1. Introduction

Project Title: Plant GIFTS (Genetics In Farming Technology and Science)

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Assistant Teaching Professor

Project Co-Leader: Erin Friedman
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Associate Professor of Biology

Total Amount Requested: $6,875

Project Summary:

Plant GIFTS will increase student understanding of heredity with a particular emphasis on breeding while also incorporating information on transmission genetics and the central dogma. Specifically, our project proposes to introduce students to the ideas of applied genetics and plant breeding technology through the lens of current global food production challenges. We will present up-to-date interactive lecture materials coupled with a group-based active learning module that can be utilized in classrooms ranging in size from 20 to 300+. Our goal is to review genetics concepts while we work to place this science into the context of the global food crisis, one of the greatest problems facing society currently and in the coming century.

Appropriate for advanced high school biology courses as well as introductory or non-majors undergraduate level classes, we will build into our module both formative and summative assessments to gauge student learning. The module will be developed in consultation with a high school teacher, and we will pilot the module in both high school and undergraduate classrooms. Prior to its dissemination, we will utilize multiple layers of project assessment to evaluate and revise our module, its content, and the suggested teaching approaches. Our project deliverables will consist of a slide deck, a list of all formative and summative assessment questions, handouts for the group activity, and a video tutorial for teachers.

2. Project Description
A. Goals and Objectives:
The main goals of our project are two-fold: (1) to review basic genetics concepts and add in the complexity of plant breeding to students' understanding of how biological information is stored, processed, and passed down to later generations and (2) to fit this knowledge into a broader global framework, addressing the current and future global food crisis as well as a scientifically-backed understanding of modern, genome-edited crop production.

International global food shortages are already upon us, and continuing effects of global climate change together with increasing populations will worsen this crisis in coming generations. Continuous and increasing exposure to anti-GMO and anti-science rhetoric leaves high school and undergraduate students vulnerable to inaccurate understanding of these critical issues. By presenting valid scientific discoveries and expanding students' understanding of the connections between historical breeding techniques and modern plant breeding methods, we hope to counteract this false messaging. Therefore, we believe that the subject matter covered in our project is extremely important, a powerful tool for helping students form connections between the classroom and their everyday lives, and a way to form a more educated population that will develop and support scientifically-backed solutions to feeding the growing world population.

Plant GIFTS will align with the ASPB's **Breeding** principles for teaching plant biology. To contextualize the main points of our module and our active learning component, we will begin with a review of the Central Dogma and Transmission Genetics. The majority of our module will cover Breeding, with a focus on how "selection of particular plant phenotypes has been integral to the development of human society" and "tracking changes in allelic diversity…allows plant breeders…to improve crop productivity".

For undergraduate classes, our module will additionally align with the Biological Evolution objective that covers Biodiversity and Humans, including the following:

- Human selection has affected almost every aspect of crop plants, including their structure, reproduction, genetics, and adaptation.
- Agriculture shapes human populations, including their size, distribution, and cultures.

The module will cover the following core concepts and competencies from Vision and Change:

- Information flow, exchange, and storage
- Evolution
- Systems
- Ability to apply the process of science
- Ability to use modeling and simulation
- Ability to understand the relationship between science and society

For upper-level high school courses, our module will also cover the following core concepts:

- The functions of genes and their products can be affected by the environment and other genes at one or many steps involved in producing a trait.
- Evolution by natural selection is a process by which inherited traits influence how likely an organism is to survive, reproduce, and pass those traits to its offspring.

- Genetic variation and the phenotypic variation it leads to are the basis for evolution.

As described in section C below, these learning outcomes will be assessed via both formative and summative assessments.

B. Project Details: (Note: Underlining indicates alignment with goals and objectives in part A) Our module will begin with a few "clicker"questions that review background concepts and vocabulary essential for genetics and heritability. These and other similar questions can be answered either via an electronic polling system or, if such a system is not available, each student will be given 4 different colored index cards, where each color represents a different answer (A thru D) and can be held up by the student to respond to the questions. Following this, an interactive slideshow will review concepts of Punnett squares, alleles, phenotype, and genotype. We will then focus on one particular crop species and discuss how human selection has affected that plant, moving on to review modern breeding techniques including the current usage of CRISPR technology to improve crop plants. Clicker questions and open-ended questions will be inserted throughout these slides for group or individual work. At this point, we will introduce concepts of population growth, the global food crisis, agriculture, and climate change, and we will tie these together as we start to discuss our group activity. Briefly, this activity will involve students looking over a list of potential genes that can be inserted into a plant, making predictions about which modifications to choose to make a seed that is likely to survive year-to-year climate changes in its growing region, and then participating in a simulation of events that could affect their crop. The group who has the largest crop at the end of the simulation wins; groups can make new predictions based on initial results, and the class can play multiple rounds of the simulation. The lesson will end with additional slides and discussion questions related to society's need for increased food production, scientific and ethical questions related to GMOs, and anti-science rhetoric. Questions to understand student attitudes surrounding these topics will also be included.

