An Interdisciplinary Team-based Research Initiative Through Active Learning to Increase Undergraduate Students' Motivation, Engagement, and Retention

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Dr. Shahnam Mirzaei is an assistant professor in the Department of Electrical and Computer Engineering at the California State University, Northridge. He has received his Ph.D. from University of California, Santa Barbara (UCSB) in the area of Electrical and Computer Engineering at 2010, His M.Sc. from California State University, Northridge, and his B.Sc. from University of Tehran. Dr. Mirzaei has worked as an application engineer for six years from 2000 to 2005 with focus on problem solving and resolving design issues with regards to Xilinx FPGAs and SoCs. After receiving his Ph.D., he has worked as an R&D engineer in the area of signal processing for three years from 2010 to 2013. Dr. Mirzaei started his academic job as an assistant professor at California State University, Northridge at 2013. His research interests fall into the realm of reconfigurable hardware, signal and image processing, and embedded systems. In recent years, he has focused on developing techniques for hardware acceleration of software algorithms and implementing signal processing applications on on reconfigurable hardware. Dr. Mirzaei has been the recipient of Electrical and Computer Engineering Department Fellowship Award in Spring 2010 from University of California, Santa Barbara, Radar Systems Spot Award Achievement Certificate in recognition of superior individual effort for developing signal processing algorithms, in February 2011 from Exelis (currently known as Harris Corp.), Inc. and 59th Annual National Engineers Outstanding Engineering Achievement Merit Award in Universal City, California in February 2014. He has collaborated actively with researchers in several other disciplines of, particularly computer architecture, reconfigurable hardware, and signal and image processing. He has been a member of Technical Program Committee for International Conference on ReConFigurable Computing and FPGAs in 2013 and IEEE Journal of Transactions on VLSI Systems in 2016.

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Abstract-Recent engineering education research point out several key problems that engineering students experience during the academic years. Electrical, Electronics, and Computer Engineering majors are not exception to this. The key issues vary from one major to another but some can be pointed out such as: low motivation, low retention rate in engineering programs, switch to other majors or drop out from engineering program, poor teaching and advising, the difficulty of the engineering curriculum, and a lack of "belonging" within engineering majors. Statistics indicate a large drop in the continuation rate between the first and third years among Science, Technology, Engineering, Math (STEM) students. As students encounter increasing course difficulty in the early stages of their programs, they often lack motivation to persist because they have weak connections to their majors and potential careers in STEM. The Summer Interdisciplinary Team Experience (SITE), part of the National Science Foundation Science Talent Expansion Program aimed at increasing the number of bachelor degrees awarded in STEM fields, focused on students finishing sophomore-level courses in engineering, math, and physical sciences. The primary goal of SITE was to create a STEM community through participation in small research projects that students worked collaboratively on from concept to completion. In this 3-week summer program, students in interdisciplinary teams of ten worked closely with faculty mentors to develop solutions to socially relevant STEM problems. The projects emphasized hands-on activities and interdisciplinary team-based learning and decision making in order to keep students motivated and interested throughout the project. Faculty mentors first introduced the team to the project concept, then helped them develop the skills and knowledge needed to implement solutions. At the end of the 3-week period, each team made a formal presentation that discussed goals, methodologies, challenges and results. The presentations were accompanied by a live demonstration of the final product. Qualitative assessment based on participants' answers to exit questionnaires show that the program has relatively accomplished its goal to increase motivation to complete the STEM major.

1. Introduction

A noticeable part of traditional engineering curricula includes topics such as math, physics, and chemistry. Often, these topics are taught outside the engineering colleges and departments. On the other hand, engineering educators take different approach where they emphasize more on applications rather than theory. This leaves the gap between the basic science courses and engineering courses. Even though achieving competency at basic science courses are imperative to engineering students, yet students do not grasp their relevance to their major. Our approach is trying to fill this gap by showing real life applications and examples and how science helps engineering solve complex problems.

The SITE projects emphasized hands-on activities and interdisciplinary team-based learning and decision making in order to keep students motivated and interested throughout the project. Faculty mentors first introduced the team to the project concept, then helped them develop the skills and knowledge needed to implement solutions. The introduction to the project concept was given to the group by the faculty mentor along with the specification and constraints. Each group was divided to smaller groups and the work was divided among all. The students were responsible to perform a goal oriented research towards the solution and come up with a final product according to the initial specification. At the end of the 3-week period, each team made a formal presentation that discussed goals, methodologies, challenges and results. The presentations were accompanied by a live demonstration of the final product. Qualitative assessment based on participants' answers to exit questionnaires show that the program accomplished its goal to increase motivation to complete the STEM major. Although our program was not limited to Under Represented Minority (URM) students, the participation of URM students far exceeds their representations in most of the participating STEM majors. Survey results show that participation in SITE was particularly beneficial for URM students.

