

Engaging Community College Students in Computer Engineering Research through Design and Implementation of a Versatile Gesture Control Interface

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Abstract

Given the important role of community colleges in undergraduate education, in order to increase the recruitment of STEM students and improve undergraduate STEM education, it is crucial to develop strategies to inspire community college students' interest in STEM. With support from the Department of Education Minority Science and Engineering Improvement Program (MSEIP), a cooperative internship program between Cañada College, a Hispanic-Serving community college in California's Silicon Valley, and San Francisco State University (SFSU), a public comprehensive university was developed to engage community college students in leading-edge engineering research. In summer 2016, five sophomore students from Cañada College participated in a ten-week computer engineering research internship project in the Intelligent Computing and Embedded System Laboratory at SFSU. This internship project aimed to develop an intelligent electromyography (EMG)-based gesture control interface (GCI) which deciphers EMG signals collected from forearm muscles to identify users' intended hand and arm movements. The GCI has great potential to provide natural human-machine interaction in a variety of applications, from assistive devices through rehabilitation therapy to virtual reality (VR). The developed interface provides easy connection with a commercial EMG-based armband Myo and a modular software engine for customizable gesture recognition as well as a special pipeline for converting recognition decisions into control commands for external applications. The students also conducted usability testing of the GCI on human subjects by using it to control a first-person shooter (FPS) VR game which was developed by another community college student intern. The project provided a great opportunity for the student interns to gain research experience and learn valuable knowledge in human machine interfaces, EMG signal processing, and gesture recognition. It also helped them improve their skills in experimental design, data analysis, scientific writing and presentation, as well as teamwork and time management. The outcome of this project indicated that the internship program was an effective method for inspiring community college students' interest in computer engineering research and strengthening their confidence and capability in pursuing an engineering profession.

I. Introduction

There is broad consensus that a substantial increase in the number of professionals in the science, technology, engineering, and mathematics (STEM) fields is essential to continued U.S. economic

competitiveness and growth. In the STEM education pipeline, community colleges play a unique and significant role in preparing students to continue their STEM education at four-year institutions. The role of community colleges in undergraduate education is even more prominent for individuals from groups traditionally underrepresented in STEM fields such as female and minority populations^{1,2}. Providing opportunities to engage community college students with STEM research experiences is a significant strategy for increasing the recruitment and retention of STEM students. However, implementing this strategy in community colleges is challenging due to the lack of research resources at community colleges. Establishing collaborations between community colleges and research universities is a recommended approach to address this challenge³. With support from the Department of Education Minority Science and Engineering Improvement Program (MSEIP), the Engineering Department of Cañada College, a Hispanic-Serving community college, partnered with the School of Engineering of San Francisco State University (SFSU), a public comprehensive university, to develop and implement the *Accelerated STEM Pathways through Internships, Research, Engagement, and Support* (ASPIRES) project, aiming to enhance interest and increase retention for underrepresented students in STEM. One of the main activities of the ASPIRES project is a 10-week summer research internship program, which provides opportunities for Cañada College engineering students to conduct research internship in the research labs at SFSU. Among the five research internship projects conducted at SFSU in summer 2016, this paper details the computer engineering project, which involved five sophomore student interns in the development of a versatile gesture control interface (GCI) in the Intelligent Computing and Embedded Systems Laboratory (ICE Lab). The student interns were mentored by a faculty advisor and a graduate student from SFSU.

This internship project aimed to develop an intelligent electromyography (EMG)-based GCI which deciphers EMG signals collected from forearm muscles to identify users' intended hand and arm movements. The GCI has great potential to provide natural human-machine interaction in a variety of applications, from assistive devices through rehabilitation therapy to virtual reality (VR). The developed interface provides easy connection with a commercial EMG-based armband Myo and a modular software engine for customizable gesture recognition as well as a special pipeline for converting recognition decisions into control commands for external applications. The students also conducted usability testing of the GCI on human subjects by using it to control a first-person shooter (FPS) VR game which was developed by another community college student intern. The project provided a great opportunity for the student interns to gain research experience and learn valuable knowledge in human machine interfaces, EMG signal processing, and gesture recognition. It also helped them improve their skills in experimental design, data analysis, scientific writing and presentation, as well as teamwork and time management. The outcome of this project indicated that the internship program was an effective method for inspiring community college students' interest in computer engineering research and strengthening their confidence and capability in pursuing an engineering profession.