Our project will be modular in nature in order to easily adapt to various class lengths and number of class periods that will be utilized, but will require at least one undergraduate lecture class to complete and can likely cover a week of an upper-level high school science course. For example, the review material at the start can be minimized or eliminated, and teachers can choose to have students work on open-ended questions in groups, individual minute papers, or as outside work. Our target audience is upper-division high school through introductory and non-majors undergraduate biology courses with classes ranging from 20 to 300+ students. For classes with higher enrollment, TA support would be helpful but not required. Our project deliverables will consist of a slide deck, a list of all formative and summative assessment questions, handouts for the group activity, and a video tutorial for teachers.

Timeline for Project Completion:

Fall 2022	**Spring 2023**	**Summer 2023**	**Future**
Develop Curriculum; Initial classroom testing	Additional classroom testing; Formal assessment; Revision	Final Revisions and formatting; Produce video instructions; Dissemination to ASPB	Prepare for publication

C. Expected Outcomes and Evaluation:
Evaluation of our project will cover both assessment of the module itself (pre-dissemination) and assessment of student understanding of the concepts covered and their attitudes towards these ideas (within the module itself). To achieve the former goal, we will use layers of evaluation at various points in our module creation. First, once we have our basic framework in place, we will hire an undergraduate student to help find any knowledge gaps in our slides, vet our formative assessments, and evaluate our ties between information and current trends and technology. Next, we will visit an upper-level high school classroom local to one of the project leaders to practice our module, ask for student feedback, and self-reflect on the success of our student learning outcomes. The high school teacher will also assist in this stage of module development. Finally, we will make use of the services offered by the project leader's university to evaluate our module when it is deployed in a lower division undergraduate biology course. UC Merced offers, via its SATAL Program (https://crte.ucmerced.edu.672elmp01.blackmesh.com/satal), student-run classroom evaluations that assess the teaching and learning experiences during a particular class session including student engagement, instructor use of class time, and range and effectiveness of the various teaching practices that the instructor uses. This evaluation uses the COPUS method of classroom observation, which is well-studied and validated (Smith et al., "The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices", CBE-LSE, 2013). Once we have received our COPUS results, we will make final adjustments to our module. Through these multiple stages of project assessment, we will create a well-vetted module that is useful at various academic levels.

The second aspect of evaluation is student learning. Students are expected to gain knowledge in plant heritability and genetics through our module, and this knowledge should also strengthen their overall understanding of basic genetic concepts. Instructors will be able to assess student learning via both formative and summative assessments. Formative assessment will include the following: regularly spaced "clicker" style questions, which can either be used with a clicker system or with polling flashcards as outlined above; worksheets for use with the active learning component of our module that will allow students to practice their predictive modeling skills; and questions for minute papers that can be asked pre- or post-module, or assigned as homework assignments. Summative assessments can vary depending on the type and level of the course that is using the module. To meet these varying needs, we will create a variety of low-, mid-, and high-level Bloom's questions for teachers to use on quizzes or tests. Further, we will provide teachers with links to information on various biology concept inventories that they can use with their course to gain further understanding of the students' conceptual knowledge of the genetics content covered in the module. Lastly, we will include a short series of questions that can be used before or after the presentation of the module that will allow the instructor to identify student attitudes towards genetics, anti-GMO rhetoric, and modern plant breeding techniques. These optional questions can be used pre-module to guide how much the instructor needs to emphasize these concepts or post-module to determine how much they need to go into these ideas in future components of the course.