This paper describes an active learning team based experience. "Summer Interdisciplinary Team Experience" (SITE) is a summer short program to address some of the concerns engineering students face today by engaging students in the learning process [1]. The SITE; part of the National Science Foundation Science Talent Expansion Program; aimed at increasing the number of bachelor degrees awarded in STEM fields, focused on students finishing sophomore-level courses in engineering, math, and physical sciences. The primary goal of SITE was to create a STEM community through participation in small research projects that students worked collaboratively on from concept to completion. There is ample evidence that research experiences for undergraduate students are important in enhancing learning, interest, and persistence in STEM fields [2]. Other studies also indicate that summer research experiences have a strong positive effect on subsequent entry to Ph.D. STEM programs [3]. In particular, research activities have been found to be important for retention of URM students and disadvantaged economic groups [4, 5, 6]. In this 3-week summer program, students in interdisciplinary teams of ten worked closely with faculty mentors to develop solutions to socially relevant STEM problems. The nature of the problems focused more on the engineering aspect and problem solving skills rather than strong technical content and furthermore they were intentionally chosen so that they needed less mathematical background.

SITE is open to majors in computer science (CS), engineering (ENG), mathematics (MATH) and physical sciences (SCI, Biochemistry and Chemistry, Geological Sciences, and Physics and Astronomy). The program focuses on these majors because the number of graduates in these fields is low compared to those in other majors such as Biology. The goals of SITE are to increase students' critical thinking, teamwork skills, and motivation to eventually increase student engagement, motivation, retention rate, and obtain a bachelor's degree in their field. The experience of using their STEM knowledge to solve a problem affirms the importance of STEM careers and inspires them to graduate in these majors.

We will describe the criteria for the student and faculty mentor selection process in detail. The demographics of the student participants and assessment of the results will be discussed. At this early stage of students' educational careers, SITE represented one of the first times that many of these students were able to engage in important aspects of engineering career. After getting the SITE experience, students did benefit from:

- Working in teams
- Working with students of different backgrounds
- Exposure to other fields
- Meeting faculty on a close basis
- Working on projects with real applications and constraints
- Integrating material learned in courses to solve complex problems
- Opportunity to think about careers in industry
- Stronger resume for future career applications
- Going through the process of making an engineering product from concept to completion

In this paper, we will give an introduction to different components of the SITE program. Then we will introduce the SITE projects from 2011 to 2016. In the Fall semester preceding an upcoming SITE program, faculty submit proposals for team projects. The selection of final projects by the STEPS' principal investigators (PIs) is based on the relevance of the topic to the goals of SITE and the potential for engaging students with challenging hands-on activities. The scale and scope of projects must be appropriate to the 3-week time frame and information and tools needed to solve it, to development and testing of ideas/devices, to the final presentation of possible solutions. Each project under SITE program is led by a faculty member from the CECS (college of engineering and computer science). There are also projects within SITE program that are led by other faculty in CSM (College of Science and Mathematics). To provide multiple perspectives on the relevance of the problem and the technical and scientific knowledge needed to solve it, visiting lecturers from other fields lead lectures and/or activities during the program in coordination with the team leader. Field trips are also used where appropriate. Graduate or advanced undergraduate students assist the team leader with the preparation and execution of the hands-on activities.

The overarching goal was to increase the number of bachelor degrees awarded to STEM majors. We sought to do this by attaining a 10% increase in retention of all majors in the College of Engineering and Computer Science (CECS) and the College of Science and Mathematics (CSM). During the 5-year period of the grant, the entering first-time-freshmen cohorts ranged from ~1000 to 1200 students, half of whom typically graduate from our institute in 6-7 years. We employed three strategies to retain more students through completion of their STEM degrees:

1) Fostering success in lower-division mathematics
2) SITE (Summer Interdisciplinary Team Experience)
3) Careers in STEM Seminars

We used a STEPS website to provide information about grant activities. To improve success in mathematics we improved the initial placement in the foundational mathematics sequence and the first-time pass rate in foundational math courses through mandatory supplementary laboratories for at-risk students. Both strategies were important to retention because students who underachieve at the start become dissatisfied with the slow progress in engaging with the major because of lack of Calculus prerequisites. The greatest loss of STEM majors at our institute occurs between sophomore- and junior-level coursework because these students lose motivation to stay in STEM as course difficulty increases and connections to their majors and potential careers are weak. SITE targeted this student population in a 3-week-long team project that highlighted problem solving and hands-on activities and created strong bonds between students and between students and faculty mentors. The Careers in STEM Seminars invited STEM professionals to speak not only about their work, but also about the path that they took in their education and early careers to reach their current positions. These seminars sought to inspire students to stay with their STEM majors through difficult times and to overcome obstacles in their education to gain rewarding careers in STEM. This paper elaborates the efforts made by SITE program to address part of the major problem.

