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Investigating the Effects of Mechanical Vibrations on Oryza Sativa: An Interdisciplinary Summer Undergraduate Research Experience

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Abstract

In the summer of 2017, the Chico STEM Connections Collaborative (CSC^2) initiated and supported a summer research opportunity for underrepresented minorities within the College of Engineering at California State University Chico. The aim was to recruit and retain students in science, technology, engineering and mathematics (STEM) majors and facilitate their academic success through hands on learning. Through an application process which considered student interests and backgrounds, awardees were paired with a faculty mentor to work on a research project over the summer. Students received a stipend and nominal equipment budget to purchase small items to support their research projects. This paper documents the experiences of one interdisciplinary team, comprised of students and faculty from the Colleges of Agriculture and Engineering, and assesses the qualities of their investigation into a novel biophysical treatment on rice seeds. For this project, three mechanical engineering students teamed up with three agricultural students to investigate the influence of mechanical vibration on the germination rate of rice seeds. Led by faculty members from each college with backgrounds in engineering and plant and soil science, the team was provided with a robust research and learning environment in which to work directly with the faculty mentors. The results of their work and the factors which helped lead to their summer undergraduate research experience are considered herein.

I. Introduction

The CSC² Undergraduate Research (UGR) Program is designed to facilitate and support Hispanic, low-income, and/or first-generation STEM students to develop academic research and career preparation experience over summer break. The UGR Program is led by dedicated staff across 3 colleges who organize and develop a comprehensive schedule of weekly workshops, seminars, and trainings across the summer session. The combination of direct research and professional development provide a first-hand exposure to emerging issues and real-world training needed to advance in science, either as graduate students or bachelors-level working scientists. To apply, undergraduate students must be a declared major within the Colleges of Agriculture, Engineering, Construction Management and Computer Science or Natural Sciences. Students must be in good academic standing (GPA of 2.5 or better) and completed their sophomore year. Junior and non-graduating senior students were also considered. Faculty mentors with new or on-going research projects applied to the program by submitting a project description and research plan. Through the application process, faculty project descriptions were provided to students to identify areas of interest and create student-faculty teams. To help enable and support these projects, students receive a $3500 stipend and faculty are reimbursed up to $250 for student research supplies. The first year of this summer program (2017), the CSC² program hosted a total of 31 students working across 14 different projects. Table 1 describes the student majors and their respective projects.

Table 1: Project descriptions for the CSC² summer research program.

Project	Majors (number of students)	Description
1	Mechanical, Mechatronic, Manufacturing (2)	Biodegradable plastics research
2	Mechanical, Mechatronic, Manufacturing (2)	Waste to energy research
3	Mechanical Engineering (1)	Molecular dynamics simulation
4	Mechanical and Civil Engineering (2)	Aerodynamics and wind tunnel testing
5	Mechanical and Mechatronic Engineering (2)	Mechanical properties of Silicon scaffolding
6	Mechanical, Mechatronic, Agriculture (6)	Enhanced seed germination
7	Civil Engineering (1)	Water treatment systems
8	Civil Engineering (2)	Environmental effects of water treatment
9	Civil Engineering (1)	Seismic risk assessment with software
10	Concrete Management (1)	Optimizing air void hazards in concrete
11	Electrical Engineering (2)	Privacy-protection in cloud computing
12	Computer Engineering (3)	Low power modes for Ag sensor networks
13	Computer Science (3)	Software start-up development
14	Computer Science (3)	Data privacy for research purposes

Responsibilities

The UGR summer research Program began the first week of June, two weeks after the spring semester ended, with students working on a project directly supervised by a faculty mentor. In addition to research, the UGR Program also provides professional development workshops with a targeted focus on the process of applying to graduate schools and professionalism. Combined, students were expected to spend approximately twenty hours each week. Workshop series topics and dates for the 2017 summer cohort are given in Table 2.

Table 2: Workshop Schedule.

