**Practical Application of Robotics Competition for STEM Education**

**Abstract**

As robots become an increasingly integral part of our society, the study of robotics has a great potential to influence Science, Technology, Engineering and Mathematics (STEM) education. Robotics is a multidisciplinary field and requires an organic integration of resources and optimized operation for its impact to be maximized. This paper presents the practice and significance of using a robotic submarine competition (Robosub competition) to improve the engineering education of STEM majors at California State University, Los Angeles (CSULA). The competition requires students to design and build a submarine robot to autonomously navigate through a series of tasks that mimic ongoing research in robotic systems. First, the organization of this program at CSULA is introduced, including the involvement of faculty advisors, a student organization, and senior design teams. Second, the integration of this program into students’ curricular and extracurricular activities are discussed. Many design tasks can be used strengthen a variety of courses throughout almost all engineering and computer science disciplines. Aside from that, student participants obtain many core skills that are critically important for them to be successful in their future careers. These skills include major related technical skills and beyond, such as communication, leadership, management, and cooperation skills. Third, the impact of the competition among student participants, the engineering program, and the institution are summarized. Although this program has only been established for about two and a half years at CSULA, many positive results in improving college engineering education have been achieved. Finally, discussion of the existing challenges to maintain the program long-term and possible future solutions are presented.

**Introduction**

Interest in robotics has been continuously growing at an astonishing rate in recent years. It has become increasingly common to see robots in almost every aspect of our lives, including package delivery, elderly care, rehabilitation, home appliances, self-driving cars, education and several such major implementations. Since robotics is a multidisciplinary field, it naturally creates an environment that allows students from multiple majors (especially science, technology, engineering, and math majors) to work together to develop innovative solutions. In addition to specific technical skills, students acquire other professional skills from this team-based working environment. Hence, robotics is believed to be a suitable tool that could potentially transform STEM education. However, due to its multidisciplinary characteristic, there are also challenges associated with integrating robotics into a curriculum from any specific major. Therefore, robotics competitions become a very important part of STEM education.

The utilization of a robotics competition to improve STEM education has become a prominent research topic. Studies on the multidisciplinary nature of robotics have shown that it can be a valuable tool for hands-on learning of a variety of engineering and science topics [[1]](https://paperpile.com/c/VpiJWA/H4na). Since robotics incorporates numerous STEM fields, mentorship and learning across complementary STEM disciplines can be achieved [[2]](https://paperpile.com/c/VpiJWA/aAg3). Top universities have incorporated robotics into their curriculum through LEGO Mindstorms, an educational robotics kit that is distributed worldwide, as Drew et al. [[3]](https://paperpile.com/c/VpiJWA/lD1ly) state, “with additional enhanced creativity achieved through competitions within the class settings and often between various universities and colleges.” Yao et al. [[4]](https://paperpile.com/c/VpiJWA/Wkyl2) showed that robotic competitions can be used as educational tools beginning in the first year of a curriculum. Beach et al. [[5]](https://paperpile.com/c/VpiJWA/2CYZE) studied the current nature of robotics competitions, and proposed a method of formulating competitions to entice students to push the boundaries of what robots can do, rather than simply completing tasks and playing games. Not only in college level STEM education, robotic competitions have been widely used for K-12 education; whereby, studies have shown improved STEM and other assessment (ACT, SAT) scores as a function of K-12 student participation in robotics competitions [[6]](https://paperpile.com/c/VpiJWA/EhU95) [[7]](https://paperpile.com/c/VpiJWA/1IS8u). Moreover, competitions have been shown to enhance students’ motivation to learn in both the K-12 and university setting [[8]](https://paperpile.com/c/VpiJWA/uP3Um). Additionally, the benefit of robotics projects in promoting teamwork and leadership skills which can’t be developed in class, has been shown in [[2]](https://paperpile.com/c/VpiJWA/aAg3)**.** Given the necessity for teamwork across multiple disciplines, robotics provides an excellent platform for senior design/capstone projects, campus organizations, and design competition teams.

While many positive results have been reported in the literature, there remain several challenges in effectively managing a robotics competition and related activities such that a students’ learning outcome can be maximized. First, many robotics competitions are demanding in terms of resources. The lack of ample funding experienced by this particular team during the past year has created an improvisational stigma among members working on creating parts of the sub, which requires much more time and effort to be put into the project that places stress on participating students. Moreover, the multidisciplinary nature of the project complicates the communication process between teams, as knowledge limitations prevent students from fully understanding the portions of the project other students have worked on. Thirdly, maintaining the interest and motivation of students has proven difficult with the resources provided to the team this year. Students become intimidated by the large scale of the project and underestimate their abilities to participate in the project, leading to members becoming inactive or reluctant to attempt to face challenges.

To tackle the above mentioned challenges, this paper presents the practice and significance of using a robotic submarine competition (Robosub competition) to improve the engineering education of STEM majors at CSULA. The work presented in this paper provides guidance for management of other college robotics competition activities. The paper describes the Robosub competition; implementation of a Robosub team at CSULA, survey data from current and former members detailing its impact on student skill development and career opportunities post-graduation. Finally, the paper discusses the current challenges faced by the organization at CSULA and possible future solutions to these challenges.