II. Internship Program Activities

The computer engineering project group consists of one full-time intern and four half-time interns. The faculty advisor gave a presentation to introduce the research project on the opening day of the internship program. The ten-week activities for the research project were divided into

two-week literature study and project preparation, seven-week project development, and one-week report writing and presentation preparation. The group discuss the project progress with the faculty advisor in 2-hour weekly group meetings. In each meeting, individual slide-based oral presentation was given by each intern, followed by 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. A journal club activity was also organized where each intern presented one related research paper once every other week.

The progress and outcome of all the participating research projects were evaluated in several ways, including a mid-program presentation, a final oral presentation, a poster presentation, and a final written report. The presentations were conducted at SFSU. 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.

III. Design and Results of the Research Project

A. Project Background

In recent years, gesture recognition has gained popularity in several fields, as it provides a potential solution to a variety of problems. Research has been done on hand gesture recognition for a defined sign language library, in order to help people with hearing impairment communicate more conveniently⁴. Gesture recognition has also been applied to assist persons with limited mobility, enabling the use of gestures as control inputs for powered wheelchairs⁵ and other assistive devices. Studies involving VR environments have made use of gesture-based control schemes⁶, as they allow for a natural, immersive user experience.

Whatever the intended use, gesture recognition requires some means by which to track a subject's movements and position. Previous works have used computer-vision to fill this need, with impressive results. The effectiveness of this approach is however limited by the capabilities of the camera. Lighting must be adequate and the motions of interest must be performed within its field of view. Motion-sensing gloves have also been used in hand gesture recognition; however, these devices are typically bulky and inconvenient for the subject to wear. A more recently emerging approach makes use of biosignals to determine the subject's movements. The electrical signals collected from a person's muscles, commonly known as EMG signals, have been shown to be intrinsically tied to the person's intended movements⁷. EMG signals can be captured with relative ease by attaching pairs of electrodes along the subject's muscles.

This internship project aimed to develop an intelligent EMG-based GCI which identifies the user's hand and arm gestures from EMG signals collected from forearm muscles as well as provides interfaces to external gesture-controlled applications.

B. Design and Implementation

The MyoHMI Platform

The GCI was developed by expanding an existing research platform MyoHMI⁸ – a flexible software human-machine interface (HMI) for gesture recognition previously developed in the ICE Lab, with the intent of improving its usability and functionality. MyoHMI facilitates the interface with a commercial armband called Myo as shown in Figure 1, which records eight channels of EMG data at 200 Hz, and collects kinematic data at 50 Hz via an inertial measurement unit (IMU). The software platform integrates a user-friendly graphic user interface (GUI) and a sequence of signal processing modules for EMG feature extraction and pattern classification. Figure 2 details foundational structure of MyoHMI. The *MyoData* module provides connection to the Myo armband and collects multiple channels of EMG signals as the system input. The input signals are segmented by overlapped sliding analysis windows as illustrated in Figure 3. For each analysis window, the *FeatureCalculator* module extracts EMG features which characterize individual EMG signals. To recognize the user’s gesture, EMG features of individual channels are concatenated into one feature vector and then sent to the *Classifier* module for gesture classification. The gesture classification algorithm consists of two phases: training and testing. In the training phase, a set of EMG data are collected from each investigated gesture for the *ClassifierTrainer* module to create a classification model that maximally distinguishes the EMG patterns of different gestures. In the testing phase, the feature vector extracted from new incoming EMG signals is sent to the classification model to identify the user’s gesture. In MyoHMI, four time-domain EMG feature extraction methods have been implemented, including mean absolute value (MAV), waveform length (WL), number of zero crossings (ZC), and number of slope sign changes (TURN). Two pattern classification algorithms have been implemented in the NMI, including linear discriminant analysis (LDA) and support vector machine (SVM). A friendly GUI based on C++/CLR and Microsoft .NET Framework was also implemented to allow users to easily access all the modules in the platform.



