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Introducing Emerging Computer Engineering Research to Community College Students through a Summer Internship Project on Development of a Mobile Gesture Recognition System

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Introducing Emerging Computer Engineering Research to Community College Students through a Summer Internship Project on Development of a Mobile Gesture Recognition System

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Abstract

Community colleges play an important role in STEM education because they enroll almost half of the nation's undergraduate students. Undergraduate research experience has been proven effective to engage and retain students in the STEM fields. In order to provide community college students with opportunities and experiences in cutting-edge engineering research, a cooperative internship program between a community college and a public comprehensive university has been developed. In summer 2018, the program engaged 20 community college students in six 10-week engineering research projects conducted at the four-year university. This paper mainly describes the computer engineering internship project, in which four sophomore students from the community college developed a mobile gesture recognition system by integrating bio-signal processing, machine learning, real-time system design, and mobile and cloud computing technologies. The project was conducted in a research lab at the four-year university and was supervised by a faculty advisor and a graduate student mentor. The research outcome of the project as well as the results of the pre- and post-program surveys show that the internship program was a great success in allowing the student interns to gain valuable computer engineering research experience and strengthening their confidence and interest in pursuing a STEM profession. The program also helped the students improve their skills in teamwork, time management, scientific writing, and presentation.

I. Introduction

An adequate supply of quality workers in the science, technology, engineering, and mathematics (STEM) fields is vital to continued US economic growth and competitiveness [1]. Community colleges enroll almost half of the nation's undergraduate students, thus their role in undergraduate STEM education is very important, especially for individuals from groups traditionally underrepresented in the STEM field. With support from the Department of Education Minority Science and Engineering Improvement Program (MSEIP), a project named *Accelerated STEM Pathways through Internships, Research, Engagement, and Support* (ASPIRES) has been developed by Cañada College, a Hispanic-Serving community college in the Bay Area, aiming to increase recruitment and retention of underrepresented students in STEM.

Undergraduate research experience has been proven effective to engage and retain students in the STEM fields [2-3]. However, conducting research at community colleges is challenging because of the limited research resources available. In order to provide community college students with opportunities and experiences in cutting-edge engineering research, one of the main activities of the ASPIRES project is a cooperative internship program between Cañada college and the School of Engineering at San Francisco State University, a public comprehensive university. In summer 2018, the program engaged 20 community college students in five 10-week engineering research projects conducted at San Francisco State university. Each project was supervised by a faculty advisor and a graduate student mentor. The faculty advisors were faculty members who had active research projects and research labs at San Francisco State University. The student mentors were generally research assistants who had been working with a faculty advisor for a certain period of time and identified by the faculty advisor as the project mentor before the internship program started. The disciplines and contents of the research projects are listed in Table 1.

Table 1. Disciplines and contents of the engineering research projects

Discipline	Content of the research project
Civil Engineering	Collapse simulation of building structures
Civil Engineering	Topology optimization
Computer Engineering (this paper)	Development of a mobile application and cloud computing framework for gesture recognition
Electrical and Computer Engineering	Autonomous vehicular control using Nvidia's Jetson TX1
Electrical Engineering	Design and optimization of non-volatile latch using anti-fuse memory technology

This paper mainly describes the computer engineering internship project, in which four sophomore students from Cañada college developed a mobile gesture recognition system by integrating bio-signal processing, machine learning, real-time system design, and mobile and cloud computing technologies. The project was conducted in the Intelligent Computing and Embedded Systems Laboratory (ICE Lab) at San Francisco State university and was supervised by the lab director and a graduate student mentor. The research outcome of the project as well as the results of the pre- and post-program surveys show that the internship program was a great success in allowing the student interns to gain valuable computer engineering research experience and strengthening their confidence and interest in pursuing a STEM profession. The program also helped the students improve their skills in teamwork, time management, scientific writing, and presentation.