**Background of Robosub Competition**

The first Robosub competition was held during the summer of 1998. Since then, there have been 21 iterations of the competition, all sponsored, and in some part managed, by The Association for Unmanned Vehicle Systems International (AUVSI) and The Office of Naval Research (ONR) [[9]](https://paperpile.com/c/VpiJWA/F7mSr) . Each year AUVSI and ONR, in conjunction with industry partners, organize the annual Robosub competition as a means of fostering multidisciplinary engineering education and early career development through the medium of underwater autonomous robotics. The competition and its organizers strive to be the liaison between engineering students who are motivated to work in robotics with the industry leaders in autonomous systems. The allure of prestigious industry sponsors, such as Northrop Grumman, General Atomics, and SpaceX, which were featured sponsors of the most recent Robosub competition, coupled with the fast-paced and ultimately collaborative learning environment a competition creates, has proven to garner the attention and motivation of engineering students at CSULA. In order to maintain this allure, and to ensure student teams are being appropriately challenged, significant effort is put forth in developing a new iteration of the competition each year. From competition to competition, the student tasks, theme, and objectives are revised and updated. While the tasks and theme of the Robosub competition are updated annually, the overarching goal of the competition and the relevant technical skills that must be developed in order to compete remain the same. Creating the updated competition tasks and objectives is overseen by the Robosub Competition Team and is described elsewhere [[10]](https://paperpile.com/c/VpiJWA/vgPfc). The competition design is primarily a function of decisions regarding the “arena”, the closed body of water the competition will take place in, and the “mission”, the set of tasks and objectives which change year-to-year. Since 2002, the Robosub competition “arena” has been the U.S. Navy’s Space and Naval Warfare Systems Center Pacific (SSC Pacific) TRANSDucer Evaluation Center (TRANSDEC) in San Diego, CA. The “mission” design is driven by the following selected requirements as they are presented in [[10]](https://paperpile.com/c/VpiJWA/vgPfc):

* Interesting, challenging tasks for teams
* Build relevant technical skills
* Portions of the mission must be tractable for students new to the field and competition
* Tiered success

These requirements illustrate a deliberate design intent from the organizers for the competition to be accessible to students at every stage of their college career, whereby there are portions of the competition that are simple enough to be completed by a team competing for the first time, with successive tasks of increasing difficulty that will challenge even the most experienced students.

**Implementation of Robotics Competition at CSULA**

The Robosub team at CSULA was founded in 2016, providing a multidisciplinary platform for students of all majors and backgrounds to participate in the creation of an autonomous submarine robot for the annual Robosub competition. Students gain various technical and soft skills, as well as form lasting relationships with other team members and faculty advisors. The competition provides networking opportunities to assist students with their career goals after graduation, as well as a fun and interactive learning environment. Since its inception, the team has expanded its member count from 10 to nearly 40 participating members and has even sponsored several capstone senior design teams with the engineering college.

As shown on Figure 1, CSULA’s Robosub team is composed of four primary groups:

