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Community College Undergraduate Research using a Student-Driven and Student-Centered Approach

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Abstract

This paper describes a framework for conducting undergraduate research at a community college using student-driven, student-centered projects. The framework functions within time and resource constraints faced by many community college faculty and illustrates opportunities to facilitate meaningful student work within these constraints.

Research projects were conducted by four students, working in groups of two, over the course of nine months. The projects were mentored by an engineering community college faculty member and supported by an NSF funded LSAMP grant program. Students utilized Arduino Uno microcontroller kits to learn the basics of the hardware and software components. Through guided and independent literature review activities student teams selected research topics. Faculty led student teams through the development of specific research questions and design of experiment details. Student teams were provided with necessary equipment to supplement the Arduino kits and conducted their independent studies. Faculty assisted the student teams with data analysis and result interpretation. Students summarized and presented their work in research poster presentations at the local transfer university at a sponsored research symposium at the end of the project.

The success of this framework is that it required minimal resources, was manageable by busy faculty, and provided meaningful learning experiences for students throughout the project. Based on the success of this project the framework is being used again this year to now serve 13 students engaging in seven new undergraduate research projects at the community college.

Introduction

This project was developed through a collaboration between two community college faculty at Cuesta College in San Luis Obispo, California as part of an LSAMP (Louis Stokes for Minority Participation in STEM) NSF grant. The overall goal of the grant is to support traditionally underserved students majoring in STEM succeed at the community college and to transfer into a four-year institution as STEM majors. One of the main pillars of the program is to expose students at the community college level to undergraduate research so that when they transfer, they have had equitable access to similar experiences as their university and white student counterparts.

The framework presented is supported by research that shows that 1) undergraduate research is a high impact practice that can have a particularly significant impact on traditionally underserved students [1-2], 2) student centered methodologies, including active learning, activities with a focus on professional development (collaboration and communication skills), and activities that are directly related to their chosen career are effective in helping students to persist and succeed in STEM pathways [3], and 3) open-ended, student-driven projects, that require students to define the project parameters rather than being assigned specific parameters to adhere to or meet have been shown to result in valuable learning experiences, build confidence, increase interest in STEM, and deepen understanding of the engineering design process [4-6].

This was the first year of implementation and while there were lessons learned and improvements to be made in future iterations, the project proved very successful regarding both student learning and student satisfaction. This paper focuses more on the over-arching framework employed rather than the details of the individual undergraduate research projects, since such details will be different for each group of students when using this approach to project development. Details are used to provide an example, but the intent is to present a general framework that can be utilized by any STEM discipline.

Undergraduate Research Framework

The projects utilized Arduino microcontrollers, taking advantage of their versatility to be applied to a wide array of science and research projects with students at all levels, from K-12 to graduate studies [7]. The project timeline started in the spring semester (January) and concluded with a poster presentation at a sponsored research symposium in October at nearby California Polytechnic State University, San Luis Obispo (Cal Poly), the following fall semester.

Spring Semester

The project kicked off with a brief introduction to the Arduino Uno microcontrollers. Students were placed into teams of two based on academic interests and each team was given an Arduino Uno Starter Kit [8]. The kits include an Uno board, a circuit breadboard, capacitors, resistors, transistors, LEDs, a variety of sensors, motors, and wires, and a projects book that covers 15 practice projects. The starter kits allow students to learn the basics of Arduino programming and electronics at their own pace through the series of projects. After spending two weeks getting familiar with the kits, students were provided guidance on how to read academic articles [9], and introductory articles [10-13] with examples of Arduino used in academic research to review and summarize. Students were then instructed to explore additional research examples on their own through library and internet searches to further inform their thinking on what options they had for developing their own projects [14-16].

Using the background information attained through the hands-on, self-guided projects and the literature review, students worked together to brainstorm ideas for their own projects. Faculty led group discussions facilitated the selection of research topics and development of research questions and hypotheses. The final steps in the spring semester were the identification of experiments to test the research questions/hypotheses and the physical set up of the experiments.

The projects undertaken by the two groups of students were very different from one another. One group had an aerospace/robotics engineering concentration, and they utilized the Arduino Uno technology to study flex sensor versus thumb-stick accuracy and precision for robotic applications. The other group took an environmental/water quality approach and used the Arduino Uno technology to study changes in pH of water in fertilized versus unfertilized soils.

Summer

The faculty mentor had a professional commitment that required them to be out of town for the summer, which resulted in the opportunity for students to work in their teams, independent of faculty, over the summer to advance their experiments and collect data. Positive outcomes from this experience include the increase in confidence students gained through troubleshooting and problem solving on their own.

It's worth noting that these gains in confidence were evident *at the end of the project*, as the summer experiences also created opportunities for the students to doubt themselves. Working with the faculty mentor in the fall to make sense of the experience and relate it to their goals and careers was a necessary next step.