II. Overview of the ASIPRES Internship Program

A. Recruitment of Program Participants

The ASPIRES interns were recruited through an online application process. Before the recruiting process starts, the faculty advisor of each research project prepared a description of the project as well as required and recommended background knowledge needed for the research project. The application package includes the applicant’s GPA, intended major, STEM courses completed, other skills, training and experience, a statement of academic plan, career goals, and research interests, and a statement of why the student wants to participate in the internship program. Each selected student was assigned to a specific research group mainly based on their declared major and academic preparation.

B. Program Activities

The 10-week summer internship program consists of program activities such as opening day and closing day that involve all program participants, as well as within-group activities that focus on individual research project.

1) *Opening Day*: All student interns, involved faculty and staff members, student mentors, and program coordinators participated in the opening day activities. Morning activities mainly consisted of a brief introduction of the internship program given by the program coordinator from Cañada College, followed by San Francisco State University faculty advisor or student mentor presentations on the introduction of individual research projects. In the afternoon, the student interns went to the assigned group to meet with the faculty advisor, student mentor, as well as the rest of the group members in the research labs and discuss the content and plan of the project.

2) *Project Time and Weekly Group Meetings*: Each research group consisted of one full-time (32 hours per week) intern and two to three half-time (16 hours per week) interns, mentored by a half-time (20 hours per week) SFSU graduate student. To track their working time, a logbook is used for the interns to record their daily check-in and check-out time. To encourage teamwork and cooperative learning, the computer engineering group executed an additional strategy by letting the interns and the mentor exchange weekly availability in the first group meeting and determine their weekly working schedule in the lab to maximize the overlaps among group members. The 10-week activities for the computer engineering project presented in this paper were generally divided into two-week literature study and project preparation, seven-week project development, and one-week report writing and presentation preparation. The group discussed the project progress with the faculty advisor in 2-hour weekly group meetings. The group meeting agenda included individual PowerPoint slide-based oral presentation given by each intern, followed by a group discussion. The presentation consisted of three components, including 1) project progress for the past week, 2) plan for the next week, and 3) issues and questions need to be discussed.

3) *Mid-program and Final Presentations*: The progress and outcome of each research project were evaluated in several ways, including a mid-program presentation, a final oral presentation, a poster presentation, and a final written report. Faculty advisors and graduate student mentors were served as judges to rank all the groups according to their performance of the final oral presentation (50%), poster presentation (25%), and report (25%). A winning project was then selected among all participating groups.

4) *Closing Day*: The interns' final presentations were conducted on the morning of the closing day, followed by the closing luncheon with the certificate presentation and winner announcement. Afternoon activities include post-program surveys and peer evaluations.

5) *Post-program Activities*: In order to provide more opportunities for the interns to exchange experiences and network in the bigger community, the interns' written papers and posters were revised with the help of faculty advisors and then submitted to various national and regional conferences such as American Society of Engineering Education (ASEE) conferences, and the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) National Diversity in STEM Conference. Upon acceptance, the ASPIRES program will provide financial support for the interns to attend the conferences and present their work.

III. Design and Outcome of the Research Project

A. Project Overview

This computer engineering internship project aimed to develop an electromyography (EMG)-based mobile gesture recognition system by integrating bio-signal processing, machine learning, real-time system design, and mobile and cloud computing technologies. The skeletal muscles of human body naturally produce electrical activity by the contraction of muscles. EMG is a technique of recording and evaluating these electrical activities. EMG pattern recognition (PR) is a widely used method to interpret EMG signals to identify the user's intended movements [4]. EMG PR-based control interfaces have great potential for intuitive and natural control of neurorehabilitation applications such as neural prostheses which restore function for patients with limb loss or impairment [4-6]. However, to apply EMG-controlled systems in practice, some challenges remain. The system needs to be low-cost, portable, real-time, and robust. Moreover, EMG PR algorithms typically require the collection, storage, and processing of a large amount of EMG data to provide accurate and reliable movement recognition. In this project, a mobile Android application, paired with a commercial EMG sensing Armband *Myo* (Thalmic Labs), was developed as a user friendly and mobile EMG PR solution. The application was aided by the Amazon Web Services (AWS) cloud computing platform to provide sufficient computing power and storage.