2. The Summer Interdisciplinary Teams Experience (SITE)

The components of SITE were developed using emerging best practices in STEM education and the strengths of our own institution. In 2004 the Committee on Facilitating Interdisciplinary Research, convened by the National Academy of Sciences, presented a report on facilitating interdisciplinary research based on surveys, focus groups, and interviews, as well as a thorough review of the literature [7]. The report presents evidence-based consensus on the study's statement of task by an authoring committee of experts. They found that undergraduate students showed "great enthusiasm for interdisciplinary and problem-driven questions, including those of societal relevance." They also provided a list of recommendations at different levels of the educational process from the development of interdisciplinary courses and programs to interdisciplinary Research Experiences for Undergraduates (REU). The report on "The Logic of Interdisciplinary Studies" [8], based on an extensive compilation of studies until the time of publication, summarized a variety of benefits to the students who partook in interdisciplinary activities. They found that participants had an increased ability to think critically, creatively, and more cooperatively with better understanding and retention of material, and the development of the capacity to find interconnections among fields compared to non-participants.

SITE offers students great opportunities to participate in research projects that have an interdisciplinary perspective and are related to sustainability issues of interest to the campus and the community at large. Our institute (not mentioned due to blind review policy) has had a strong commitment to sustainability issues on the institutional level and by individual faculty in their research. In 2009 the Institute for Sustainability was established to foster research and curriculum on diverse impacts of economics, science and technology, and social equity on sustainability. Its mission is to "promote, facilitate, and develop educational, research, and university and community programs related to sustainability." The Institute is committed to serving our campus community by increasing interdisciplinary and cross-functional communication, and supporting and aiding in the development and application of sustainability practices within the university and community. In past years the Institute has partnered with the local community and industry on projects related to solar cell technology, transportation, campus food gardens, increasing recycling, and water conservation. Some of the SITE projects were inspired by these themes. Among all SITE projects, four projects directly and 10 project indirectly address the sustainability issues (The list of the projects can be seen in Table 2).

SITE is a 3-week-long program open to majors in computer science (CS), engineering (ENG), mathematics (MATH) and physical sciences (SCI, Biochemistry and Chemistry, Geological Sciences, and Physics and Astronomy). The program focuses on these majors because the number of graduates in these fields is low compared to those in other majors such as Biology. The goals of SITE are to increase students' critical thinking, teamwork skills, and motivation to eventually increase the retention rate and obtain a bachelor's degree in their fields. The experience of using their STEM knowledge to solve a problem that has socioeconomic and/or ecological/resource relevance affirms the importance of STEM careers and inspires them to graduate in these majors.

Each year, about 40-42 students are selected from a competitive application process, open to continuing students and incoming transfer students. To be eligible, students must have completed at least one semester of calculus, one laboratory science course, and one additional course in their majors. The first priority is given to the target population of students transitioning between the sophomore-level and junior-level coursework. The second priority is given to freshmen transitioning to sophomores and early-stage sophomores. Once the candidates are chosen, selection aims to optimize the diversity of the cohort within the groups according to major, ethnicity, gender, and GPA. Applicant GPAs range between 2.0 and 3.9, with an average around 3.0. The STEPS team organizes the students in teams of 10 (and in some cases up to 12 when grouping in 10 was not possible) students ensuring that a diverse range of majors and student abilities are represented in all teams.

Throughout the 3 weeks, the projects emphasize hands-on activities, the development of critical thinking and teamwork skills, and close connections to the faculty mentors. All SITE members gather for brown-bag lunches on the first two Fridays to share progress on their projects, including how problems were overcome and plans for the following week. At the conclusion of SITE, each team makes a professional presentation describing their solution to the real-world problem that required integration of knowledge from the different disciplines. In attendance are the SITE participants, the faculty mentors, the STEP PIs, members of the Internal and External Advisory Boards of the STEP program, and other faculty and administrators. Table 1 shows the student participation through the life of the project.

Table 1. SITE student participation

	2011	2012	2013	2014	2015	2016	Total
Number of applicants	41	69	69	57	104	84	424
Number of participants	30	40	43	42	41	40	236
Participants from CECS	N/A	33	36	35	34	32	170
Participants from CSM	N/A	7	7	7	7	8	36
Projects from CECS	2	2	2	3	4	4	17
Projects from CSM	1	1	2	0	0	0	4
Joint projects from CECS & CSM	0	1	0	1	0	0	2

The event culminates with a celebratory luncheon in which each student is individually presented with a certificate of completion of the program, a stipend check, and a t-shirt. Students who complete the summer experience with no unexcused absences receive a $1,000 stipend for their participation in the program. They are also given early registration, an important benefit to sophomores who have the last registration dates in the university. Project leaders are paid $9,000. The visiting lecturers including faculty from other institutions, experts from industry, or university technical staff, were given a $500 stipend for a full day of instruction. Each team leader is allowed $2,000 to hire student assistants and $2,000 for equipment and supplies. All expenses are covered by the NSF grant. The average cost per student is roughly about $2300.00.