Date	Workshop
June 6	Applying to Grad School
June 13	Preparing for the GRE
June 20	Life in Grad School
June 27	Careers with a Science Bachelor’s Degree
July 11	Do’s and Don’ts of a Scientific Talk
July 18	Careers at a National Laboratory
July 25	How to Make a Scientific Poster
August 1	Technical Resumes 101

Workshops were conducted from noon to 1pm on Tuesdays with attendance required. Note, early workshops in the series were directed at educating students about graduate school with later workshops providing exposure to divers careers in science and tips on how to enhance professionalism in conduct and presentations. The counterpart to the weekly Tuesday workshops was weekly seminars on Thursdays. Seminars were also held from noon to 1PM with UGR faculty mentors giving instructional to informative presentations ranging from the scientific method and engineering design process to specific faculty research conducted about the durability of material undergoing a freeze-thaw process. The complete list of topics and dates are given in Table 3. An important goal of the UGR Program was to help students appreciate the need to balance the demands of research, workshops, and seminars with fun and adventure. For example, periodic social events such as a BBQ’s and hiking adventures to a local national park were organized and led by the staff to facilitate a sense of community.

Table 3: Seminar Schedule.

Date	Seminar Title
June 8	Literature Review/Water Topic
June 15	Testing Hypothesis/Scientific Method
June 222	Engineering Design
June 29	Engineering Education Research
July 6	Simulation/Experimentation
July 13	Computer Simulations
August 3	Freeze-Thaw Durability

Finally, the program culminated in August with a two-day symposium where students presented their work to their research peers and faculty. To document their summer research experience, a final report from each student project was submitted.

II. Project Showcase

Of the 14 summer research projects conducted, this paper will assess and showcase the qualities of one interdisciplinary research team's project investigating the effects of biophysical treatments (mechanical vibrations) on Oryza Sativa, more commonly known as rice. This research topic and experimental process was new and untested when the students and faculty first met to begin their summer research collaboration. The topic required the broad backgrounds and expertise of both the College of Agriculture and the College of Engineering. The team was comprised of three students and one faculty mentor from each college. For simplicity, the team was known as the seed vibrations team.

Experimental Conditions and Instrumentation

From the beginning, the seed vibration team was a tight collaborative effort that required considerable iteration across the primary development of equipment and experimental conditions. In fact, the group started with some barrowed electronics and quickly began to innovate and build parts necessary to make rigorous scientific measurements and test working and more refined hypothesis.

The first step was students taking the initiative to construct a housing device to isolate vibrations. This led them to engaging with 3-D printing equipment available in the College of Engineering. With all having no prior experience, the team taught themselves how to operate and successfully designed and printed several housings to hold experimental equipment and isolate mechanical vibrations into rice seeds. To produce controlled mechanical vibrations, the team utilized small magnetic exciter (speakers) which required a solder connections. Team members learned, practiced, and improved soldering skills and successfully built multiple experimental apparatuses. One team member documented the project across all stages of development. Examples of the students demonstrating 3-D printing and soldering approaches are shown in Figure 1.

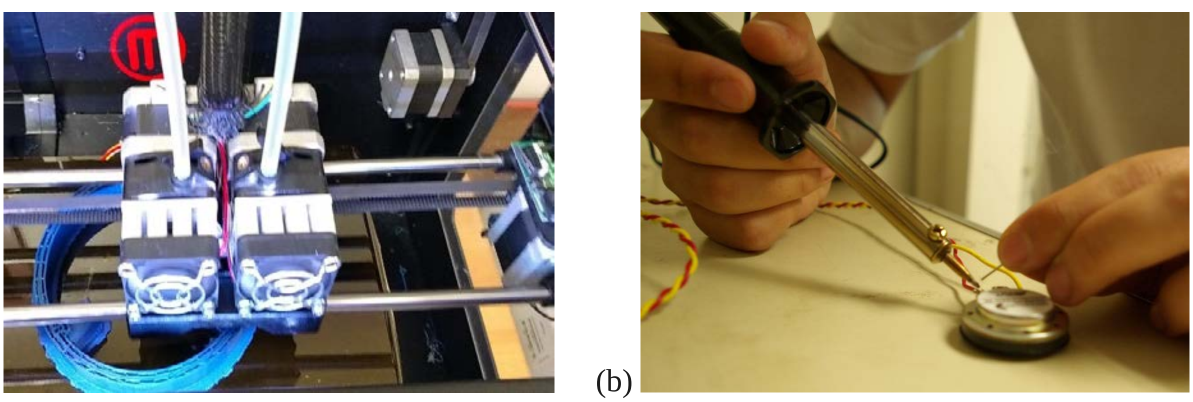
(a) (b)


Figure 1: (a) Experimental prototype being 3D printed and (b) student soldering.