B. Design and Implementation

Figure 1 shows an overall architecture of the mobile gesture recognition application. The application was developed in Java using the Android Studio software. The system inputs are multiple channels of EMG signals collected from the Myo armband, which is worn on the user's forearm. The armband has eight EMG sensors and a 9-axis inertial measurement unit consisting of a three-axis gyroscope, a three-axis magnetometer, and a three-axis accelerometer. The acquired EMG and IMU data can be streamed into other devices (e.g. computer, smartphone) using the Bluetooth Low Energy (BLE) communication protocol. The system mainly provides five functionalities: data collection, feature extraction, pattern classification, a graphic user interface (GUI), and data management on both local and cloud platforms.

1) *Data collection*: The *MyoGattCallBack* module collects input EMG signals and IMU data from the Myo armband. The data are segmented by overlapped sliding analysis windows and then fed into the *Feature Calculator* module.

2) *Feature Extraction*: For each analysis window, the *Feature Calculator* module extracts EMG features that characterize EMG signals. In this project, six features were implemented including mean absolute value (MAV), waveform length (WAV), number of slope sign changes (Turns), number of zero crossings (Zeros), scaled mean absolute value (SMAV) and adjacency uniqueness (AC) [6-8]. To identify the user's intended movement, an EMG feature vector is formed by concatenating features extracted from individual channels and then sent to the pattern classification module for motion recognition.

3) *Pattern Classification*: This module consists of two sub-modules: *Classifier Trainer* and *Classifier*. The *Classifier Trainer* trains a classifier model by learning from a set of labeled EMG data from every investigated gesture using various machine learning algorithms. The trained model is then used in the *Classifier* module to predict the user's intended gesture. In this project, the open-source Statistical Machine Intelligence and Learning Engine (SMILE) library was used to implement a variety of pattern classification algorithms, including Linear Discriminant Analysis (LDA), Support Vector Machine (SVM), Logistic Regression, Decision Trees, Neural Network, and K-Nearest Neighbor (KNN). The classification decisions can be output to control external devices or applications.

4) *GUI*: A friendly GUI was implemented to allow the user to easily access all the functionalities provided by the application, as well as visualize the raw data, extracted features, and pattern classification results in real time. Figure 2 shows the several representative the designed GUI.

