
- graphing and statistical skills
- writing & communicating science findings

Post-evaluation: refine or develop new materials for the next semester.



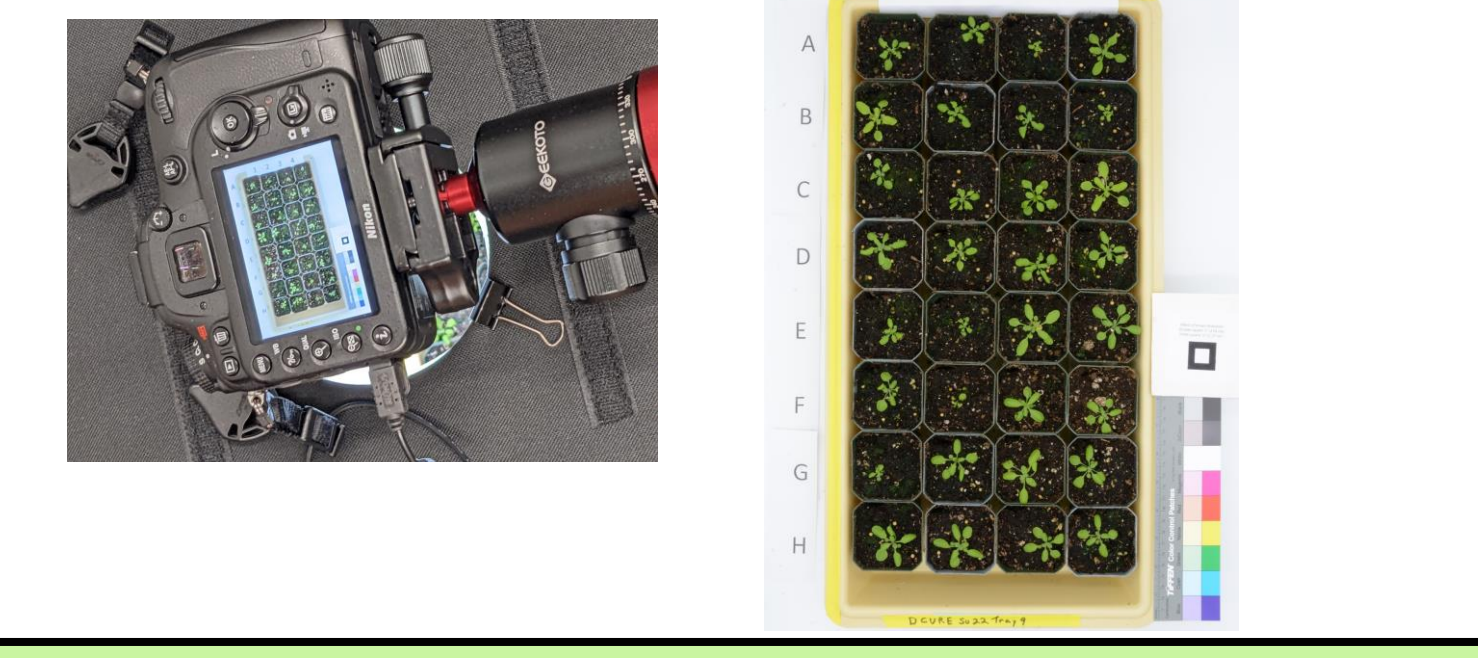
Randomized and replicated design: in growth chambers