1. Senior Design Team
2. Senior Design Advisors
3. Faculty Advisors
4. Core Members/Apprentice Program

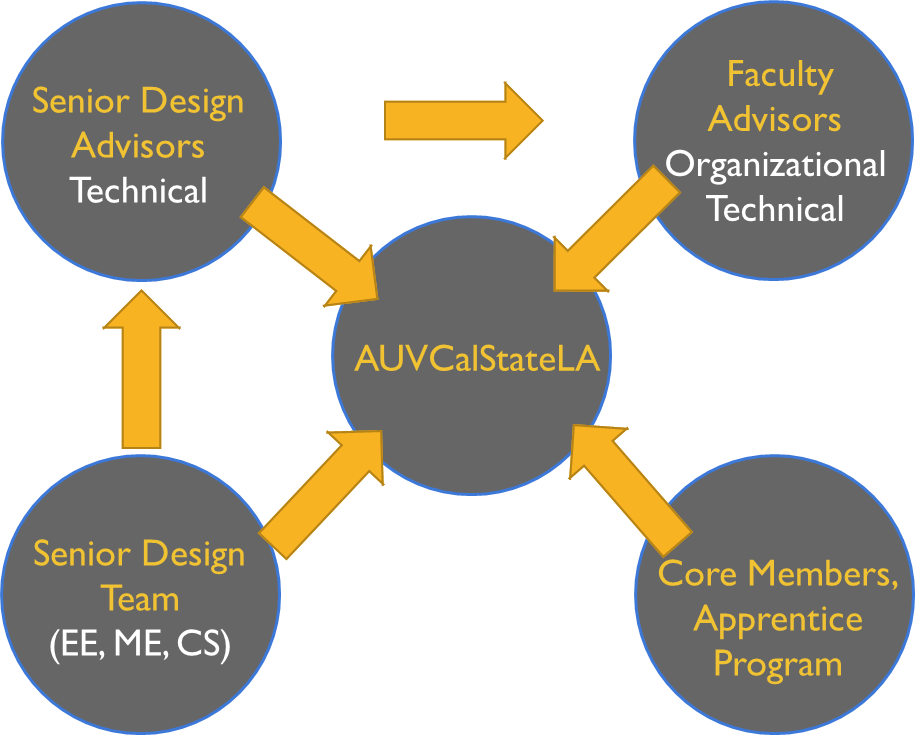


Fig. 1 Organization of CSULA Robosub Team

The senior design team is a group of students who chose (or were selected) to work on CSULA’s Robosub team as their capstone project. The RoboSub senior design members on the 2018-19 project work on improving the 2017-18 competition vehicle by adding new shelving systems, changing 3D printed parts to be more efficient, and improving the weapons systems designs from the previous vehicle. The senior design advisors are members of the engineering faculty who facilitate the senior design program and instruct its associated course. The faculty advisors are the group of faculty who advise the entirety of the club. Although there is overlap between the senior design advisors and the faculty advisors, the faculty advisors manage a myriad of other challenges within the organization, such as funding, general club members, and overall organization status and progress. The core members/apprentice program constitutes the population of students who are in the club and working on the project but are not on the senior design team. The apprentice program refers to the relationship between the senior design team and lower classmen general membership, whereby the senior design team is encouraged to mentor the core members (apprentices), using the experience they have gained over their degree program to guide and advise club members on their individual designs and projects. This relationship offers the senior design team to exercise leadership skills, and allows for rapid learning and advanced progress among the core general membership of the club.

The activities organized by the student organization benefit students from multiple majors throughout the college, mainly through three channels – senior design groups, organization members, and other students who participate in activities organized by the group. The team deeply impacts about 30 students per year (who work closely with the team) through activities, benefits more than 100 students per year through talks in classrooms, and reaches out to hundreds of students at CSULA as well as other local middle and high schools through various outreach activities.

The activities provided by the organization allow students to learn about several different interesting subdivisions of engineering, including manufacturing, 3D printing, circuit design, PCB fabrication, underwater acoustics, actuation, sound filtering, autonomous systems, computer vision programming and machine learning. Moreover, the organization provides opportunities for students of all levels, with beginning students participating in workshops and gaining hands-on experience, and more experienced students doing research and testing methods to be used on the final robot. In addition, the organization’s workshops and general meetings are open to all CSULA students and advertised via our social media, so even students who do not wish to participate in building the sub can learn and benefit from the organization’s events. Students from all majors are welcome to join and participate in the project, and since the organization’s establishment, members’ majors have included electrical engineering, mechanical engineering, computer science, business, physics, communications, and math.

Through the organization’s workshops and events, students learn how to share their knowledge with others and inspire other students to pursue careers in engineering. The organization’s faculty advisors arrange several events throughout the year for students in and outside of the organization, such as visits from industry professionals and tours of industry workplaces. The organization also participates in campus events and community outreach, such as Boeing Day, the CSULA welcome back BBQ, Science Bowl, presentations in introductory engineering classes, and the CSULA Mash-up. At each of these events, representatives from the Robosub team talk to students ranging from middle school to graduate level. The project is showcased, and in some cases, such as classroom visits, an informal presentation is given on the background of the project and what it has to offer for engineering students. These events provide information to students of all majors across the campus, and hopefully spark interest in the project for students who would like to participate.

The first sub built by the team in 2017, nicknamed Eagle I, consisted of a pelican case enclosure with T-slotted aluminum bars for the frame (Figure 2). Many of the electronics systems on Eagle I were similar to those implemented in future submarine iterations. While Eagle I was an outstanding first attempt at creating an autonomous submarine robot with few guidelines, it left much to be improved upon for future robots. The second year of Robosub at CSULA (2018) included the designing and building of a second generation submarine robot, nicknamed Eagle II. In moving to this second iteration, the entire frame, hull, and bulkhead were redesigned, as well as improvements made to many of the electronics systems (Figure 2). The major improvement in this area was the addition of a Doppler Velocity Log (DVL), a sophisticated sensor designed to aid in accurate navigation.

Due to Eagle II’s strong performance in many areas during the competition, the 2019 CSULA Robosub team opted to make improvements on Eagle II rather than to create a new competition vehicle. The main improvements Eagle II required were an improved computer vision system and a functioning hydrophones system. In addition, many of the new members worked with materials already present in the lab to recreate the various robot subsystems for experience working with autonomous submarine robotics.

**Impact of Robotics Competition on Student Learning**

Appropriately incorporating the robotics competition, or any type of student design competition, into an engineering student’s education is challenging for both the student and the faculty [[11]](https://paperpile.com/c/VpiJWA/iNcLF). The student must devote a significant amount of time and effort, which could otherwise be spent on coursework. Nevertheless, the engineering student is positioned to attain immensely valuable experience and skills from the Robosub organization that could not be gained in the standard engineering curricula. This is not to say that the engineering curriculum is inherently incomplete or lacking without the student design competition, but rather it is a reality of the constraints imposed by a classroom, subject-specific, learning environment. The designed submarine was tested extensively through several sessions of algorithm training in a controlled pool environment. Through this, students get experience applying their coursework to a real project while making mistakes and trying different approaches. The free form, multidisciplinary, self-driven, and long-term learning that the Robosub organization fosters in students is unparalleled. Although it may be difficult to implement, subjective and objective findings have been produced to support the assertion that student design competitions greatly enhance the value of an engineering degree, with some studies going to the extent of interweaving the student design competition project, at its various phases, into the engineering curriculum as a graded requirement [[11]](https://paperpile.com/c/VpiJWA/iNcLF). The faculty advisors face a similar commitment that requires dedication and sacrifices, but results in faculty-student relationships that cannot be replicated in a classroom. Moreover, involvement in design competition projects has shown to have a positive effect on student retention and continuation to graduate school [[12]](https://paperpile.com/c/VpiJWA/dVbXo).