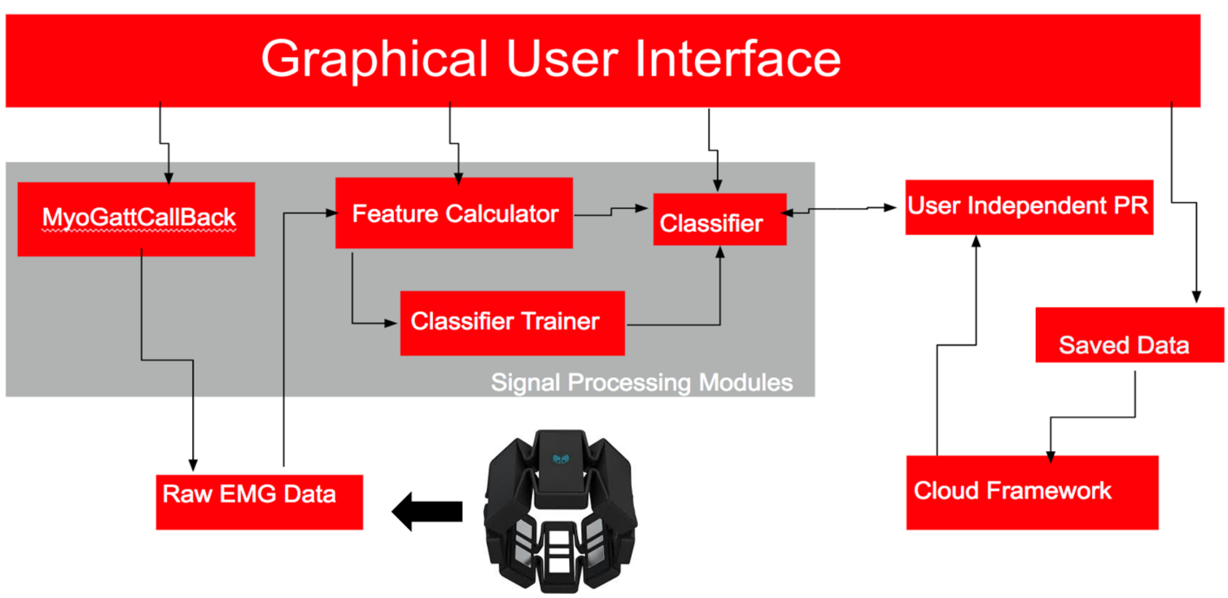

Figure 1. Overall structure of the Android application

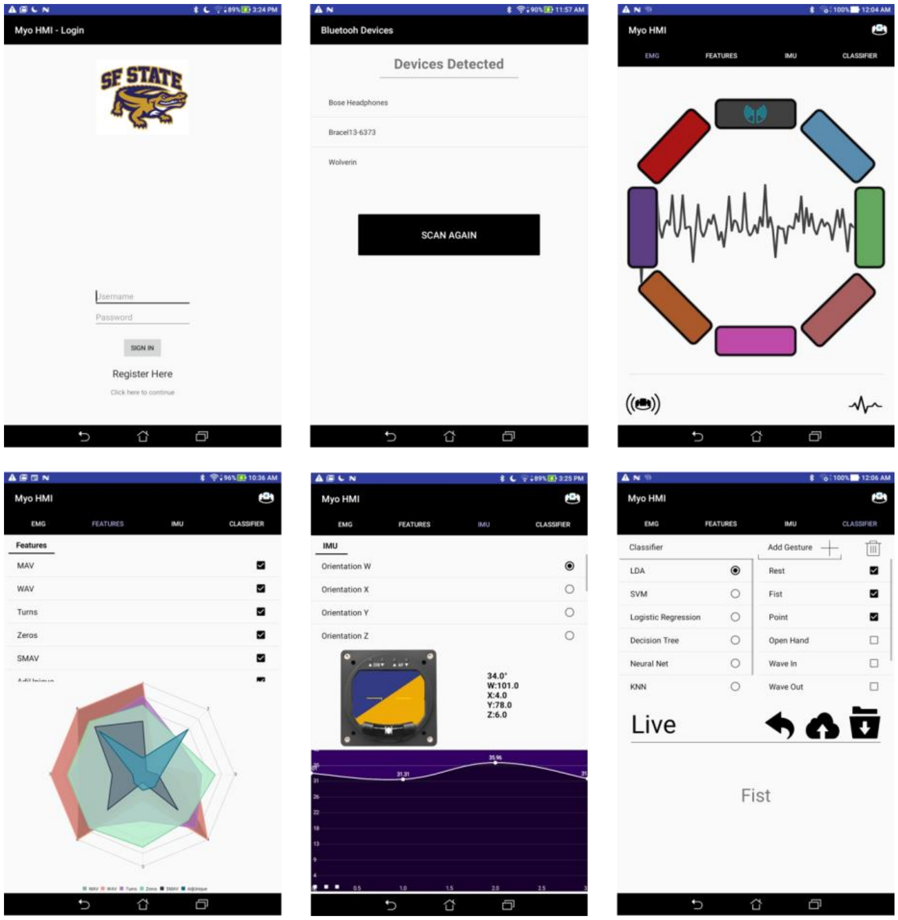

Figure 2. The designed GUI of the Android application. From top to bottom, left to right: User Login page, Bluetooth Connection tab, EMG tab, EMG Feature Extraction tab, IMU tab, and Classifier tab.