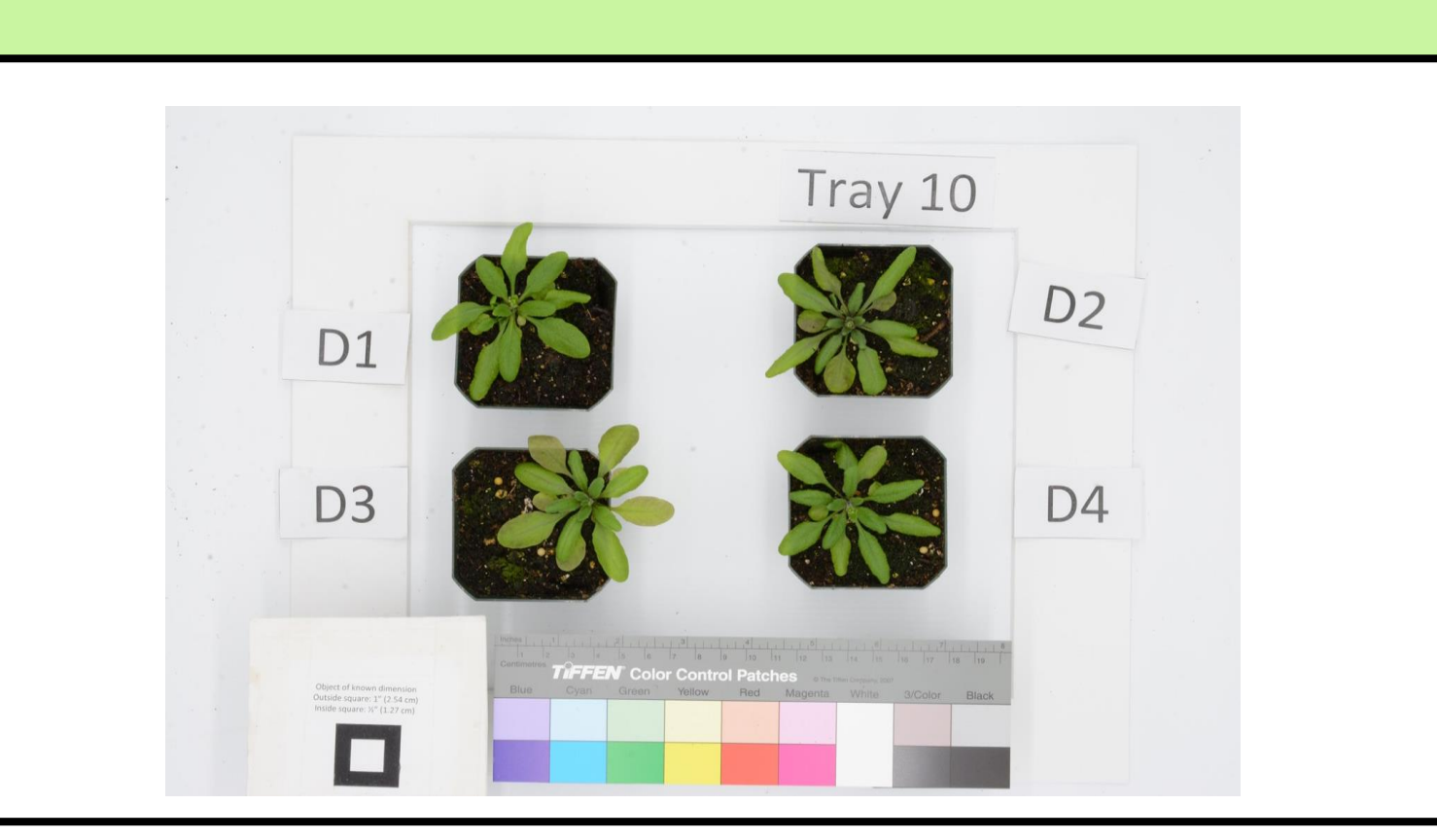
Herbarium sheet scans at reproductive maturity: count fruit with seeds



Photos: 17 d old seedlings: measurement rosette diameter



Photos by individual pots: 28 d old seedlings



Broad hypothesis are refined and adaptable to courses based on investigation focus: molecular biology, plant biology, ecology & evolution, introductory biology & genetics.

Evaluation study sample

Spring 2022: 476 students; Fall 2022: 354 students
 Spring 2023: 264 students; Fall 2023: 120 students
 Spring 2024: 134 students Total # of Course Sections: 39
 Institutions: 12 total, 2-yr, 4-yr, Public, Private, PUI, HBCU, HSI
 Courses: 1st year, 2nd year, upper division

Student Outcomes: Discoveries & Data Skills

- "It helped show me a taste of how being a scientist would work in real life."
- "The importance of both phenotypic plasticity and genotypic variation in shaping plant responses to nutrient availability in *Arabidopsis thaliana*. Findings contribute to a better understanding of how plants adapt to changing environments and highlight the need to consider both genetic and environmental factors in plant biology research."
- "I learned how to use Image J effectively." & "Excel skills have improved."
- Overall:** The DCURE facilitated students' understanding of real-world scientific work, highlighted the importance of phenotypic plasticity and genotypic variation in plant responses, and enhanced their proficiency in using tools like Image J and Excel for data analysis.

Student Outcomes: Metacognitive Gains

- "Science is an incredibly collaborative field, as having our colleagues all help to collect data significantly cut back on the workload. I was also able to use their findings in my own research."
- "Mutations can have many different effects and can take way more than one experiment to fully understand the effects of it."
- "I just felt like I was in control. I like collecting the data. It felt good to understand the results that were found."
- Overall:** Students gained a deeper appreciation for the collaborative nature of science, the complexity of understanding mutations through multiple experiments, and experienced a sense of control and satisfaction in collecting and interpreting data.

Student Plant Research: Course-Based Discovery

Data from a pair of students in Spring 2022: Students collect data and graph data in Excel on mutant and wildtype plants grown in 2 environments.