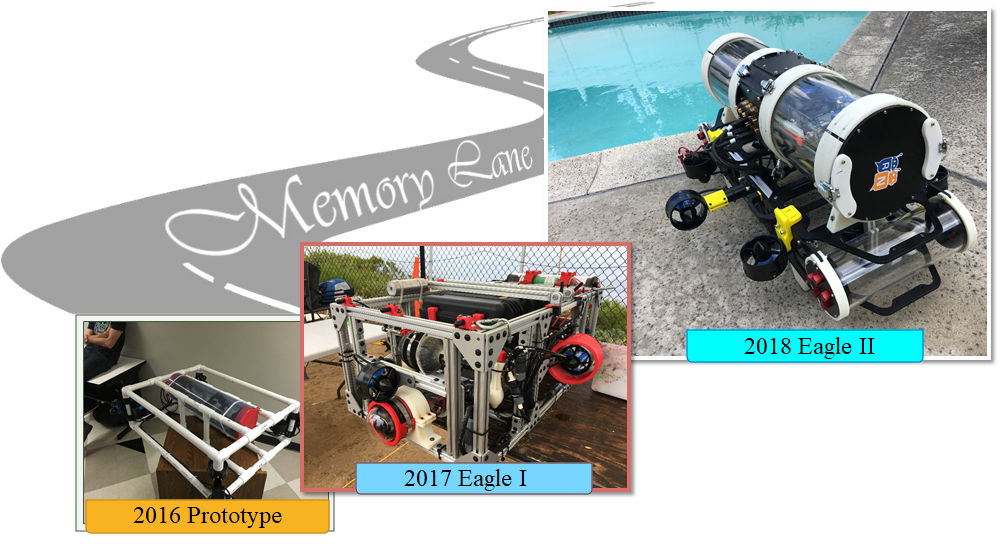


Fig. 2 Evolution of CSULA’s Autonomous Underwater Vehicle

Opportunities to gain hands-on experience are inherent to the project-based Robosub organization. Engineering students must proficiently apply the course material they have learned, as well as their engineering intuition, in order to build a successful and working AUV. Additionally, students have the opportunity to learn how to apply the knowledge gained from their own research into niche subjects. The hands-on experience students gained varied across the three main engineering disciplines (mechanical, electrical, and computer science).

The mechanical engineering (ME) team had the opportunity to fully embellish their engineering creativity through the use of 3D Computer Aided Design (CAD) software during the design phase. While this was partially the use of CAD skills learned through required coursework, the complexity of the AUV design required students to expand their capability beyond what was learned in a semester course. Students had to become familiar with various mechanical design aspects which were not initially considered, such as cost analysis, material selection, design for assembly, fits and tolerances, and design for manufacture. Mechanical students were exposed to manufacturing techniques such as 3D printing, milling, turning, CNC machining, and electroplating. Additionally, the mechanical team was responsible for all mechanical assembly, which exposed students to the extensive use of hand tools such as wrenches, drills, taps, and grinders.

The electrical engineering (EE) team was able to exercise printed circuit board (PCB) design, power systems management, control systems design and implementation through embedded sensors, and wiring schematic design and management. CAD was used to design the circuit boards which would manage critical operating components of the AUV. PCBs were designed and manufactured for thruster control and navigation, battery management, and sensor/actuator communication and control. Moreover, the electrical team was able to integrate multiple electrical engineering sub disciplines into one system in which they had to manage the physical component design, as well as the embedded system software and algorithms. The electrical team was also responsible for all electrical assembly and thus had to learn and exercise competence in hands-on skills such as wire stripping, soldering, splicing, and crimping. In conjunction with custom PCB work, the EE team integrated commercial off the shelf (COTS) components into the overall electrical architecture shown on Figure 6, primarily the CPU’s, motherboard, and Arduinos, components that were used after students made an informed decision that some existing circuit boards would meet all requirements and promote system simplicity and readiness.

The computer science (CS) team were uniquely challenged by the hands-on experience gained through Robosub. CS students, in general, rarely have the opportunity to work on a hands-on project throughout their curriculum. The CS team was responsible for the AUV’s computer vision system and the integration of the EE team’s navigation algorithms into a larger navigation/overall vehicle communication and management system. The CS team worked with large sets of image and video data to refine the AUV’s object recognition through the implementation of machine learning algorithms.

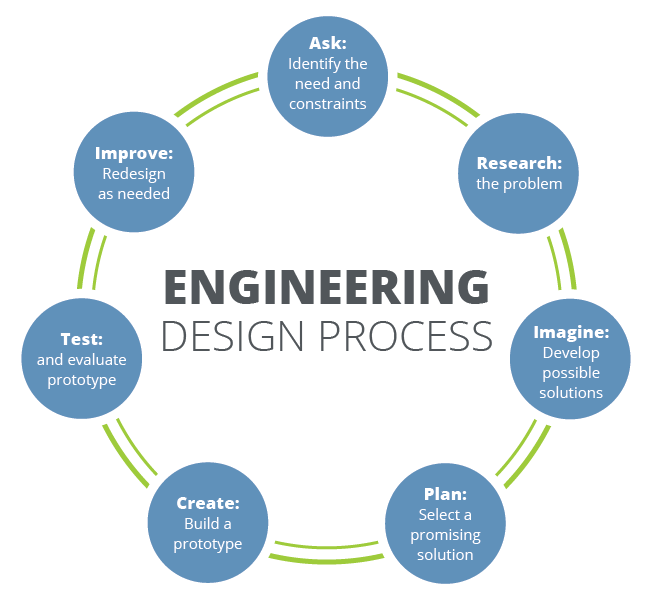
Engineering education, and academia more generally, has experienced a push for hands-on and workplace applicable skills building in addition to traditional lectures. However, a challenging aspect of this type of learning is that it inherently induces failure, and it’s difficult to teach students that failing, and requiring multiple attempts for success, can be seen as a positive and natural part of the learning process [[13]](https://paperpile.com/c/VpiJWA/RvkCU). Engineering designs and projects become increasingly more difficult and complex when implemented into a physical system. It is common for unforeseen consequences of design decisions to become apparent once manufacturing has begun or is complete. Consequently, certain aspects of an engineering design/project can only be properly assessed and revised after manufacturing and testing. The testing process takes place when the first stage of the project - planning and manufacturing - has been completed and algorithms for stabilization and computer vision are tested. Buoyancy is continuously adjusted to account for new weight being added to the sub, and everything is tested repeatedly to ensure maximum optimization of all systems integrated.