5) *Data Management*: The developed application integrated both mobile and cloud computing techniques to store and process data instantly and sufficiently. Specifically, a MySQL database was created and managed in the AWS cloud server, which allows data from multiple users to be efficiently managed. More importantly, this opens the possibility for user independent pattern classification, which aims to train a universal classifier by utilizing many users' data. Figure 3 shows an example of multiple users' data stored in the MySQL database.

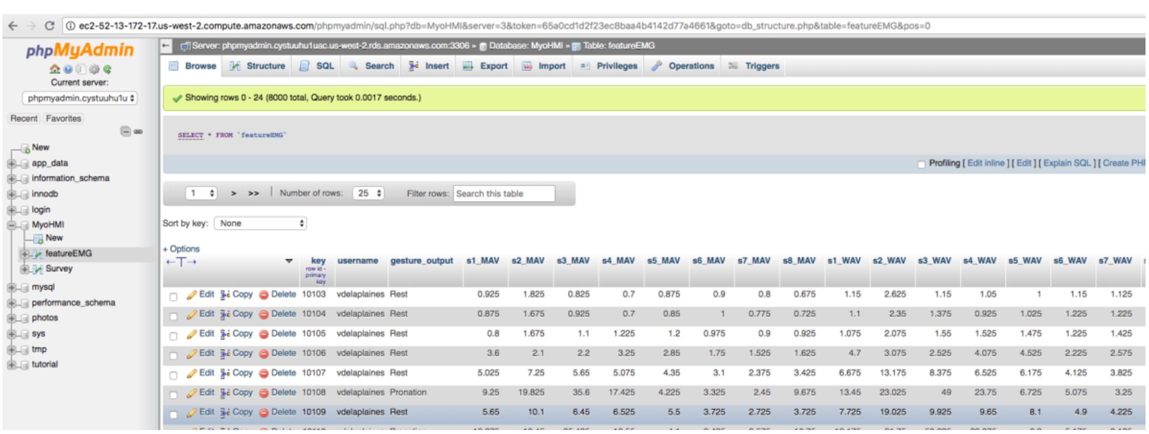

Figure 3. EMG data from multiple users stored in a MySQL database hosted on AWS.

C. Outcome of the Project

To evaluate the developed application, experiments were conducted on ten subjects. Figure 4 shows a photo of the experimental setup. The interns learned the process of designing experimental protocols, conducting user test, analyzing the experimental results, and presenting the project outcome in both oral and written formats. In addition, in order to make this project open to the public as a long-term goal of the research, a Github Wiki page was also developed as shown in Figure 5.