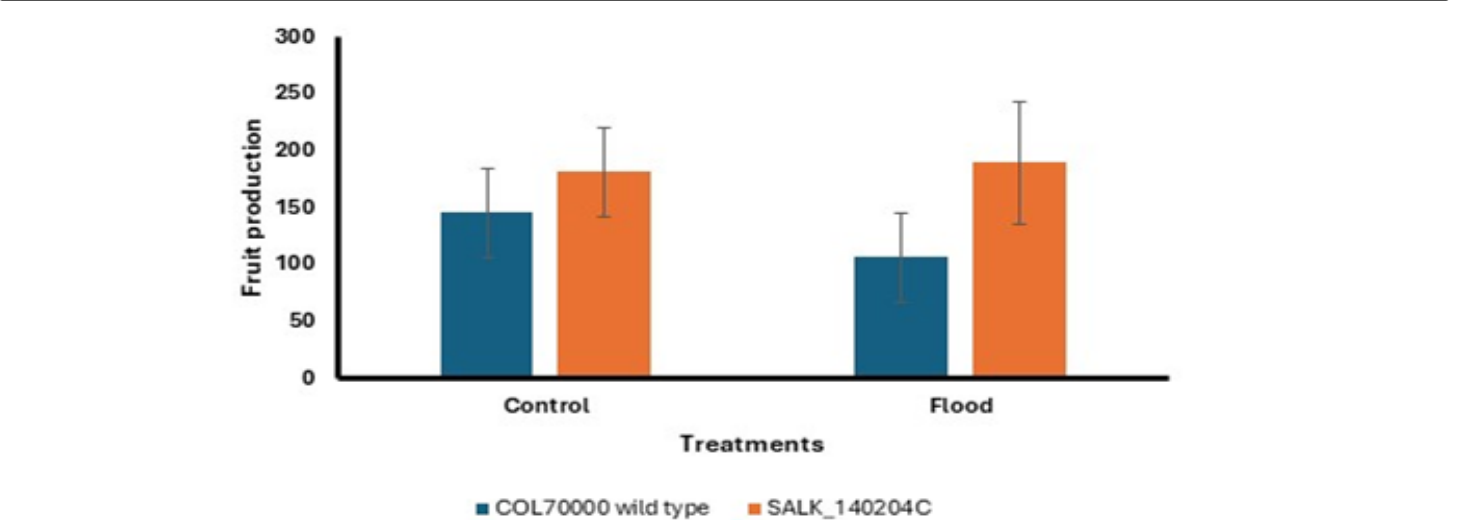


Figure 1. Students in DCURE discover significant differences between wildtype (blue) and mutant (orange) in fruit production. They found that genotypes differ in plasticity to water treatments.

Data from multiple Spring 2022 classes: Students contribute to larger data set on gene functional groups. Independent study and upper division DCURE student's graph in R.