State-of-the-Art Equipment

As a key aspect to experimental research is testing validation, the faculty taught the team members how to operate and utilize state-of-the-art equipment to validate and implement controlled responses. The team then used a laser displacement sensor capable of measuring one micron movement to test experimental apparatus and treatment conditions. Also crucial was an oscilloscope to observe the response and quantify frequency and amplitude. After ensuring testing requirements were met, the complete experimental setup could be realized. Using high resolution function generators and voltage amplifiers, each station was controlled and powered separately to enable three simultaneous experiments. Prior to this project, none of the students had experience with such kinds of equipment. The faculty worked closely with the students to train the students on operations and identify the safety hazards associated with each piece of equipment. Students capturing the laser displacement readings and the final experimental setup are shown below in Figures 2 and 3, respectively.

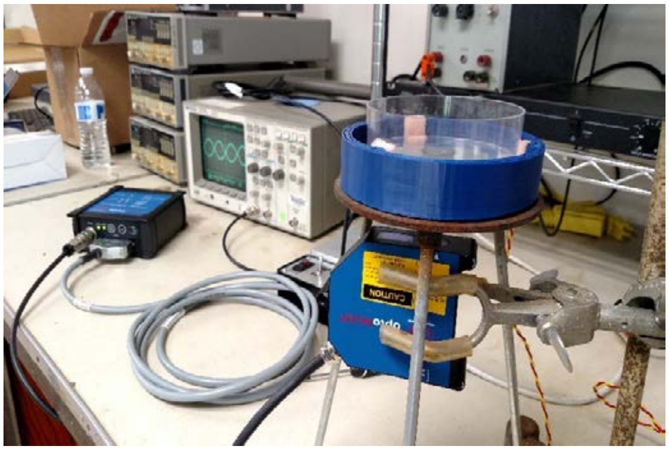


Figure 2: Students using a laser displacement sensor to validate vibration effects.

Figure 3: Final setup with three experimental stations.

Innovation and Results

One of the greatest project challenges was monitoring numerous seeds and treatment conditions simultaneously to determine the precise germination time during research trials. Seeds needed to be monitored around the clock to test varying experimental conditions administered to the rice seeds to detect potential differences in germination rates. Considering these experiments lasted for 7-10 days and needed to be checked through day and night, the team was faced with a daunting challenge of documentation. As a solution, the students built waterproof seed trays to organize treated seeds and a flatbed scanner with computer software to facilitate almost continuous assessment. The scanner would take hourly high resolution images to capture and document the time needed for each seed to germinate. Students generated and tabulated date for germination times by visual validation (a time consuming task) and plotted results. Figures 4 and 5 show the scanner setup and experimental results, respectively.

Figure 4: Scanning bed with seed organizer during experiment.

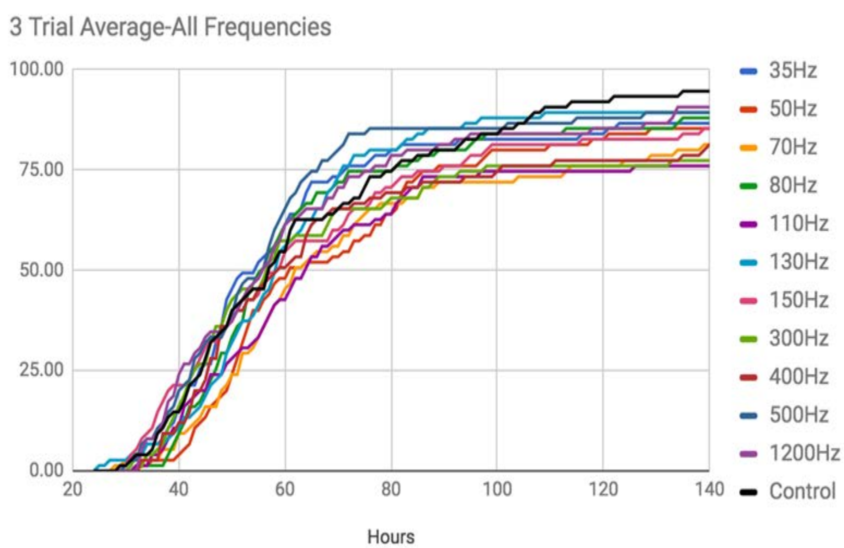


Figure 5: Experimental results for a broad range of mechanical vibration.