Figure 1. Myo Armband.

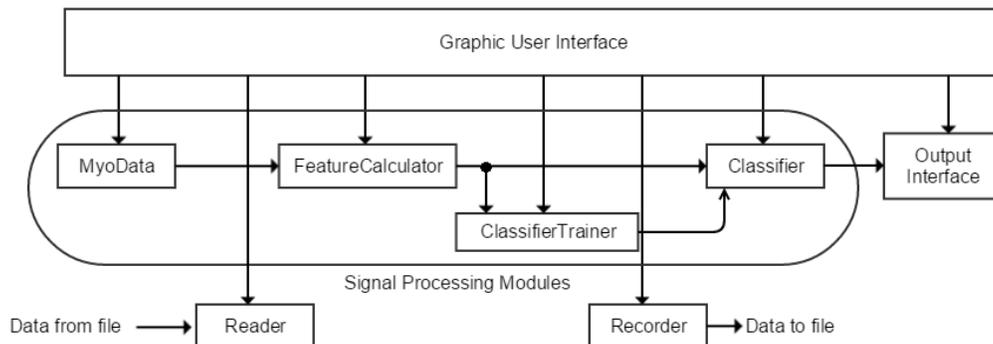


Figure 2. Overall structure of MyoHMI

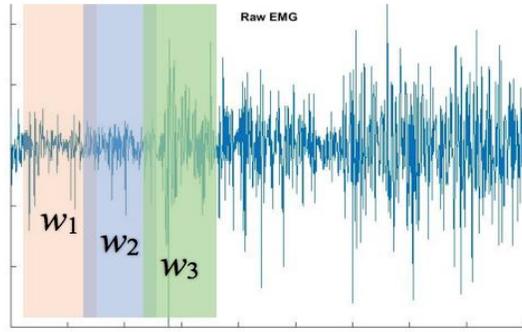


Figure 3. Overlapped windowing scheme

Expansion upon MyoHMI

Figure 4 shows the overall structure of the GCI developed in this internship project. The blue boxes indicate the additions or changes made to the original MyoHMI platform and the arrows help indicate in which part of the platform those changes were applied.