All TAs, faculty, and students were actively working together as teams during this three week period but TAs and faculty have spent much more time (depending on the project) preparing the material for the courses. For the projects presented in this paper, faculty and TAs have spent 2-3 hours per day for the duration of one month. The NSF funding has ended and unfortunately it is not possible to continue this project even though students showed a lot of interest in the program. Should the fund be available, this can be a very successful program to increase the motivation and retention for engineering programs.

3. SITE Projects

Table 2 presents the list of projects pursued from 2011 to 2016. We had three projects for the first year and four projects for the following years. Among all projects, 56% of the projects were assigned by the faculty from Electrical and Computer Engineering (ECE).

Table 2. List of SITE projects

Session	Project Title
Summer 2011	Global Positioning Satellite (GPS) Instruments and Plate Tectonics (ECE)
	Constructing an Earthquake Seismometer
	Solar Energy vs. Wind Energy Competition (ECE)
Summer 2012	Electric Bicycle Design for a More Sustainable Campus (ECE)
	Sustainably-powered, Non-polluting Water Purification System
	Construction of an Earthquake Seismometer and Early Warning System
	Natural Hazards and Resources of the San Gorgonio Pass Region
Summer 2013	Harvesting Energy from Human Movement to Charge Hand-held Electronic Devices
	Construction of an Optical Polarimeter for Sky Measurements
	Measuring Aerosols Locally and Understanding Climate Globally
	Green Design for campus Buildings
Summer 2014	Implementation of Spectral Imaging Using Fourier Transforms on Reconfigurable Hardware (ECE)
	Impact of Solar and Wind Generation in the Environment and in Sustainability from the Electrical Engineering Point of View (ECE)
	Future Modern Electric Grid: Generation, Transmission and Distribution (ECE)
	How Sustainable are the Green Buildings?
Summer 2015	California Drought - What Can Californians Do?
	DC (Direct Current) Home (ECE
	Autonomous Collaborative Exploration: An Attempt to Learn Robot-Environment Interaction (ECE)
	Photovoltaic (PV) Power Generation (ECE)
Summer 2016	Green Energy (ECE)
	Smart Home Energy Management System (ECE)
	Electric Speed Drives in Transportation (ECE)
	Where Art Meets Science – Evolution of Imaging through Light and Color (ECE)

Specifically we will discuss two SITE projects in great detail in the area of Electrical and Computer Engineering. At first, the common elements of all projects are discussed. This includes introduction to topics and background, students' learning objectives, project description, support material, skills achieved for STEM carriers, and weekly agenda. To be eligible, students must have completed at least one semester of calculus, one laboratory science course, and one additional course in their majors. This paper is the result of the collaboration of primary investigators (PIs) and a faculty mentor leading a couple of projects within SITE program. In the following we will discuss two projects introduced in 2014, 2015, and 2016 by the faculty mentor in electrical and computer engineering (ECE) department in more detail and provide in depth review of these projects. We will discuss the objectives of these projects and what students were expected to learn in these experiences. The weekly agenda will be included for each course that lists of all activities performed by students in each week.

3.1 Autonomous Collaborative Exploration: An Attempt to Learn Robot/Environment Interaction

Introduction and Background: Robots are increasingly becoming popular in our daily lives, from the automated vacuum cleaners to the rovers exploring Mars. Intelligent robots can autonomously plan and execute instructions to accomplish a task and adapt to uncertain environments. Generally capable behavior requires high-level planning and programming, but interaction with the environment must ultimately be performed by sensors at the physical level. This project takes on hands-on approach to introducing the concepts in robotics, using LEGO Mindstorms [9] autonomous robot developed by MIT Media Lab for the first time. The Lego Mindstorms hardware contains software and hardware to create customizable robots. Mindstorms kit (Figure 1) includes an intelligent brick computer that controls the system, a set of modular sensors and motors, and Lego parts to create the mechanical systems to the extent of imagination. The hardware and software roots of the Mindstorms hardware system goes back to the programmable brick created at the MIT Media Lab.