III. Assessment

Three distinct qualities standout as significant pieces that contributed to the team's overall success. First and foremost, the team formed a strong sense of camaraderie and purpose. From the beginning, there was obvious excitement at the novelty of engineering students collaborating with agricultural students. With strongly contrasting educational backgrounds, one might have guessed this would lead to difficulties. Ironically however, this clearly helped facilitate an early and ongoing sense of partnership. The three agricultural students were often thrilled to help weigh in on plant science issues and to teach their three counterparts in engineering. At the same time, the engineering students were excited to be utilizing their knowledge and background to help the agriculture students understand how the experimental equipment worked. As a result, these different disciplines complemented each other extremely well. Each was empowered and the team developed a strong sense of unity. Furthermore, since the research project was conducted on the university farm, the students were exposed to a refreshing contrast to typical classrooms and laboratories. As one of the engineering students put:

"*Researching out on the farm was a lot different than what I thought research would be like, you're surrounded by life-stock, orchards, and great scenery. You're able to enjoy your time.*"

To expand the investigation beyond germination, the team took the initiative to plant and observe early plant growth of the experimentally tested rice seeds. This allowed the students to work in the farm greenhouses and expand their experiences (Figure 6).

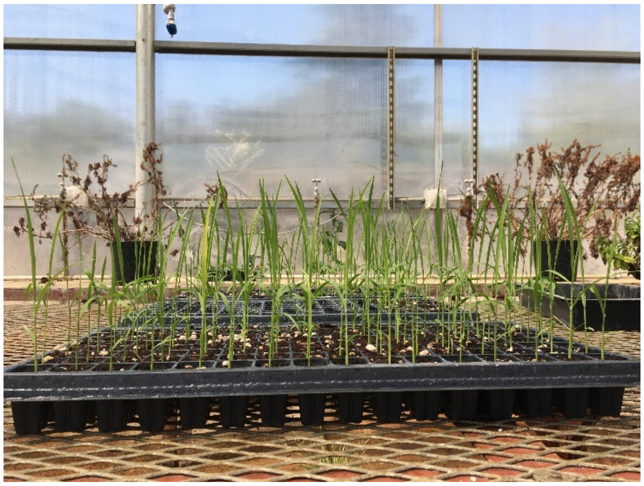


Figure 6: Post treatment seeds planted to continue comparison.

The second critical aspect of overall team success was they were all heavily involved in the actual design and development of the experimental equipment and procedure. As well, they helped define testing parameters such as frequencies and duration. Interestingly, such a responsibility on the part of students was contrary to the original mission statement of the UGR Program, which deemed desirable projects for the students to be more well-established research programs. Fortunately, this requirement was relaxed for the seed vibration project. Impressively, the team consistently rose to meet a constant stream of unknowns. From the experimental design to the testing procedure itself, the team innovated and employed solid logic and scientific principles to development a very successful project. As a testament to the team's unique camaraderie, they never gave up and always worked through these obstacles. They taught themselves how to operate a 3-D printer and designed key experimental components. They learned how to operate state-of-the-art instrumentation to validate test methods. They helped optimize the test plan and data collection system. They constructed specialized compartments to enable scanning and documentation of results. They conducted an expansive array of test trials and processed the results. Undoubtedly, the team's unity and mindset were crucial. As one of the team members sums up:

"*Throughout the program there were many obstacles that we encountered, and going through them helped us mature*"

The third important consideration for the team's success was that the faculty mentors purposefully enabled an open minded, enjoyable, but rigorous working environment. Understanding that the students were getting involved in a rather complex and undeveloped research topic, there was a recognizable need to foster creative solutions and a positive work ethic. Both faculty mentors were careful to maintain an openness and willingness to appreciate the students' ideas and concerns. Often asking what they thought and/or if they had any suggestions proved invaluable as on several occasion the students made major contributions to optimize the experimental process. On one such instance, the team was being tasked with monitoring dozens of test trials simultaneously. Each would last for days and require judicious and painstaking visual inspections. When asked about this, there was indeed some amount of despair expressed by requiring such a daunting task. However, with free reign to create novel solutions, the team developed an inexpensive solution to utilize scanner beds with seed trays to automatically record and document the experimental results. In fact, the idea originated by one of the team members who was notoriously late, if not unreliable. The key point here was that every one of the team members had distinct talents and abilities, and by taking steps to ensure a positive working environment each member played a key role in the team's success. As one team member's response sums up:

"*I really like the environment that this research was done in, very open minded and leaves room for ideas and creativity*"