Fall Semester

Upon return for the fall semester, faculty and students met weekly leading up to the research symposium, which was held in mid-October. Project tasks during this time began with analysis of the data collected during the summer experiments, discussions about what could be learned from the data and how to best present that information. Mentor feedback and guidance was critical at this stage to help students to realize that their research experience was in fact valuable and complete. Based on however much they were able to get done, there was something to learn. Multiple meetings, sometimes in person, sometimes over Zoom, were spent discussing the findings and how to best represent them graphically.

Students worked in their teams to create informational graphs to present their data and highlight trends. Through the meetings and discussion with the faculty mentor, they developed their own discussion around the analysis and conclusions that had been drawn and were able to summarize their findings on academic posters. Each of these steps included one or more meetings with the faculty mentor for review and feedback.

Additionally, while the information was still at the front of their minds, one meeting was dedicated to resume updating and development of project descriptions to include there.

Research components and the approximate time commitment of faculty and students for each component is summarized in Table 1.

Table 1. Summary of undergraduate research components and associated faculty and student time commitments

Research Step		Duration	Faculty Commitment	Student Commitment
Introduction to microcontrollers	Spring Semester	2 weeks	4 hrs: prepare an introduction describing the basic components of an Arduino Uno microcontroller,	6 - 10 hours: Working through specific introductory activities in the kit as assigned by faculty mentor.
Literature review	Spring Semester	2 weeks	4 hours: work with library to find a few articles, assign reading and post websites to guide additional discovery of example projects	6 - 10 hours: read and summarize assigned papers, explore additional research projects that utilize microcontrollers for data collection
Brainstorming	Spring Semester	1 week	1-2 hrs: meet with students to facilitate brainstorming session	1 - 2 hrs: meeting with research partner and faculty mentor to discuss readings and generate ideas
Research topic selection	Spring Semester	1 week	1-2 hrs: meet with students to facilitate selection of topic based on prior brainstorming	1-2 hrs: meet with research partner and faculty mentor to select topic based on prior brainstorming
Development of research question, hypotheses, and experiment methodologies	Spring Semester	2 weeks	4 hrs: guide students through process of developing research questions, creating a hypothesis, and determining experiment details	4 hrs: work with research partner and faculty mentor to develop research questions, create a hypothesis, and determine experiment details
Experiment physical set up	Spring Semester	4 weeks	8 hrs: facilitate purchase/acquisition of necessary supplies for experiment apparatus	8 hrs: communicate clearly about needs for experiment set, set up as materials are provided
Run experiments and collect data	Summer	10 weeks	N/A: Allow students to run experiments and collect data	10 hrs: run experiments and record results
Data analysis	Fall Semester	3 weeks	6 hrs: meet with students to discuss results, help them to identify trends, understand and communicate their findings	6 hrs: organize and review data, compare to research questions and hypothesis, discuss with team, what did we learn from this?
Poster preparation	Fall Semester	2 weeks	4 - 6 hrs: help students organize their results on posters, guide them through development of the elevator speech	10 - 12 hrs: Organize research (literature reviews, experiment methods, results and findings) onto poster. Develop and practice elevator speech.
Resume updates	Fall Semester	1 week	2 hrs: review summaries from posters, assist students with resume updates and project tasks appropriate for highlighting this experience	2 - 5 hrs: update resume to include summary of undergraduate research project experience
Dissemination of results	Fall Semester	1 day	4hrs: attend the symposium	4hrs: present at the symposium

Student Feedback Data Collection, Methodology and Results

Student driven projects allow students the space to be creative and problem solve independently which helps improve confidence and increase persistence in STEM. Student reflection, paired with mentor feedback and guidance, is important to successful active and experiential learning [17-18]. Students benefit both from the opportunity to consider what their experience has been, and to learn from their instructor(s) how those experiences relate to the larger professional environment, thereby assimilating their experiences and increasing the chances of converting them to true learning.

To assist students in understanding why the steps they were taking were important, they were asked to keep design notebooks and submit written summaries of their work at milestone points. This provided opportunities to reflect on and document the processes rather than remain only focused on the research questions themselves. In addition, after the conclusion of the project a simple five question feedback survey was administered. The details and results of the survey are presented below.

Student Survey

All four student participants completed the survey. The questions asked were:

1. At the beginning of the project, how confident did you feel about conducting STEM research? (Scale 1-10)
2. At the end of the of the project, how confident did you feel about conducting STEM research? (Scale 1-10)
3. Based on this experience, for which of the following skills or areas have you experienced significant growth?
   - Understanding the research process
   - Communication Skills
   - Team Collaboration
   - Technical Skills
4. Briefly describe how this experience has affected you.
5. Please provide feedback on how we might improve the experience in the future.

Data Analysis

Table 2. Student Research Confidence Before and After the Project (Mean Paired Difference: -4.5)

	Before	**After**	**Difference**
Student 1	6	10	-4
Student 2	4	8	-4
Student 3	6	10	-4
Student 4	3	9	-6

Table 3. Student Areas of Significant Growth

Significant Growth Areas	Percent of Students
Understanding the research process	100%
Communication Skills	75%
Team Collaboration	100%
Technical Skills	100%

Table 4. Student Free Response Feedback to Question 4 "Briefly describe how this experience has affected you."