The manufacturing phase of the project was crucial to student learning as any error in design would become apparent once parts were actually built and assembled. Some common issues for the mechanical designs were difficulty of installation (improper consideration of assembly clearance), ill-consideration of manufacturing difficulty, and chiefly, the ability to waterproof/seal a component. The electrical team faced challenges with overclocked servos, overheating, and shortages due to improper wire termination. The CS team faced a myriad of issues all the way through to the day of the Robosub competition. The complexity of the tasks, as well as the essentially infinite number of environmental variables to consider with regards to the computer vision and sensor navigation, led to many challenges for the computer science team.

The engineering design process is, as detailed by the Accreditation Board for Engineering and Technology (ABET), “engineering design is the process of devising a system, component, or process to meet desired needs.” The aim is to optimize time and materials while still producing a quality product through “establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation.” Engineers must be aware of the realistic constraints of their project, such as, “economic factors, safety, reliability, aesthetics, ethics and social impact.” A diagram showing the details of the process is shown on Figure 3. Following the engineering design process is crucial to finishing a project successfully.

Schools with ABET accreditation, such as CSULA, include the engineering design process in various courses throughout the curriculum; however, this abstract introduction to a process so crucial for successful engineering leaves many students lacking in their abilities to follow it [[15]](https://paperpile.com/c/VpiJWA/a79Du). Since the engineering design process can only be fully understood through direct implementation, student projects, such as Robosub, have a large impact on participating students’ abilities to produce successful projects post-graduation.

Through the Robosub project at CSULA, students follow the engineering design process very closely. The competition rules provide the constraints for the project. Students then research different ways to create stabilization and computer vision systems that can navigate the obstacles of the competition, seeking out technical reports from past competing teams or research papers to compile a list of possible approaches. Once an approach is decided upon, a reasonable plan is developed to accomplish the goals required for success in the competition. What comprises a reasonable plan is determined by the realistic constraints detailed by the ABET definition; the Robosub team must ensure the safety, reliability, and cost-effectiveness of the robot, and the plan for achievement must reflect these constraints. Then, several months of prototyping, testing, and redesigning occur to produce the best functioning robot possible with the necessary computer vision, weapons, navigation, and stabilization systems. This experience cannot be adequately presented through simply viewing the steps of the engineering design process; diagnosing and finding solutions to issues are not skills that can be taught, but rather come with experience [[15]](https://paperpile.com/c/VpiJWA/a79Du).



*Figure 3: Diagram detailing the steps of the engineering design process* [*[14]*](https://paperpile.com/c/VpiJWA/TIeMQ)

**Career Impact and Soft Skills Developed**

The technical skills, teamwork, leadership, and networking opportunities provided by the Robosub project and the competition prepare students for a successful engineering career post-graduation. RoboNation competition participants are more likely to be considered for internship and entry level job openings than students who have not participated in any extracurricular engineering events [[7]](https://paperpile.com/c/VpiJWA/1IS8u). This is due to the importance of technical skills, concrete understanding & application of course material, and experience with the engineering design process [[16]](https://paperpile.com/c/VpiJWA/WyebR). Additionally, hiring managers look for students who have leadership and teamwork experience to ensure that those hired will be experienced enough to handle the projects [[17]](https://paperpile.com/c/VpiJWA/SbmxI).

Since these skills provide great benefit for students applying to jobs post-graduation, it is important that they obtain these skills. Undergraduate classes provide the knowledge necessary to be an engineer, but the application of this knowledge is what students typically have a difficult time acquiring [[18]](https://paperpile.com/c/VpiJWA/KAvfT). The CSULA Robosub project provides the means necessary for students to gain various technical and soft skills that recruiters look for in candidates.

Across all undergraduate institutions, there is a trend of engineering graduates lacking in technical or soft skills used practically in the workplace environment [[17]](https://paperpile.com/c/VpiJWA/SbmxI). With a lack of attention given to practical skills in classroom environments, it is vital for students to gain these skills elsewhere. A survey of current Robosub members was conducted during Fall Semester 2018. The survey consisted of a set of open ended questions relating to soft and hard skills developed via the Robosub project competition. The survey was administered to 20 students in total, 10 of which were current Robosub members and 10 of which were previous Robosub members. All survey participants were asked to provide various levels of feedback on their experience on the team.