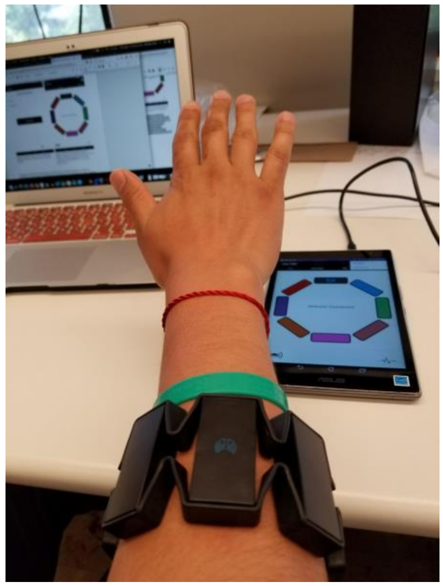

Figure 4. Setup of the experiment for system performance evaluation

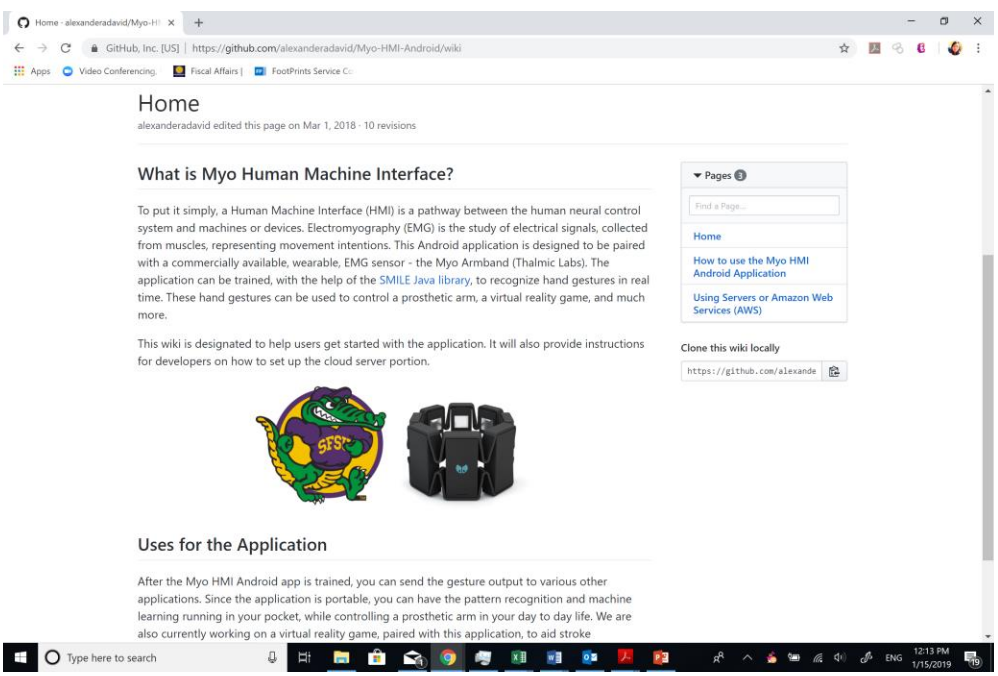

Figure 5. Screenshot of the Github Wiki page for the project

IV. Assessment of the Research Internship Program

To assess the effectiveness of the research internship program, a pre- and post-program survey was conducted. Responses from all the student interns participating in the program are summarized in Tables 2-4. Table 2 summarizes the results of the survey on student motivation and purpose for participating in the internship program. Table 3 summarizes the averaged students' level of satisfaction with the program activities and results. Table 4 shows the student responses to the pre- and post-program surveys on student perceptions of their skills and knowledge needed for research and academic success.

Table 2. Results of the survey of student motivation and purpose for participating in the internship program

Pre-program prompt: What do you most want to learn or gain from your internship this summer? 1 - Strongly Disagree and 5 –Strongly Agree.
Post-program prompt: Please indicate the degree to which your internship experience helped you learn or gain each of the following. 1 - LEAST helpful and 5 - MOST helpful.

	Average Response		
	Post	**Pre**	**Diff**
Gain hands-on experience in research	4.28	4.72	-0.44*
Solidify my choice of major	3.92		
Gain skills needed to successfully complete a BS degree	4.12		
Clarify whether graduate school would be a good choice for me	4.08	4.08	0.00
Clarify whether I wanted to pursue a STEM research career	4.08	3.84	0.24
Work more closely with a particular faculty member	4.00	4	0.00
Get good letters of recommendation	3.80	4.08	-0.28
Have a good intellectual challenge	4.28	4.48	-0.20
Read and understand a scientific report	4.24		
Write a scientific report	4.00		
Ask good questions related to the scientific process	4.20		
Set up a scientific experiment	4.16		
Work with others to plan and conduct scientific experiments	3.96		
Talk to professors about science	4.04		
Think like a scientist	4.12		

* The change is statistically significant at $p < 0.050$.

Table 3. Summary of Student Satisfaction with the Summer Research Internship Program

Question: How satisfied are you with each of the following? 1 being LEAST satisfied and 5 being MOST satisfied. Check N/A you did not participate.

