Integrating Service Learning with Undergraduate Robotics Research

R.S. Renner and B.A. Juliano
Institute for Research on Intelligent Systems
California State University, Chico
400 W. First Street
Chico, CA 95929-0410

Abstract

Through a National Science Foundation (NSF) grant, the authors have forged an interdisciplinary effort to integrate graduate and undergraduate research, curriculum, and outreach projects that promote service learning in robotics and intelligent systems. The authors have founded the Institute for Research in Intelligent Systems (IRIS) and the Intelligent Systems Lab (ISL) as advisory and resource centers, respectively, to support these endeavors.

The ISL typically invites four to six students per semester to join the ISL Research Team. As ISL Research Team members, these students are expected to participate in all three focal areas of the IRIS mission. They participate in individual and team research projects, assist in the development and implementation of course workshops, and contribute to multiple outreach activities throughout the year. Hence, the ISL provides its team members with the opportunity to take on many roles, from researcher to educator. It is their role as educators that is the focus of this paper.

Introduction

California State University, Chico (Chico State) is primarily an undergraduate teaching institution. However, we are fortunate to have strong academic programs in undergraduate and graduate Computer Science, and a Mechatronics program, within the College of Engineering, Computer Science, and Construction Management (ECC). Furthermore, the college is very supportive of student research and student participation in competitions and outreach activities. Most disciplines within the college are accredited by the Accreditation Board for Engineering and Technology (ABET 1999; 2005).

Over the past few years, ABET and other organizations nationwide have begun to acknowledge the changing societal demands facing computer scientists and engineers. They anticipate a need for greater interpersonal skills, communication skills, interdisciplinary teamwork, social and ethical responsibility, lifelong learning, and educational experiences that can help them develop such skills (Coyle *et al*. 2003; ABET 1999, 2005; ASEE 1994; Dahir 1993; Nagchaudhuri 2000; Tsang 2000). In recent years, engineering education has seen a significant increase in emphasis on experiential education and on the "soft skills" that engineering students will need when they enter the workplace (ASEE 1994; Dahir 1993). Many of these skills are exemplified by the changes in program outcomes, mandated for engineers by ABET in their *Engineering Criteria 2000* (EC 2000) accreditation guidelines (ABET 1999), and again reinforced when proposed for Computer Science for the 2006-07 accreditation year (ABET 2005). In consensus with EC2000, the 2006-07 proposed changes to the ABET criteria for Computing disciplines includes outcomes associated with 1) teamwork and communication, 2) an understanding of professional, ethical, and social responsibilities, and 3) ability to analyze the impact of computing on individuals, organizations, and society.

As a result, many engineering programs have introduced service learning components into their curriculum (Coyle 2003). Given that programs in the sciences and engineering are already typically high unit majors, it is often difficult to package all the core concepts and essential educational experiences into a traditional curriculum. Often, experiential learning is accomplished through a capstone course or senior project. The paradigm presented in this paper suggests an alternative venue for providing experiential learning through service learning, outside of the classroom. What is presented here is the integration of service learning with undergraduate robotics research. There are numerous community outreach activities in education that can benefit from such a fusion.

Service Learning

As a teaching methodology, service learning provides experiential education through performance of meaningful community service. It assumes integration of service activities with classroom instruction and reflection. It is hypothesized that meaningful community service, combined with classroom instruction and reflection, can enrich the learning experience, promote civic responsibility, and strengthen one's community. The Corporation for National and Community Service has the following to say about service learning (NSLC 2006):

- Promotes learning through active participation in service experiences

- Provides structured time for students to reflect by thinking, discussing and/or writing about their service experience
- Provides an opportunity for students to use skills and knowledge in real-life situations
- Extends learning beyond the classroom and into the community
- Fosters a sense of caring for others

The coordinator of Service Learning at Chico State claims that "in order for students to become competent thinkers and problem solvers, they must be active partners in the learning process." She goes on to promote practices that engage students in the "exploration of worthwhile issues" and "involvement with the community" and "hands on experiences ... to facilitate mastery of the subject matter and a sense of civic responsibility" (Davis 2006). The president of Chico State cites service learning as an integral part of the university mission. This commitment is reflected by the university membership in Campus Compact, and the university strategic plan (Zingg 2005). In fact, according to Campus Compact (CC 2006), 91 percent of college campuses have included civic engagement and community service in their mission statements.