The results show that students reported a significant increase in skills and knowledge both inside and outside the classroom. For instance, some students reported gaining skills such as programming in Arduino and Python, which are not skills included in the engineering curriculum at CSULA, but are used in several industry applications. Another member reported learning how to design an electrical schematic and PCB, which is nearly universally a required skill for electrical design. Nearly all participants expressed satisfaction with their experiences applying their coursework to the part of the project they are working on, and the remaining participants expressed their delight in having an opportunity to learn skills and do work not directly related to their field. In such cases, students rely on their peers to provide assistance and support in learning the concepts. According to a sophomore mechanical engineering student working with Arduino programming for the weapons systems, “We worked well in...a small group so it was nice for everyone to get along, share materials and thoughts. It was also nice to rely on when I had questions I couldn't answer myself”. The CSULA Robosub project helps students apply and solidify the concepts covered in their courses, encourages students to learn and practice interdisciplinary skills, and provides a network of engineering students that can support them in their knowledge and learning endeavors. Regardless of the subject, the 2019 Robosub team has proven to be a successful learning environment for the students involved in the project.

In addition to an increase in technical skills of current members, several students reported, in the same survey, that their soft skills improved through teamwork and presentations. Working in small teams benefitted the students because it gave them a chance to develop their leadership skills and learn how to manage a project while maintaining a functional team dynamic. An electrical engineering student on the current senior design team stated that their communication and organization skills had improved since beginning work on the project, while a computer science student on the senior design team claimed that their most improved skills were leadership and teamwork. A few of the newer Robosub members expressed improvement in other areas, such as public speaking and general communication skills in a team environment.

In a separate survey administered to former members of the CSULA Robosub team, several students from the areas of mechanical engineering, electrical engineering, and computer science shared their insight on how being a member of the Robosub team helped them acquire their jobs and put forth their best work in the workplace. Over half of those surveyed reported having an internship before graduation, and all participants reported being currently employed. Two former computer science students on the team report currently working as Software Engineers at Raytheon, a former electrical engineering student is working as an Engineer at SPAWAR, another former electrical engineering student is working as a Software Engineer at CamZone, and a former mechanical engineering student is working at the California Institute of Technology as a Research Engineer. Two former members are pursuing higher education, one of which is also employed.

There is a wide range of knowledge and skills gained by former members of the Robosub team. Some of these include computer vision knowledge (machine learning, image processing, computer vision libraries such as OpenCV, architecture and design patterns with ROS), knowledge of Arduino microcontrollers, circuit analysis, electronic design, knowledge of materials, fabrication processes, prototyping and 3D printing, and analysis with common engineering softwares such as SolidWorks and MATLAB. For instance, one former team member stated, “I learned how to do material research that best suited our need since we needed corrosion resistant, lightweight, and inexpensive [materials]… I learned how to do preliminary static basic finite element analysis on CAD models to determine the stress concentrations. This was done using the built in SolidWorks simulation. I was able to find stress concentrations on the cross-members that held the hull onto the frame statically. I also improved my understanding of rapid prototyping, in our case, 3D printing which was used to create many fixtures and mounting brackets.” The experience former Robosub members gained not only prepared them for the constraints of real-world engineering projects, but also provided a good learning environment for the technical skills needed to carry out the engineering design process.

The former Robosub members that currently hold industry positions expressed how much their teamwork experience assisted them in developing soft skills. Survey participants gained skills in leadership, teamwork, public speaking, stress management, communication, and organization. One student stated, “I learned how to work with a large scale team [with] different backgrounds that had goals on a large project. Previously during my CSULA career, I would only work with 1-3 other individuals max, and all within the same field as me.” The CSULA Robosub team provides opportunities for students to work with other students from many different disciplines, with the common goal of producing the best possible competition vehicle. This mirrors the engineering projects most students are hired to take part in, which is why interdisciplinary communication and compatibility is essential to a functional engineering team (Insert Reference). Another student shared their insight on the teamwork skills they gained throughout their time on the team: “Not everyone is capable of doing everything due to a major constraint: time. Splitting tasks and trusting teammates to accomplish a task is key… Also, we would ask each other for feedback on a design choice. If we are ahead or behind, we would help each other and finish any action items required.” Being able to trust teammates and work together is an essential component for progress and product delivery. Students on project teams have the benefit of gaining these teamwork skills in an environment where everyone has a common goal and is motivated to achieve it.

Finally, each former member was asked to report on what they personally feel they gained from being on the Robosub team. Many participants discussed what they enjoyed about being on the team, and others talked about how they felt their experience helped them to gain their current position. After being asked how their experience on the CSULA Robosub team helped them obtain their current position, one engineer said, “I believe Robosub was definitely the reason why I was hired. I have been in Robosub since it first started. I learned the way to think at a system level, rather than a component level. This means that any sub system you are designing, it has to be compatible with the main system. It has to do its job, while not affecting anything else. This is a key aspect in any major project, not to be thinking at only a component level, but how that component can affect the entire system.” Another current engineer said, “I was hired for the knowledge I gained from Robosub, such as integration of hardware to computers, and knowledge of computer vision.” The skills each engineer gained on the Robosub team helped them to obtain their current positions, since these are the skills that set them apart from other applicants. Along with these career benefits come the enjoyable experiences from being part of the team, described by one former member as, “The challenge, competition, and creative effort required to solve difficult problems. Additionally, the drive and passion of the team and momentum carried across the various majors/specialties.” Another former student described their most enjoyable experiences as, “Working late night with teammates that eventually became very great friends.” The CSULA Robosub team offers everything that traditional education lacks in facilitating, from technical skills and learning to teamwork and strong leadership to lasting relationships and friendships formed with like-minded individuals.