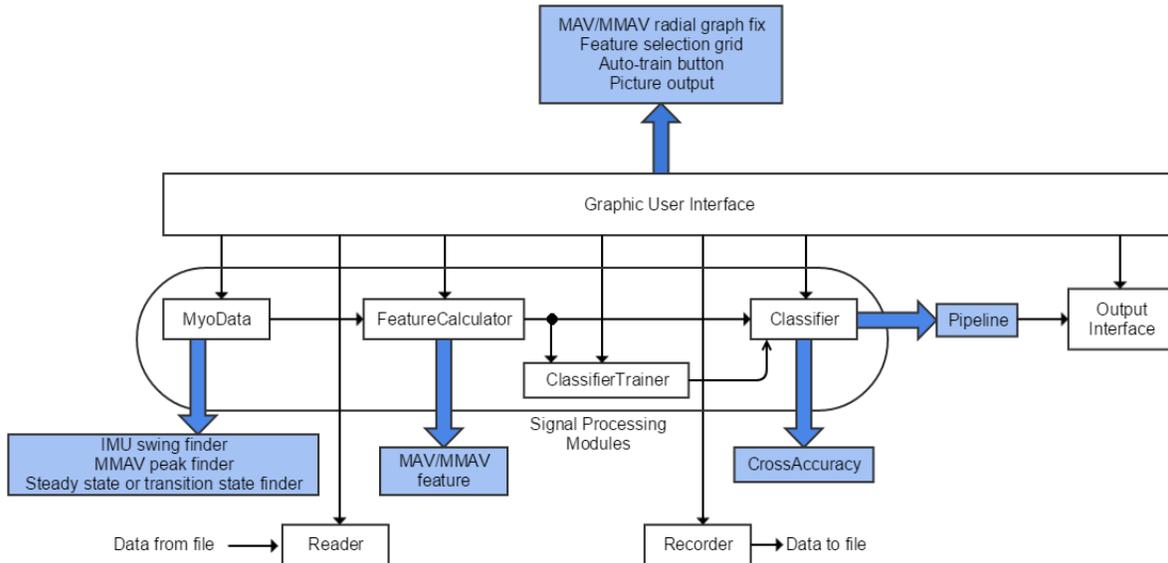


Figure 4. Overall structure of the GCI developed by the interns. Blue blocks indicate features that have been added to the original MyoHMI structure.

FeatureCalculator

An additional EMG feature was added to *FeatureCalculator* called scaled mean absolute value (*SMAV*). The calculation of this feature for channel i is shown in (1).

$$SMAV_i = MAV_i / MMAV \quad (1)$$

Where $MMAV$ is the average of the MAV across all channels. This results in seven independent features that represent the magnitudes of the channels relative to themselves but independent of overall magnitude of gesture being performed.

Classifier

The *classifier* module had the *crossValidation* function added. This function was originally only implemented in the SVM model. This made it impossible to generate the confusion matrix by using the LDA model because the GCI would stop working. The function was moved from the *SVMAgent* file to the classifier file, so that all models would have access to use this function via inheritance.

GUI

Overall, the GUI had most of the changes done to it. In the *EMG* tab which is used to visualize EMG data and features in real-time, the *SMAV* feature was added to the radial graphs; additionally, a bug related to those graphs were fixed. Originally, if the EMG values were greater than the maximum values of the graphs, the EMG data would not display. Now, if the value is greater than the graph's maximum value, the EMG data is shown as the maximum value. This is shown in Figure 5.

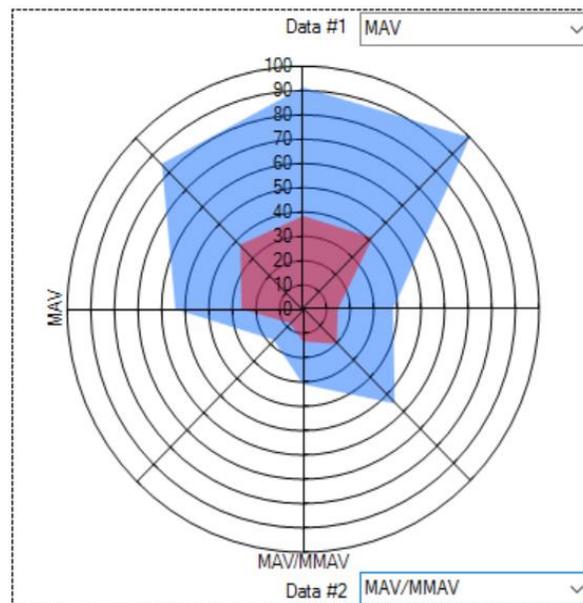


Figure 5. Fixed radial graph showing MAV and SMAV EMG signals.

Additionally, as shown in Figure 6, a feature selection grid was added, which allows the user to determine which features from which channel to pass to the classifier. It also gives flexibility to the GCI as more features can be added or removed in future versions of the GCI.

An auto-run button was added, which makes the training and data gathering process easier. The feature gives the user the ability to set a specific delay time between training two features. Another feature present in the classifier tab is the picture output, which was added to the GCI. Both features can be seen in Figure 7.