Student 1:
"A chance to apply my skills and learn knew [sic] ones. Also a chance to push myself."
Student 2:
"This experience helped me understand the research process and what goes into developing a research question and experiment. I feel more confident in practicing the scientific method."
Student 3:
"This research project has enhanced my learning experience as I applied the knowledge from STEM courses such as Electrical circuits and MATLAB."
Student 4:
"It was an amazing experience that built up my confidence and understanding towards conducting STEM research! I know of the steps needed toward concentrating and refining topics of study that I'm interested in. Throughout the process, it was helpful to have Dr. Adams to help guide and advise us through areas where we were having some difficulty. It also helped having the Arduino Starter kit to better understand how to utilize it to get key information we needed for our research. When we were able to present our research at Cal-Poly, it was fun to share our findings and process with those interested or curious while I had gained so much information from researching and conducting the experiments."

Table 5. Student Free Response Feedback to Question 5 "Please provide feedback on how we might improve the experience in the future."

Student 1:
“It was perfect.”
Student 2:
“It would have been more helpful to have a lab space or workshop to work at. It is very difficult sometimes to organize with a partner as Cuesta is a commuter school and my partner lived 1.5 hours away from me.”
Student 3:
No response
Student 4:
“I think what may help is understanding there will be work even outside of the semester as we still took some of that time to gather data and get our posters ready to present. The starter kits were incredibly helpful in understanding the utilization and capabilities of the Arduino while giving us blocks of code and information that we could use for our projects. Also, starting earlier in the semester will help with better adjusting the timeline for the project's completion.”

Summary

All four participants reported a significant increase between their before and after research confidence level. On a 1 to 10 scale, 1 corresponding to “no confidence at all” and 10 to “very confident”, students had at least a four-point increase in their confidence level with three of the students expressing their confidence level as a 9 or higher at the end of the project. All four students expressed significant growth in understanding the research process, team collaboration, and technical skills and in addition, three of the students also expressed significant growth in their communication skills. The gain in confidence and skills was also shared by the students in the free response question related to the effects of the research experience.

The main improvement feedback provided by the students was related to clarifying timeline expectations and providing a designated space to conduct independent work. The LSAMP faculty in charge of providing the structure and space for the experience and the faculty mentor agree with the students and their suggestions. The feedback on this initial attempt at creating a college-wide research program at a community college will help as the college continues the development of the program.

Among the most impactful summary reflections were the student poster presentations themselves. Students documented and demonstrated their knowledge of their projects; stating the motivation for the projects, the research questions, illustrating the experimental methods utilized, and presenting the collected data in graphical format to highlight trends and what was learned from the observations. They had developed an intimate understanding of their work through the different processes of review, topic selection, experiment design and implementation, and data analysis and discussion. The process of summarizing everything into a poster presentation helped them to synthesize their experience and concisely articulate it. The learning was evident when seeing how they shared their projects at the research symposium; students excelled at engaging with symposium attendees to talk about their work and explain their projects. It was a perfect culmination of everything they had done.

Two of the four students have transferred to Cal Poly in engineering programs, and the two students who remain at Cuesta College are participating in the undergraduate research project again this year.

Limitations

The authors acknowledge that conclusions based on the student feedback survey are limited by the small sample size and partially by the design of the instrument. Several student responses include verbiage from the questions indicating that the wording of the questions may have influenced the free response answers. Moving forward, questions will be evaluated and improved to provide more explicit measures of student growth based on the undergraduate research experience. In addition, the students will complete the "before and after" questions at the beginning and end of the project instead of both at the end.

Future projects

The success of this first iteration of undergraduate research - with one faculty mentor, two engineering projects, and four students - has led to an opportunity for the program to grow undergraduate research at the community college. Now on the second iteration, this year there are five faculty project mentors facilitating seven projects for 13 students. The projects will expand beyond engineering to also include biology, chemistry, and computer science.

California Central Coast Community Colleges Collaborative (C6) LSAMP grant funding allowed for paid student and mentor participation. Students participated in the project as a paid research internship and the community college faculty instructor who mentored the project was also compensated. The current grant is due to expire in May 2025. There are plans to re-apply for another cycle of three years, in addition the college is exploring ways to institutionalize different components of the program with an emphasis on finding funding sources for undergraduate student research experiences. One of the major programs that will be utilized to help with the funding endeavor is the MESA (Mathematics, Engineering, Science, Achievement) program that has been recently codified into California Education Code, SB 444. For students that don't qualify for MESA, there are opportunities to utilize funds from other state grants including HSI-STEM grants, and programs similar to the LAEP (Learning-Aligned Employment) program which offers students funding for educational costs by participating in career-related employment [19]. An additional resource to explore is collaboration with the college foundation to help with the funding for students and participating faculty.

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