3. Statement of Teaching Philosophy

Active learning is a cornerstone of the student-centered classroom that increases conceptual understanding of the material and can lead to higher exam scores and pass rates. It also increases student engagement, STEM identity, and feelings of belonging and community. Despite the fact that the two PIs have never taught at the same institution, both utilize active learning techniques in all classes regardless of size. On a given day, one could observe us teaching students to solve problems using case studies, leading a group discussion of scientific literature, guiding students through modeling activities using Lego bricks or Play-Doh, helping students through problem-solving activities, or analyzing the results of a scientific study. When lecturing, we build in thought questions, chances to reflect, and think-pair-share activities. We use online polling systems to allow students to respond to directed questions about the content and assess their own understanding. We take time to give the students sample problems to work on in class and then walk around the room, looking at their work, answering questions, and engaging with their learning process. These active learning experiences are straightforward, no-stakes practice sessions for students to try out what we have taught them. Through these activities, students gain practice in the subject matter while becoming more comfortable asking questions, and we gain insight into what difficulties they are having in the course. Additionally, in all of these examples, the student is not passively sitting and listening to an instructor talk about science. In our classrooms, students are spending more than 50% of their time engaging with the content, manipulating it, and presenting it either orally or in writing. Our students have frequent opportunities to self-assess their understanding, to ask questions, and to discuss with their peers. We utilize these techniques because they have been demonstrated to work, and they work particularly well for our students. But it's not only our students who learn in our classrooms; teaching allows us to learn something new every day, and we plan to continue to refine and improve our instruction techniques for as long as we have students to teach.

Project Leader Findlater has spent the last 10 years teaching a variety of chemistry and biology courses to majors and nonmajors alike. Trained as a plant geneticist and molecular biologist, graduate school also taught her that teaching was her true interest. She has taught intro plant biology and an upper level medicinal botany class, but even while teaching introductory general chemistry, she worked to include examples about plants and agriculture. Her biggest teaching joy is to help students understand how STEM is important in their daily lives. She recently relocated to her current institution as an Assistant Teaching Professor.

Project Co-Leader Friedman has been teaching biology to undergraduates for 18 years in settings ranging from small, private liberal arts colleges to large state universities. She challenges herself to incorporate plant biology examples and topics into each course, from introductory biology to cell communication to cancer biology, and she has mentored a wide array of student-initiated plant biology research projects. She has developed many classroom and laboratory materials for use in her classes (e.g., Terry & Friedman, "Monarchs and Milkweed: A Case Study on Energy Cycles in the Biological World." National Center for Case Study Teaching in Science, 2019; Friedman & Terry "Investigating enzyme structure and function through model-building and peer teaching in an introductory biology course." CourseSource, 2020). Dr. Friedman's commitment to teaching was recognized by the Virginia Foundation for Independent Colleges with the H. Hiter Harris III Rising Star Award in 2017.

4. Itemized Budget

Findlater stipend: 90 hours @ $25/hour = $2250
Friedman stipend: 90 hours @ $25/hour = $2250
Undergraduate student stipend: 40 hours @ $25/hour = $1000
High school teacher stipend: 15 hours @ $25/hour = $375
Travel costs: $1000
Assessment: $0
Publication: $0
Total Budget: $6,875

Budget Justification:

Project Leader Findlater will develop project materials; supervise the undergraduate student; implement assessments and identify areas for revision; prepare materials for publication and dissemination; film and produce video tutorial.

Project Co-Leader Friedman will develop project materials; work with high school teacher to pilot the module; implement assessments and identify areas for revision; prepare materials for publication and dissemination; film and produce video tutorial.

UC Merced Undergraduate Student will review and correct any knowledge gaps in the slides, vet formative assessments, and evaluate ties between information and current trends and technology; assist with curriculum test-runs and review; and format documents and handouts to be teacher- and student-friendly

Central Virginia High School Teacher will work with the Project Leaders to integrate the module into the existing curriculum based on NGSS and state SOL standards alignment; help run the module with students in their classroom; administer assessments to measure student learning outcomes; solicit student feedback; and self-reflect on the success on our student learning outcomes

Travel: Airfare, ground travel, and local lodging for Project Co-Leader Friedman to travel to the home institution of Project Leader Findlater to implement the module in an undergraduate classroom, and conduct the COPUS Assessment, and collect student data.

Assessment: Concept Inventories are freely available. COPUS Assessment will be provided by the SATAL program at the Project Leader's institution (UC Merced).

Publication: Upon completion, a manuscript will be submitted to CourseSource for publication. CourseSource does not charge publication fees.