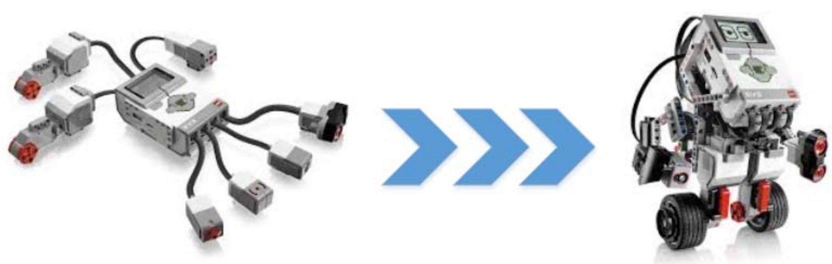

Figure 1. A simple robot made out of LEGO Mindstorm hardware

Student Learning Objectives and Achievements: By the conclusion of this project, students will have a hands-on knowledge of robotics science, research trends, and applications. Students will be able to write code for Mindstorms hardware using Mindstorms proprietary NXC combined with C programming language, execute the code on Mindstorms embedded ARM processor and verify their program. Students will be assigned different projects to explore robot interactions with environment to perform various tasks. In addition, students will learn how to work with different sensors such as touch sensors, light sensors, ultrasonic sensors, infrared sensors, etc. to interact with environment. Figure 2 shows a group of student testing their line tracker robot.

Figure 2. The testing session of line tracker robot made by students

<u>Project Description:</u> The topics included in this project are robot control, perception, decision making, navigation, and learning. This project consists of three phases conducted; each phase being performed over one week. During phase I, students will be able to:

- Understand the basics of autonomous robots, sensors and their uncertainties
- Understand Mindstorms hardware and how to program it
- Learn fundamentals of C language
- Acquire problem solving techniques and skills

Example of tasks at this level would be solving a maze. In phase II, students will be able to:

- Take a design idea from concept to hardware implementation and build the supporting mechanical system
- Enhance their knowledge and programming skills by writing simple to complex programs for Mindsotrms robots to interact with environment.

Example of tasks at this level would be communicating with robot using Bluetooth module or estimation of a distance from an obstacle using ultrasonic sensor. At the start of phase III, students are assigned a challenging project to implement on Mindstorms hardware, write the software application, execute, test, and debug the code. Students will participate in an internal competition for the most interesting and challenging project to present at the final SITE presentation day. Example of tasks at this level would be solving a maze!

<u>Support Material:</u> All the training material needed for the course will be provided on the project website. The technical contents of the course will be suitable for students with calculus I background. No robotics background is needed. Advanced scientific concepts will be avoided. This course is open to students with freshman or sophomore standing. The material in the course will be largely self-contained.

<u>Skills for STEM Careers:</u> Writing software programs; software/hardware interface techniques; using various sensors to enable autonomous robots to interact with the environment, altogether will significantly improve the resumes of project participants.

Prospective industries include design automation, robotics, biomedical science, aerospace engineering, and manufacturing.

Project Significance and Relevance: The significance of this project is to experience the design process from concept phase to implementation and producing a functioning hardware. The most important aspect of this project is to learn how an autonomous device interacts with environment and uses environmental factors such as light, sound, temperature, range to various objects, etc. to make intelligent decisions. This technology has applications in numerous fields such as design automation, aerospace, biomedical engineering, and manufacturing process.

Weekly Agenda:

Week 1

Introduction to Programming with Emphasis on Problem Solving Techniques

a. Introduction to Microprocessors/Microcontrollers and Software Languages
b. Introduction to Embedded Systems and Robotics
c. Flowcharting, Problem Solving Techniques, and Algorithm Development
d. Programming Fundamentals
e. Qualities of a Good Program
f. Variables, Data Types, Operators, Expressions
g. Loops and Control structures
h. Arrays, Strings
i. Functions, scope, and parameters
j. Input/Output
k. Introduction to LEGO MINDSTORMS EV3
l. Software Demo
m. Building and Programming Basic Robot
n. Motion
o. Movement on Predefined Path
p. Tracing a Path

Labs

1. Travel on Predefined Path: Motors, Sequences of Commands, Block Settings, Downloading and Running Programs
2. Turning: Types of Turns, Move Steering
3. Tracing a Path: Line Follower

Week 2

Robot-Environment Interaction Using LEGO MINDSTORMS EV3 Robots

a. Software, Firmware, and Hardware
b. Hardwar Platforms and Software Applications
c. Testing Robot: Running More Complex Programs on EV3 Using Different Robots
d. Interaction with Basic Sensors
    i. Touch Sensor
    ii. Color Sensor

Labs
1. Handling Obstacles: Sensors, Touch Sensor
2. Move Until Near: Ultrasonic Sensor, Thresholds
3. Turn for Angle: Gyro Sensor, Compensating for Sensor Error
4. Color Identification: Color Sensor, LCD Display
5. Playing Music: Adding Sound to Robot
6. Switches: Switches, Conditional Reasoning
7. Switch-Loops: Obstacle Detection Behavior, Repeated Decisions Pattern