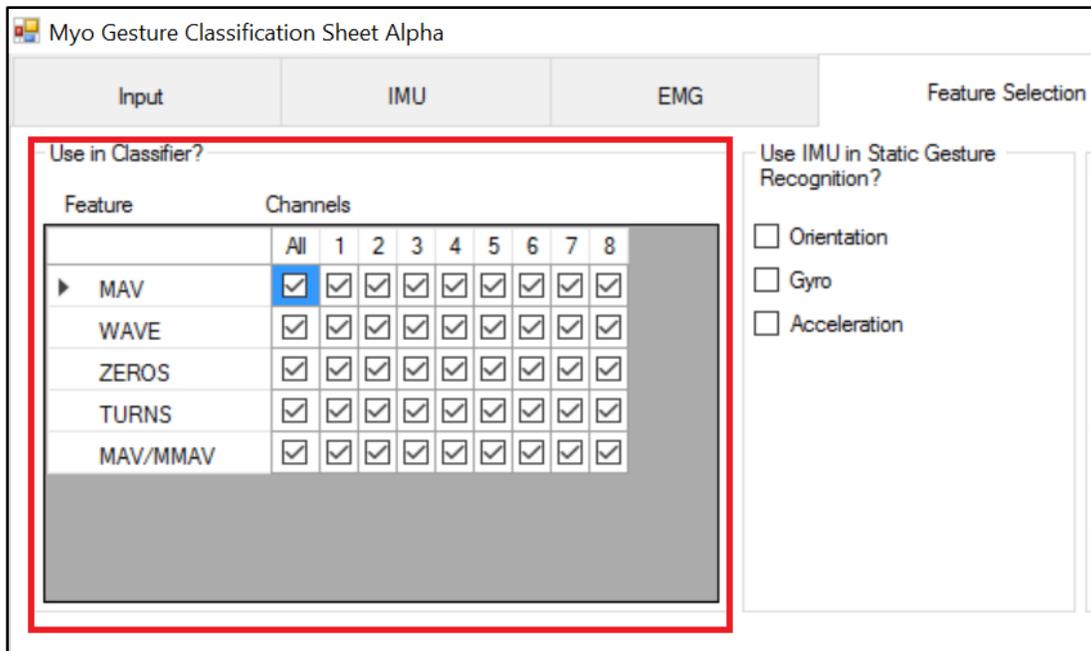


Figure 6. Feature selection grid is shown inside the red box. Here the number of channels and types of gestures to be used by the classifier can be selected with ease.