As noted by Ehrlich, service learning has become a major national movement, especially in undergraduate education. (Ehrlich 2005). Indeed this is true, with Campus Compact and EPICS leading the way at a national level (CC 2006; EPICS 2006). Ehrlich goes on to recognize that the California State University system presents a good example, with a "system-wide office of community service-learning and centers on its many campuses that work together and learn from each other" (Ehrlich 2005).

According to a study by Coyle, Jamieson, and Oakes, integration of service learning experiences into an engineering curriculum has a demonstrated positive effect for both student and community (Coyle *et al*. 2003). They go on to cite numerous examples of service learning integration into freshman-level introductory courses, capstone senior design courses,, student organization co-curricular activities, and long-term design projects (EPICS 2006). They also cite evidence to suggest that EPICS programs and service learning have a positive impact on gender and minority diversity.

While it is clear that institutions value the educational experiences of service learning, and communities can benefit from voluntary educational efforts from academe, it is not clear how such programs are to be funded or implemented. Given that science and engineering disciplines are already curriculum intense, and faculty have to be creative with curriculum development in order to avoid time-to-graduation delays, adding requirements to already over-taxed programs is a daunting task in creativity, if not pure magic. Yet, if there ever were a cohort of disciplines admittedly in need of interpersonal skills and societal accountability, surely computer science and engineering would volley for top bidding. It is essential that these disciplines follow suit with the rest of academe, and forge new paradigms for acquiring much needed experiential opportunities afforded by service learning activities in the community.

IRIS

The Institute for Research in Intelligent Systems is a formal institute within the College of ECC at Chico State. The institute received university recognition as an approved center in January 2006. The institute was founded as a joint effort between interdisciplinary faculty within the college, and funding support from the National Science Foundation (NSF)[1]. The mission of the institute focuses on the discovery, development, analysis, and integration of accessible intelligent systems research and technologies (e.g. autonomous robotics applications) for use in community and industry. Primary goals of the institute include (IRIS 2006):

- foster collaborative research within the College of ECC and across campus, in robotics and intelligent systems
- outreach to the community and recruitment of students
- oversight of camps, seminars, workshops, and curriculum decisions related to the ISL and its mission
- Set and enforce policies and management issues pertaining to the ISL and all equipment under the jurisdiction of ISL
- seek sources for continued funding of the lab and related activities

As the governing body of the lab, IRIS relies on a six-member Board, comprised of a director, two additional permanent faculty members, two interdisciplinary guest faculty, and an invited student member, to be invited from the ISL Team Member constituency.

ISL

The Chico State Intelligent Systems Lab (ISL) is a subsidiary of IRIS. The ISL provides student, faculty, and equipment resources for research, outreach, and curricular enhancement, within the confines of robotics and intelligent systems. The ISL aspires to facilitate the development of cross-disciplinary courses and exciting collaborative research projects. It enables students and faculty to investigate, design, and implement control algorithms using non-traditional techniques (ISL 2006). In the traditional

[1]National Science Foundation (NSF) Major Research Instrumentation (MRI) / Research in Undergraduate Institutions (RUI) grant EIA-0321385

classroom, students may not otherwise be exposed to technologies derived from various sub-disciplines of Artificial Intelligence, such as fuzzy logic, neural networks, genetic algorithms, hybrid approaches. Likewise, they might otherwise not be availed to methodologies designed for multi-agent systems, agent communication, vision, and localization. Following the IRIS charter, the ISL provides opportunities for interdisciplinary teams to collaborate on joint projects. Through collaboration, teams exhibit a diverse skill set and are rich in combined intellectual resources. Teamwork and collaboration provide experiences that will enhance their long term potential for success in their chosen profession.