Week 3
Getting Deeper Into Robotics Science
a. Autonomous Systems
b. Interaction with More Advanced Sensors
    i. Gyro Sensor
    ii. Ultrasound Sensor
    iii. Infrared Sensor
c. Robot-Sensor Interaction
d. Final Challenging Project: Solving a Maze

Labs
1. **Maze Solver; Putting it Altogether**: A robot is asked to navigate a maze including obstacles. It is placed at the starting position in the maze and is asked to try to reach on the goal position. Positions in the maze will either be open or blocked with an obstacle. The robot can only move to positions without obstacles and must stay within the maze. The robot should search for a solution path from the starting position to the goal position until it finds one or until it exhausts all possibilities.
2. Internal Contest!
3. Final Presentation Preparation

3.2 Where Art Meets Science: Evolution of Imaging through Light and Color

Introduction and Background: In imaging science, an image is processed using mathematical operations by using any form of signal processing for which the input is a digital image, such as a photograph or video frame and the output may be either an image or a set of characteristics related to the original image. Digital photography, on the other hand, uses digital still cameras containing arrays of electronic photodetectors to capture images focused by a lens, and then digitize and store them as a computer file for further processing, viewing, publishing, or printing. This project takes on hands-on approach to introducing the digital image processing concepts through examples and applications. The basic concepts of imaging (common between digital photography and digital image processing) will be introduced. Furthermore, the evolutionary path from light sensitive photographic film to modern digital imaging will be reviewed. More advanced concepts of digital imaging will be presented in an incremental order. Most of the photography techniques and principles will be covered in this course. Students can perceive this course as an introductory course to photography as well as image processing. Figure 3 shows the path that a digital photo travels from the subject to the final digital image that can be saved on a computer. In this course, the best effort is made to take the students through this journey.

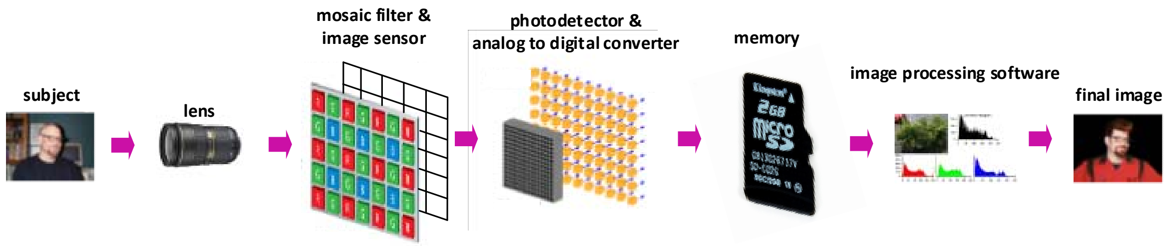

Figure 3. An end to end process of how camera turns light into a processed digital image

<u>Student Learning Objectives and Achievements:</u> By the conclusion of this project, students will have a hands-on knowledge of image processing techniques, research trends, and applications in the science of digital imaging. As a bonus, students will obtain a good understanding of the art of digital photography. Students will be able to write Matlab code for basic image processing techniques, and will apply their code to images to verify their programs. During this process, students get a chance to observe the applications of even the basic mathematical theories to the real life problems. Students will be assigned projects to explore various techniques in both fields of photography and digital image processing. Figure 4 shows samples of the photos taken by students during this short course.

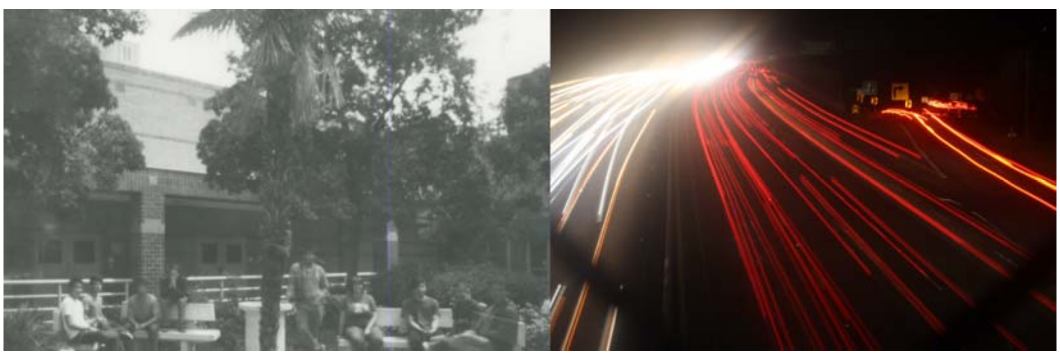

Figure 4. Examples of Students' work during the course: Left – On campus photo taken and printed by pinhole camera made by students, Right – A night photo of the freeway