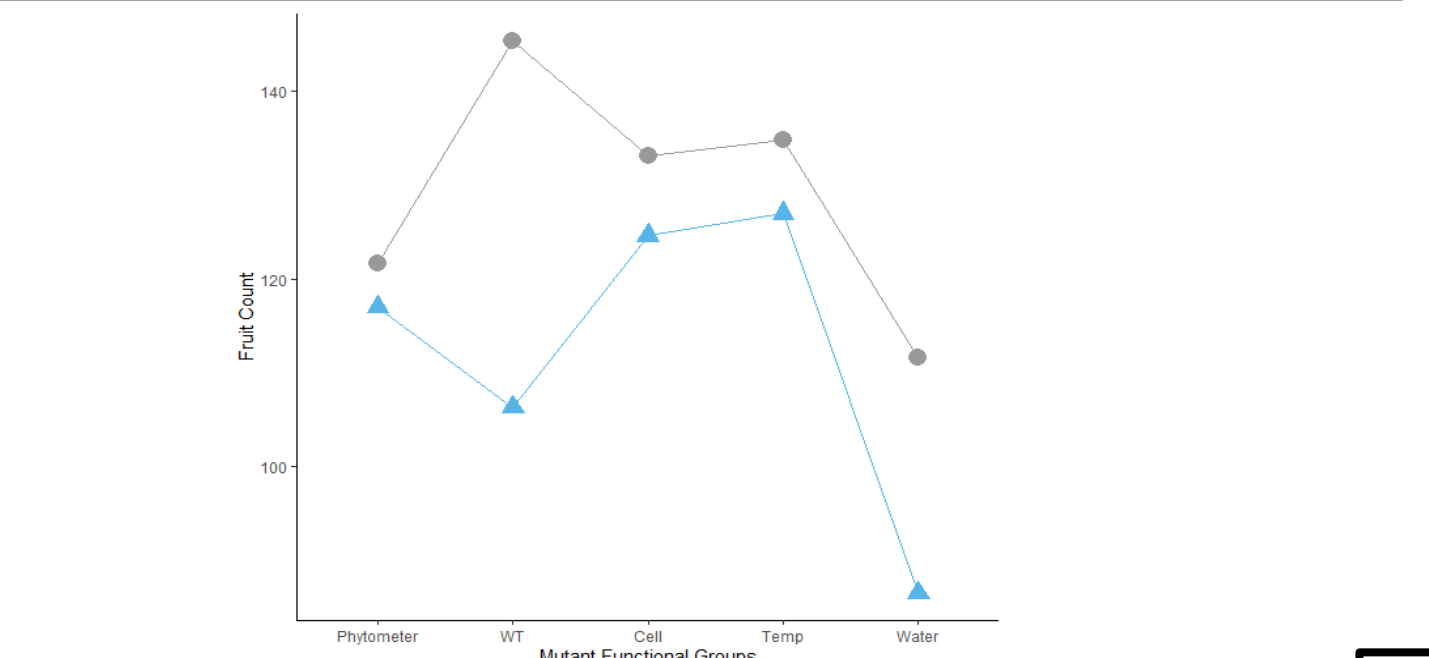


Figure 2. Students discover that effects of mutant functional groups are context dependent.

Data from multiple semesters Spring 2022 and Spring 2023 classes: Multi-semester experiments on the same mutants lead to broader discoveries.

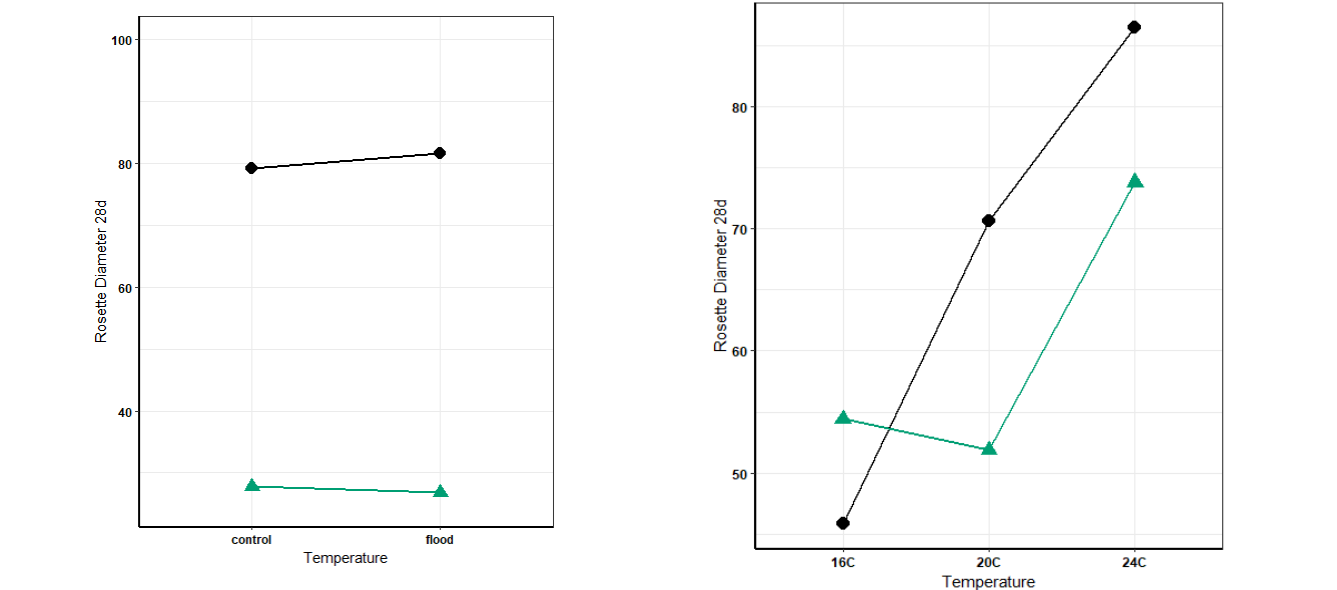


Figure 3a & b. Students make connections across water & temperature experiments of plastic responses of mutants (aqua) in comparison to control (black) in rosette size.

CONCLUSIONS & NEXT STEPS

- Students successfully participated in research in the DCURE, with enhanced opportunities and reduced barriers for participation.
- Students developed skills in real-world scientific discovery regarding genetic effects on traits. For example, the DCURE improved students' understanding of scientific work, concepts of phenotypic plasticity, and research tools.
- Evaluation contributed to updated materials and evidence of student gains in learning in biology, data analyses, technical tools, and collaboration.
- Next steps:** Compare in-person CURE to DCURE student in gains in competency, content knowledge, and self-efficacy.
 - Analyze faculty outcomes.

Literature cited

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