	Average Response
Opening Day at SFSU (June 6th)	4.43

Faculty Adviser Description of Project (June 6th)	4.39
Meetings with Graduate Student Mentor	4.40
Meetings with Faculty Adviser	4.21
Mid-Program Presentations (July 21st)	4.48
Final Presentations (August 12th)	4.27
The results of your project	4.12
Your final poster	4.38
Your final presentation	4.33
How much you learned from the program	4.60
Your group mates	4.17
Your faculty adviser	4.46
The Summer Internship Program as a whole	4.48

Table 4. Results of survey on student perceptions of skills and knowledge for academic and research success.

Question: Please indicate your level of agreement with the following statements.
1-Strongly Agree, 5-Strongly Agree.

	Average Response		
	Post	**Pre**	**Diff**
I was able to conduct the scientific research that is part of my summer internship.	4.48		
I am confident I will transfer to a four year institution.	4.76	4.80	-0.04
I am confident I will complete a BS in a STEM field.	4.64	4.72	-0.08
I can imagine myself continuing after my BS to pursue a Master’s Degree in a STEM field.	4.32	4.24	0.08
I can imagine myself continuing after my BS to pursue a Ph.D. in a STEM field/Medical School/other education beyond the Master's level.	3.88	3.60	0.28
I have a clear career path.	4.28	4.04	0.24
I have skill in interpreting results.	4.28	3.96	0.32
I have tolerance for obstacles faced in the research process.	4.40	4.12	0.28
I am ready for more demanding research.	4.28	3.88	0.40
I understand how knowledge is constructed.	4.32	3.96	0.36
I understand the research process in my field.	4.28	3.56	0.72**
I have the ability to integrate theory and practice.	4.20	3.84	0.36
I understand how scientists work on real problems.	4.40	3.52	0.88**
I understand that scientific assertions require supporting evidence.	4.52	4.04	0.48*
I have the ability to analyze data and other information.	4.40	4.04	0.36
I understand science.	4.36	3.88	0.48*
I have learned about ethical conduct in my field.	3.96	3.96	0.00
I have learned laboratory techniques.	4.32	4.00	0.32

I have an ability to read and understand primary literature.	4.40	4.00	0.40
I have skill in how to give an effective oral presentation.	4.40	4.04	0.36
I have skill in science writing.	4.08	3.68	0.40
I have self-confidence.	4.32	4.08	0.24
I understand how scientists think.	4.24	3.84	0.40
I have the ability to work independently.	4.64	4.16	0.48*
I am part of a learning community.	4.16	4.36	-0.20
I have a clear understanding of the career opportunities in science.	4.24	4.16	0.08

* The change is statistically significant at $p < 0.050$.
** The change is statistically significant at $p < 0.010$.

From the responses shown in Table 2, the biggest motivation for participating in the internship program as selected by students is to gain hands-on experience in research, followed by having a good intellectual challenge. Upon the completion of the program, the students found the program most helpful for them to achieve these two goals. In the post-program survey, the item receiving the lowest rating is to get good letters of recommendation. This is mainly because not many students have asked for recommendation letters at the time of completing the internship. The results in Table 3 shows that overall the students were satisfied with all the program activities and results. All the items in the survey received a rating of above 4. As for the student perceptions of their skills and knowledge, of the 24 items in the survey summarized in Table 4, the most significant gain is understanding how scientists work on real problems, followed by understanding the research process in the field, and then understanding that scientific assertions require supporting evidence, understanding science, and having the ability to work independently.

In the future, the internship program organizers will consider additional methods to assess the outcomes of the program more comprehensively, such as program alumni surveys and direct assessment measures of the interns' school performance in the following semesters.

V. Conclusion

The 2018 ASPIRES summer research internship program was successful in helping community college students learn valuable engineering knowledge and skills as well as gain research experience in emerging computer engineering fields. The project provided a great opportunity for the students to improve their skills in teamwork, communication, writing, presentation, project management, and time management. The outcome of this project indicated that the summer research internship program was an effective method for engaging community college students in engineering research and strengthening their confidence and interest in pursuing a STEM degree and profession.

Acknowledgement

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