<u>Project Description:</u> The topics included in this project are digital imaging science, image visual perception, image enhancement, histogram processing, image filtering, image restoration, image segmentation, and digital photography techniques. This project consists of three phases; each phase being performed over one week. During phase I, students will be able to:

- Understand the basics of imaging science
- Understand digital photography, principles, and techniques
- Understand image sensors, camera modes, metering modes, focusing modes, and basics of lenses and filters

Students exercise the concepts learned in this phase by taking photos and analyzing them in class. In phase II, students will be able to:

- Learn fundamentals of mathematical representation of digital images
- Perform basic operations on images
- Implement basic image processing algorithms using Matlab image processing toolbox

Example of tasks at this level would be the implementation of noise filter or smoothing filter. At the start of phase III, students are assigned more challenging tasks to implement and process in Matlab. Example of tasks at this level would be edge detection algorithm. Students will participate in an internal competition for the most interesting project to present at the final SITE presentation day.

Support Material: All training material needed for the course will be provided on the project website. No background is needed in photography or image processing. Advanced scientific concepts will be avoided. This course is open to students with freshman/sophomore standing. The material in the course will be largely self-contained. The technical contents of the course will be suitable with calculus I background.

Skills for STEM Careers: Writing and implementing image processing applications and algorithms using Matlab high level language to extract and analyze data from images, Improving mathematical and analytical skills of data, altogether will significantly improve the resumes of participants. Prospective industries include image forensics, astronomy, artificial intelligence, biomedical science, aerospace, video/audio engineering, photography, radar engineering, and so on.

Project Significance and Relevance: Images are increasingly key to engineering, science, and many other fields, and hence computational methods for processing image data are of critical importance. Extracting useful information from raw images involves a broad range of mathematical techniques and algorithms including but not limited to optimization, modeling, discrete algorithms, and methods for high-level image understanding. Researchers are creating new algorithms in a range of applications, from astronomy, to reconstructing volume data from medical scans, to automatically reconstructing 3D geometry from 2D photos.

Weekly Agenda:

Week 1

Introduction to Digital Camera and Photography

a. Introduction to Digital Photography
b. Introduction to Cameras
    a. Camera Sensors
    b. Lenses
c. Introduction to Matlab Image Processing Toolbox
d. Camera Basics

e. Fundamental of Digital Images
f. Color Photography
g. Introduction to Photography Filters

Labs

1. Making a Pinhole Camera!
    a. Capturing Gray Scale Images
    b. Build Camera From a Shoe Box!
2. Exercising Three Basic Rules of Photography
    a. Depth of Field
    b. Shutter Speed
    c. Film Sensitivity
3. Printing Photos

Week 2

More advanced Concepts in Photography

a. How to Create Special Effects
b. Night Photography
c. Sky Photography
d. Lens Types
e. Camera Types
f. Image Sensors
g. Rule of 600!
h. Lighting, Lighting, Lighting!

Labs

1. How to Take Good Astro-photos?
2. Long Exposures
3. Sport Photography
4. How to capture star trails?

Week 3

Image Processing Techniques

a. How to Work with Digital Images Using Matlab
b. Image Filtering
    i. Noise Models
    ii. Digital Image Filters
c. Edge Detection
d. Morphological Processing
    i. Erosions
    ii. Dilation
    iii. Opening and Closing
e. Object Detection
    i. Circle Detection
    ii. Line Detection
    iii. Introduction to General Object Detection Algorithms

Labs

1. **Fix it!; Putting it Altogether**: Groups of students are given different images with some sort of problems and asked to fix the problems using the techniques learned in the course. At the end students are required to give a presentation to the whole class summarizing their experience.
2. Internal Contest!
3. Final Presentation Preparation

4. SITE Evaluation

We had Institutional Review Board approval to conduct and report the assessment on our program. To assess the effects of SITE we have used the exit questionnaires administered on the last day of SITE and individual interviews conducted about five months after completing SITE. The statistics presented in Table 3 include all 230 students for questions 2,4,7,8 and 9. For the other questions only the responses for the cohorts 2012-2016 are included. Results parsed according to ethnicity and gender are included.

Table 3. Results of Exit Questionnaires

	Questions	**Strongly Agree or Agree (%)**		**Strongly Agree or Agree (%)**	
		All	**URM**	**M**	**F**
1	Project met or exceeded initial expectations	81.7	82.5	80.7	84.6
2	Team project made me more positive toward working in groups	87.4	88.7	89.2	82.7
3	Team problem solving with other majors was helpful	89.1	91.8	88.6	90.4
4	Better understanding of how to use skills and knowledge in their career	76.5	81.4	74.4	82.7
5	More interested in working with faculty in faculty mentored research	90.0	90.7	89.2	92.3
6	More interested in industry internship	93.0	95.9	93.8	90.4
7	As result of project more likely to stay in major	95.5	95.4	95.5	95.2
8	As result of project more likely to switch majors within CS, ENG, MATH, SCI	4.0	4.6	3.9	4.8
9	As result of project more likely to switch majors out of CS, ENG, MATH, SCI	0.5	0.0	0.6	0.0
10	Participating in project increased confidence in academic skills	70.9	72.4	69.7	73.8
11	Participating in project maintained confidence in academic skills	29.1	27.6	22.4	21.4
12	Participating in project increased desire to obtain a degree in STEM	77.5	81.6	77.6	78.6
13	Participating in project maintained desire to obtain a degree in STEM	22.5	18.4	22.4	22.2
14	Finding SITE project intellectually simulating	73.9	74.1	74.1	78.6