Finally, keeping a sense of humor throughout the summer helped keep spirits high in the face of the many obstacles and rigorous weekly schedule. During meetings and working times, the faculty did their best to make light of the effort and time required to achieve success. Throughout the summer, the team met Monday through Friday to work at the university farm. As well they attended weekly the workshops and seminars. A solid and demanding schedule no less. With the first part of the summer in experimental methods development, the second part consisted of conducting the subsequent countless experiments. As with all experimental research however, the process was not straightforward. There were many surprises and directional changes as the research developed. As one student summed up:

"*Being here this summer has showed me that research isn't always going to go the way you want it to, so you have to be ready to ask yourself new questions*"

Nevertheless, the team worked diligently throughout the summer and clearly had fun with even the major setbacks such as a bug infestation which compromised the test seeds. The team had found a rice-eating beetle within the bag of test seeds. Without hesitation, the team's reaction was to capture and study the beetle's life-cycle. They named the insect Rico and created a home for him and all of his cousins as shown on the following page in Figure 7.   Even though the entire supply of seeds was infested and much of the later experimental data was undermined by the possible influence of these insects, the team kept their sense of humor.

Figure 7: Petri dish of the rice-eating insects caught by team.

UGR Exit Survey

At the end of the UGR summer program, all students within CSC² program were asked to complete an online survey regarding their motivation and experience. Just under half of the students (i.e., 14 of 31 students) responded and the results are tabulated below. In Table 3, the motivation for students entering the summer program is clearly related to obtaining hands-on experience and exploring the possibilities within the STEM field.

Table 3: Survey response on research motivation.

What motivated you to do research?	Checked Response
To gain hands-on experience in research	13
To explore my interest in STEM	12
To clarify whether graduate school would be a good choice for me	12
To clarify whether I wanted to pursue a STEM research career	12
To clarify which field I wanted to study	8
To get good letters of recommendation	8
To enhance my resume	7
To have a good intellectual challenge	6
To work more closely with a particular faculty member	6
Other Option	1

In Tables 4 and 5 on the following page, the responses indicate that the students had a great working relationship with each other as well as with their faculty mentors, at least mostly. This certainly reflects the assessment of the seed vibrations team. Further, Table 6 indicates that students generally felt well supported during their summer work. Without a doubt, having dedicated CSC² supporting staff and faculty mentors was a crucial component to the student experience. As to the overall success of the program, the results in Table 7 suggest that students generally had a positive experience and are now more likely to consider an advanced degree program in STEM.

Table 4: Survey response on relationship with group members.

My working relationship with my research group members was...	Checked Response
excellent	7
good	6
not applicable	1
poor	0
fair	0

Table 5: Survey response on relationship with Faculty research mentor.

My working relationship with my Faculty research mentor was...	Checked Response
excellent	7
good	3
fair	3
poor	1

Table 6: Survey response on sense of support throughout summer.

How supported did you feel throughout the research process	Checked Response
very supported	6
extremely supported	4
somewhat supported	3
not supported	1

Table 7: Survey response on increased interests in STEM field.

Compared to BEFORE your research experience how likely are you NOW to: enroll in a STEM Masters, Ph.D., or professional degree program	Checked Response
somewhat more	5
much more likely	4
not more likely	2
extremely more likely	2
a little more likely	1

IV. Conclusions

From the general conclusions of the exit surveys, the seed vibrations team exemplified the undergraduate research program's overwhelming success. Throughout the summer program, the team demonstrated a remarkable sense of discipline and grit to overcome a multitude of challenges. On many occasions, they took initiative to research and learn the necessary topics to move the project forward. They were innovative and relentless. Considering that personalities can often interfere with group dynamics, this group of six students worked together impressively well. In short, they surpassed any and all expectations of an undergraduate research team. As a further indication of the team's success, three of the members continued to work after the summer ended to further the research project. Also, at least two of the members actively started preparing for graduate school. Though exact reasons for a positive outcome are difficult to pinpoint, the team was always engaged and excited to be involved in such a novel research project. Finally, a crucial part of this success was the Chico STEM Connections Collaborative (CSC^2) and its instrumental role in enabling and supporting the student and faculty collaborations. This initiative helped bridge the gap between students and faculty, encouraged community, and facilitated an incredibly successful program in helping underrepresented minority students succeed in science, technology, engineering and mathematics.

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