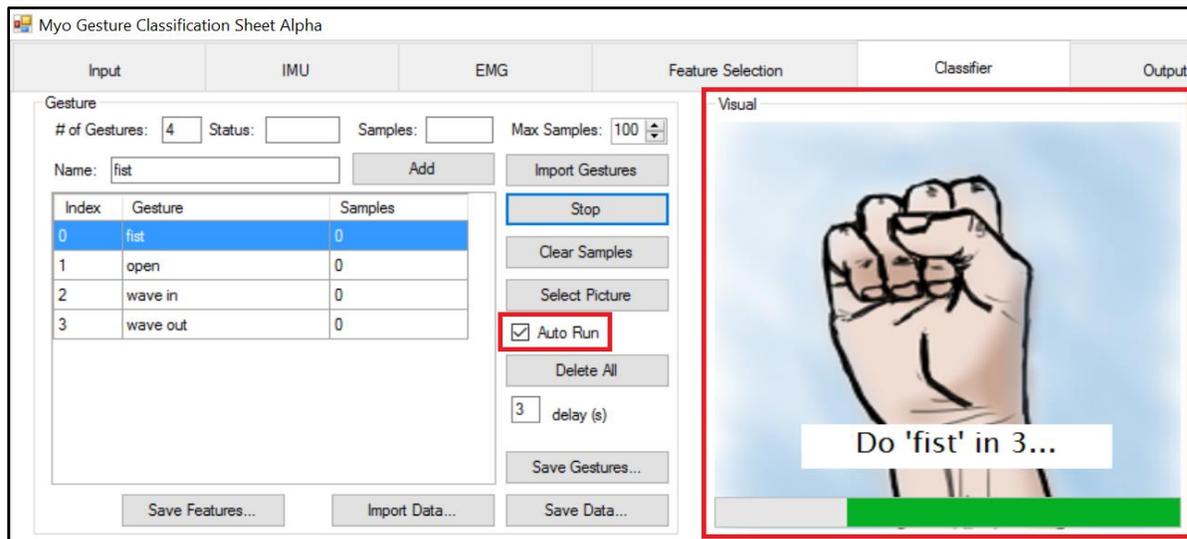


Figure 7. Auto-run button and picture output features in the current version of the GCI.

MyoData

The addition of an accurate dynamic gesture recognition module to the interface was a goal for this study, but due to time constraints, it was implemented at a very basic level. Taking advantage of the IMU data fed into the interface, an arm swing detector was built to recognize when the user's arm was swung. This feature was implemented by taking a running k -average of the most recent k samples of IMU orientation data, where k may be set by the user. A swing would be recognized for each time orientation crossed this average.

Interaction with Client Applications

A pipeline was developed in order to give the GCI the capability to output gesture classifications and IMU data to a client application. The client application can then use this data for its desired purposes. A VR video game project was developed in conjunction with this project that implemented this pipeline to use gesture output from the GCI for control purposes inside the game as opposed to standard keyboard/mouse control.

Experimental Protocol

As previously stated, a VR video game was developed in conjunction with this project as an application of the GCI. Certain gesture classifications and arms swings from the IMU were streamed to the VR game through the pipeline. The game uses this information from the GCI as a means of control. For example, if the player makes a fist gesture, the character inside the game will fire a weapon. Likewise, if the player swings his or her arm, the character inside the game will take a step.

The VR game was used as a usability assessment platform to test the feasibility of using gesture classifications and IMU data from the GCI to control the game as opposed to a standard keyboard/mouse setup. The game is an FPS with the objective to go from start to finish, without dying from the horde of zombies attacking the player, killing as many zombies as possible. Four gestures were trained to control the game: fist (fire weapon), rock on (change weapon), fist right (reload weapon), and index, middle, and ring fingers up (toggle vehicle headlight). In addition to the four gestures, arm swings were used to control a walking portion of the game, each arm swing equates to a one step inside the game.

Eleven subjects participated in the experiment (9 male, 2 female). A pre-survey was given to each subject to collect information about his or her age range, gender, and whether or not the subject had prior experience with VR or first-person shooters. Each subject conducted two trials, one for each control scheme: using mouse only and using the Myo armband only. Prior to each trial, the subject was given a training session on how to play the game. Before the Myo armband trial, each subject had to train each of the four gestures in the GCI to ensure accuracy of gesture classification. The subject then put on an Oculus Rift VR headset and played each trial of the game using one of the control schemes. Each subject then filled out a post-survey meant to gauge the subject's experience in using the two control methods.

B. Results and Discussion

Figure 8 shows a demo of a user controlling the VR game using his hand and arm gestures. On average, the trials produced higher scores with the mouse controls than with gesture controls. In addition, only four out of the eleven subjects were able to complete the game without their character dying when using gesture controls, whereas all but two of the subjects completed the game with health remaining using the mouse. There are many possible contributing factors to the overall limited usability of gesture controls. It was found that one possible issue might be the package loss during the command transmission from the GCI to the VR game. Further research has been continuing by the ICE Lab to address the issue and improve the gesture control interface since the SPIRES project ended.