There are many opportunities for Robosub students to network throughout their time on the team. The competition provides a great opportunity for networking with industry representatives as well as with other teams. Many of the Robosub company sponsors, including SPAWAR and the Office of Naval Research (ONR), MathWorks, and Dassault Systèmes, attend the Robosub competition to advertise new features and products; however, some of them also do recruitment during the competition, making it one of the best opportunities for Robosub students to network and get themselves considered for internship or job opportunities. The disadvantage to this lies in the fact that each participating team and their members have this same opportunity, so it can be quite competitive. This is why, at CSULA, the faculty advisers arrange visits by engineers from SPAWAR and the ONR to give Robosub students a chance to talk to engineers and learn more about their jobs, while possibly getting their resumes looked at and getting contacts from inside the companies. Another great opportunity for gaining inside company contacts comes from faculty advisers that can forward student resumes to hiring managers for consideration. This ensures that the students applying to certain jobs or internships will have their resumes looked at rather than possibly getting filtered out by computer algorithms. Students have many opportunities for networking through Robosub sponsors, whether this is directly through competition attendance or through Robosub faculty advisers at CSULA.

**Challenges and Future Solutions**

CSULA’s Robosub organization has been an overall success for the students involved, the faculty, and the University. Robotics competition projects provide a unique opportunity for the different sister disciplines of CSULA’s engineering department to work closely together. Students also benefit from the multidisciplinary nature of the Robosub organization as it effectively mirrors the challenging and diverse real-world projects they will take on in industry [[19]](https://paperpile.com/c/VpiJWA/MZMrT). However, the diversity of the students and student majors involved in the project proves to be an occasional source of conflict. Students from each discipline struggle to understand the nature and complexity of each other’s work, which is disruptive to the operation of a cohesive multidisciplinary engineering team. Specifically, CSULA’s Robosub team faced interpersonal conflicts in the live-testing phase of the project. During this time, the ME and EE team had completed nearly all of their active portion of the project and the vehicle had taken its essentially final iteration. The AUV was built and running well from an electro-mechanical standpoint, but the computer vision and navigation proved to be a consistent problem for the CS team. The AUV struggled to detect objects underwater due to ill-lit areas of the testing pool and water-distorted light. Additionally, tiles along the pool floors and wall were causing the AUV to have false-positive object detection. CSULA’s Robosub team realized that the CS team had a unique challenge with respect to the overall autonomous intelligence of the AUV that the ME and EE team simply did not have to worry about, and yet conflicts still arose. The CS team was frustrated to not be in the same tier of success or completion as the other sub-teams, and the pressure mounted from all parties involved to develop an intelligent autonomous system. A future solution that CSULA’s Robosub team will implement to resolve this issue is to have constant testing of the vehicles autonomous systems throughout the year. The final months before the competition are simply not enough time to assess the viability of the vehicle’s code, nor is it enough to gather the significant amount of images and video data required to create a robust database for the computer vision machine learning algorithms. This revelation in strategy will be implemented for the 2019 competition.

An additional challenge faced was the retention of new members and general club participants. New members tend to exhibit an initial excitement to develop an AUV, but club involvement numbers tend to drop off as the school year progresses. The open-ended nature of the project, whereby there are multiple suboptimal solutions to problems, and the correct approach is not always clear, tends to drive students away. To combat this, moving forward the Robosub team has reformatted its weekly general meetings to include presentations conducted by each of the sub-teams. This approach has a twofold positive benefit to the organization in that it provides:

1. A forum for new members and leadership to understand the status of each sub-team.
2. A deadline and development log to ensure weekly progress.

With this general meeting format, new members have a better understanding of the project and are able to make informed decisions about which part of the project they would like to work on. Additionally, the weekly status update fosters improved presentation skills among students and forces a measure of immediacy to their work on the project, which has led to a significant improvement in continual progression for the team. Implementing continuous improvement measures is crucial to ensuring the sustained benefit of the robotics competition to CSULA students.

**Conclusion**

Robotics competitions have proven to be an excellent platform for multidisciplinary projects and the AUV (Robosub competition team) organization has resulted in an enhancement of the CSULA engineering program for both the students and faculty involved. Students have reaped rewards in the form of technical and soft skill development, and they have had opportunities to exercise their leadership, communication, and cooperation skills. Many students reported an increase in their technical and soft skills throughout the course of the project through working with teammates and participating on different parts of the project.Moreover, students have been exposed to unique industry relations and future employment opportunities, illustrating benefits to the student which extends beyond their degree program. The development of an autonomous underwater vehicle has exposed CSULA students to the modern and agile field of robotics. While integration into the curriculum and management of the organization has proven to be accompanied with a set of challenges, faculty advisors have had an unparalleled opportunity to work closely with students to foster their academic and professional development through the Robosub competition team. Every year, the faculty advisors and organization members learn additional ways in which they can improve the program. CSULA will continue to use the integration of the Robosub competition into its engineering curriculum to increase the strength, value, and positive student outcome of its engineering programs.