Responses to all questions indicate that students highly valued their SITE experience, which has increased or maintained their interest in completing their STEM major, their academic-skill levels, and their interest in pursuing faculty research and/or industry internships. We found that for most questions URM students had comparable or slightly more positive responses to those of the whole group. Here we report on the questions in which there were differences in the responses according to ethnicity and gender. 82 % of URM students compared to 78% of all students reported that participation in SITE increased their commitment to complete a STEM major, and 81% of URM students compared to 77% of all students indicated that the program gave them better understanding of how they will use their STEM skills and knowledge in their future careers. This is specifically can be of interest as this program did not target URM students. These favorable increases are compatible with studies that indicate that URM students are particularly receptive to programs offering research experiences.

The following highlights some markers of positive impact on students:

1) 22% of students report that participation in SITE maintained their desire to obtain a degree in STEM.
2) 77% of students report that participation in SITE increased their desire to obtain a degree in STEM.
3) 87% are more positive toward actively working in groups.
4) 90% reported an increased interest in participating in faculty research and 93% in pursuing an industry internship.

In addition to the evaluation of the SITE program with questionnaires, students were required to present a progress report every Friday for the first two weeks. In these presentations, other students as well as faculty asked several questions. Furthermore, students were required to present final results along with their findings and live demonstrations of their projects. More importantly, several experts from industry were invited to the final week presentation and evaluated the students' work by asking questions. Figure 5 shows an example of a final live demonstration made by students in the robotics project.

Figure 5. The final project live demonstration of the stair climber robot

Total of 230 student participate in the SITE program, In case of gender, 23% of students were women and 77% were men. The majority having just completed their sophomore level course work. Male and female students also had similar responses on most questions, except for the following:

1) 83% of women compared to 74% of men stated that SITE gave them better understanding of how they will use their STEM skills and knowledge in their future careers
2) 74% of women compared to 70% of men reported that participating in SITE increased confidence in their academic skills
3) 89% of men compared to 83% of women found that the team project made them more positive toward working in groups.

In follow-up interviews, students highlighted the value of working with faculty on projects with real life applications, applying material learned in courses to solving complex problems, and the opportunity to think about careers in industry. At this early stage in their educational careers, SITE represented the first time that these students were able to engage in and reflect upon these important aspects of STEM training. Overall the student reports indicate that SITE led to a major commitment to their STEM careers and in particular among URM and female students who have been shown to be receptive to programs offering research experiences.

It is very difficult to prove that SITE program caused the increase in motivation even though this was seen by the faculty and TAs who were involved with students on a daily basis. However, based on the survey results and students' feedback, certain aspects of the program impacted students' persistence. Hands on approach to solve engineering problems, finding solution to real life applications and problems, and opportunity to work with faculty closely on daily basis were among some of the most important aspects. It was observed during the program implementation, students stayed for late hours without being asked to in order to finish their project and have a successful demonstration.

5. Conclusion

The project defined by SITE program have been selected carefully through an internal call for proposal (CFP) on campus. The objective of the SITE projects are increasing students' motivation, engagement, and retention through active learning for undergraduate students in science and engineering majors. In this paper, we discussed two of the projects in ECE during the years 2015 and 2016 in detail. We described the projects in great detail along with students' learning objectives, skills for STEM majors obtained by students after participating in this project, and the weekly agenda including the topics discussed and the labs implemented by students. SITE targets students transitioning between sophomore- and junior-level coursework by offering a 3-week summer research experience designed to increase critical thinking, teamwork skills, and motivation. The activities in SITE emphasize close interactions with the faculty mentors and interdisciplinary work in projects relevant to sustainability. Importantly, 78% of the SITE students are from CECS, and 43 % of participants are URM students. It is extremely difficult to track all students participated in SITE for graduation, retention, and GPA as the grant has ended. Furthermore, this task needs a longer period of time since the last students were graduated from SITE program in 2016. However, the results from questionnaires already show that the program favorably impacts the academic skills and attitudes of the participants toward their STEM majors and STEM careers. URM participants in particular strongly value this early-career research experience.

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