Figure 8. Demo of a user controlling the VR game using his hand and arm gestures

IV. Assessment of the Research Internship Program

To assess the effectiveness of the research internship program, pre- and post-program surveys were conducted for all 29 student participants including another 24 students in the mechanical, electrical, and civil engineering groups. The survey was designed to measure student motivations for engaging research, student research and academic goals, as well as their perception of the skills needed for research and academic success. This survey was adopted from the Survey of Undergraduate Research Experiences (SURE), which consists of 44 items, including demographic variables, learning gains, and evaluation of aspects of summer programs⁹. This survey was adapted to the needs of the ASPIRES internship program for community college students. Table 1 summarizes the results of the survey on student motivation and purpose for participating in the internship program. The biggest motivation for participating in the internship program as selected by students is to gain hands-on experience in research, followed by good intellectual challenge, and getting good letters of recommendation. The students found the program most helpful for them to learn how to work with others to plan and conduct scientific experiments. The only statistically significant difference between pre- and post-program responses was observed for clarifying whether to pursue as STEM research career process.

Table 1. 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		
	Pre	Post	Change
Gain hands-on experience in research	4.75	4.46	-0.29
Clarify whether graduate school would be a good choice for me	4.00	4.04	0.04
Clarify whether I wanted to pursue a STEM research career	3.79	4.36	0.57*

Work more closely with a particular faculty member	3.86	3.96	0.10
Get good letters of recommendation	4.32	4.25	-0.07
Have a good intellectual challenge	4.64	4.54	-0.10
Solidify my choice of major		4.18	
Gain skills needed to successfully complete a BS degree	-	4.21	-
Read and understand a scientific report	-	4.25	-
Write a scientific report	-	4.04	-
Ask good questions related to the scientific process	-	4.18	-
Set up a scientific experiment	-	4.07	-
Work with others to plan and conduct scientific experiments	-	4.61	-
Talk to professors about science	-	4.25	-
Think like a scientist	-	4.18	-

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

Table 2 summarizes the result of the pre- and post-program surveys on student perceptions of their skills and knowledge needed for research and academic success. Of the 21 items in the survey, the most significant gain is on understanding how scientists work on real problems. Statistically significant gains are also observed in areas including skill in interpreting results, tolerance for obstacles faced in the research process, understanding the research process in the field, ability to integrate theory and practice, ability to analyze data and other information, skill in how to give an effective oral presentation, and skill in science writing.

Table 2. Results of survey on student perceptions of skills and knowledge for academic and research success.

Question: Tell us how much you agree with each of the following statements. Response Scale: 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.

	Average Response		
	Pre	Post	Change
I have a clear career path.	3.79	4.14	0.35
I have skill in interpreting results.	3.86	4.32	0.46*
I have tolerance for obstacles faced in the research process.	4.04	4.39	0.35*
I am ready for more demanding research.	3.82	4.14	0.32
I understand how knowledge is constructed.	3.86	4.21	0.35
I understand the research process in my field.	3.21	3.86	0.65*
I have the ability to integrate theory and practice.	3.61	4.07	0.46*
I understand how scientists work on real problems.	3.61	4.28	0.67**
I understand that scientific assertions require supporting evidence.	4.25	4.43	0.18
I have the ability to analyze data and other information.	3.96	4.39	0.43*

I understand science.	3.71	4.00	0.29
I have learned about ethical conduct in my field.	4.18	4.07	-0.11
I have learned laboratory techniques.	3.82	3.93	0.11
I have an ability to read and understand primary literature.	3.82	4.07	0.25
I have skill in how to give an effective oral presentation.	3.79	4.29	0.50*
I have skill in science writing.	3.43	3.89	0.46*
I have self-confidence.	4.29	4.21	-0.08
I understand how scientists think.	3.71	3.89	0.18
I have the ability to work independently.	4.25	4.25	0.00
I am part of a learning community.	4.46	4.50	0.04
I have a clear understanding of the career opportunities in science.	4.18	4.43	0.25

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

** The change is statistically significant at $p < 0.001$.

V. Conclusion

The 2016 ASPIRES summer research internship project was successful in helping community college students gain research experience in emerging computer engineering and HMI fields as well as learn valuable engineering knowledge and skills. The project also provided a great opportunity and environment for the student interns to improve their skills in teamwork, communication, writing, presentation, 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 interest and confidence in pursuing an engineering profession.

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