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**References**

[1] [R. D. Beer, H. J. Chiel, and R. F. Drushel, “Using autonomous robotics to teach science and engineering,” *Commun. ACM*, vol. 42, no. 6, pp. 85–92, 1999.](http://paperpile.com/b/VpiJWA/H4na)

[2] [J. B. Weinberg *et al.*, “A multidisciplinary model for using robotics in engineering education,” in *Proceedings of the 2001 ASEE annual conference and exposition*, 2001.](http://paperpile.com/b/VpiJWA/aAg3)

[3] [J. Drew, M. Esposito, and C. Perakslis, “Utilization of Robotics in Higher Education,” 2006.](http://paperpile.com/b/VpiJWA/lD1ly)

[4] [J. Yao *et al.*, “‘Who Is The Biggest Pirate?’ Design, Implementation, And Result Of A Robotics Competition For General Engineering Freshmen,” in *2006 ASEE Annual Exposition and Conference*.](http://paperpile.com/b/VpiJWA/Wkyl2)

[5] [R. Beach *et al.*, “Robotics Innovations Competition and Conference(RICC): Building Community between Academia and Industry through a University-Level Student Competition,” in *American Society for Engineering Education*, 2010.](http://paperpile.com/b/VpiJWA/2CYZE)

[6] [C. J. ChanJin Chung, C. Cartwright, and M. Cole, “Assessing the Impact of an Autonomous Robotics Competition for STEM Education,” *Journal of STEM Education: Innovations & Research*, vol. 15, no. 2, pp. 24–34, 2014/07//Jul-Sep2014.](http://paperpile.com/b/VpiJWA/EhU95)

[7] [A. Melchior, F. Cohen, T. Cutter, T. Leavitt, and N. H. Manchester, “More than robots: An evaluation of the first robotics competition participant and institutional impacts,” *Heller School for Social Policy and Management, Brandeis University*, 2005.](http://paperpile.com/b/VpiJWA/1IS8u)

[8] [D. Bazylev, A. Margun, K. Zimenko, A. Kremlev, and E. Rukujzha, “Participation in Robotics Competition as Motivation for Learning,” *Procedia - Social and Behavioral Sciences*, vol. 152, pp. 835–840, Oct. 2014.](http://paperpile.com/b/VpiJWA/uP3Um)

[9] [T. Kaiser, “Robosub: A Contest-based Multidisciplinary Senior Design Capstone Project,” in *2016 ASEE Annual Conference & Exposition Proceedings*.](http://paperpile.com/b/VpiJWA/F7mSr)

[10] [J. W. Bales and D. Novick, “Designing an AUV Competition to Draw Engineering Students Towards Ocean Engineering,” in *American Society for Engineering Education*, 2011.](http://paperpile.com/b/VpiJWA/vgPfc)

[11] [A. de-Juan, A. F. del Rincon, M. Iglesias, P. Garcia, A. Diez-Ibarbia, and F. Viadero, “Enhancement of Mechanical Engineering Degree through student design competition as added value. Considerations and viability,” *J. Eng. Des.*, vol. 27, no. 8, pp. 568–589, 2016.](http://paperpile.com/b/VpiJWA/iNcLF)

[12] [C. W. S. Scott F. Kiefer, “Benefits of Mentoring Students in Design Competitions,” in *2011 ASEE Annual Conference & Exposition*, 2011, pp. 22.278.1–22.278.9.](http://paperpile.com/b/VpiJWA/dVbXo)

[13] [D. R. P. E, J. Blacklock, and J. M. Bach, “Letting Students Learn Through Making Mistakes: Teaching Hardware and Software Early in an Academic Career,” in *2015 ASEE Annual Conference & Exposition*, 2015, pp. 26.1089.1–26.1089.8.](http://paperpile.com/b/VpiJWA/RvkCU)

[14] [University of Colorado, Boulder, “Engineering Design Process,” *Teach Engineering*. [Online]. Available:](http://paperpile.com/b/VpiJWA/TIeMQ) <https://www.teachengineering.org/k12engineering/designprocess>[. [Accessed: 27-Jan-2019].](http://paperpile.com/b/VpiJWA/TIeMQ)

[15] [Y. Haik, T. M. Shahin, and S. Sivaloganathan, *Engineering Design Process*. Cengage Learning, 2010.](http://paperpile.com/b/VpiJWA/a79Du)

[16] [A. Elgafy, “Education: Multidisciplinary Undergraduate Engineering Program,” in *Encyclopedia of Energy Engineering and Technology, Second Edition*, S. Anwar, Ed. CRC Press, 2014, pp. 428–432.](http://paperpile.com/b/VpiJWA/WyebR)

[17] [B. Sripala and G. V. Praveen, “Soft Skills in Engineering Education: Industry Perspective,” *Language in India*, vol. 11, no. 10, pp. 277–283, Oct. 2011.](http://paperpile.com/b/VpiJWA/SbmxI)

[18] [D. W. Knight, L. E. Carlson, and J. F. Sullivan, “Improving engineering student retention through hands-on, team based, first-year design projects,” in *Proceedings of the International Conference on Research in Engineering Education*, 2007.](http://paperpile.com/b/VpiJWA/KAvfT)

[19] [M. P. Frank, K. E. Amin, O. I. Okoli, S. Jung, R. A. Van Engelen, and C. Shih, “Expanding and Improving the Integration of Multidisciplinary Projects in a Capstone Senior Design Course: Experience Gained and Future Plans,” in *2014 ASEE Annual Conference & Exposition*, 2014, pp. 24.566.1–24.566.21.](http://paperpile.com/b/VpiJWA/MZMrT)