Through NSF funding, the ISL has been able to support four to six students per semester, over the past three years. ISL is in its fourth year of funding and continuation funds are being sought. As funded team members, ISL Research Assistants are able to pursue approved collective and individual research projects; contribute to curriculum development, enhancement, and deployment for robotics related curriculum needs; and, participate in campus and community outreach activities. By tying outreach activities to lab assistant responsibilities, the authors have been able to provide significant service learning experiences for ISL Team members.

Research Projects

ISL Team members are provided opportunities to do independent research and team projects, in robotics and machine intelligence. The lab houses a vast array of robotics projects and platforms, at various stages of development. Projects can be viewed from the labs web page at *gotbots.org*. Currently, the team is divided into two subteams: one with a focus on robo-soccer, and the other on autonomous vehicles. Both teams are comprised of two undergraduates and one graduate, with the first author as faculty advisor for the soccer team and the second author as faculty advisor for the vehicle team. Unfortunately, the PIs currently receive no release time for their contributions to this work, so the student teams must be self-directed, reliable, and have strong team leadership by their graduate member. There are several other ongoing projects in the ISL that focus on such behaviors as swarm intelligence, multi-agent communication, localization, and vision.

As part of their research experience, the research assistants not only receive funding, but additionally may earn course credits for their senior project, master's project, or special projects class. Each semester the ISL received modest support from the department in conjunction with the college, to sponsor a visit to a robotics facility or expo. In the past, the ISL members have been fortunate to visit Lawrence Livermore National Lab, RoboNexus, Parallax, Inc., and the 2006 Robocup US Open in Atlanta. To enrich their research experience, the ISL also participates in international student exchange program with the Ecole Polytechnique Universitaire de Marseille (EPUM), and is in the process of fostering a relationship with students from the Universität Hamburg. Students from both universities have visited the lab over the past three years.

Curriculum

With the advent of the IRIS/ISL grant, the Department of Computer Science has been able to offer a new course in Robotics and Machine Learning, as well as provide resources for enhancement of existing Artificial Intelligence courses, general education courses, and honors courses. The ISL team members have been instrumental in assisting with the planning and deployment of curricular enhancements to these courses. Specifically, they have developed and instructed sensor workshops for the robotics class, configured and tested new platforms for introducing robots into the AI courses, built test platforms for classroom use, and been available to assist as TA for the robotics course when called upon. The students have also been invaluable in maintaining an organized lab space and materials inventory. They are currently assisting in design of a robotics project for the undergraduate software engineering course, and formalization of requirements for an inventory database started by an undergraduate database class last spring, with plans for redesign and completion by the software engineering class this fall.

Outreach

One of the three focuses of IRIS is outreach, this includes outreach to the community and outreach to the campus (or "inreach"). Interestingly enough, outreach and inreach activities have turned out to be a favorite activity of the ISL research team. From the earliest days of inception of the lab, to present, the students have eagerly participated in the many aspects of outreach, and eagerly proposed and organized several of the activities themselves. Outreach activities have included workshops ranging from 45 minutes to half-day, information booths, exhibitions, demonstrations, and a summer robotics camp (see Table 1). The number of students participating in each event is indicated by column #P, while the number of ISL team members or volunteers staffing the event is indicated by #S. The larger the staff numbers, the greater the requirement for detailed planning and organization, application processing, and team oversight: all tasks handled by the lab directors. The ratio of participants to staff is dependent upon the needs of the event and the availability of ISL members. With hands-on workshops and camp, having a ratio of one coach for every four participants is quite effective. Of course, this is a luxury afforded by the availability of the ISL and student vol-

unteers. Chico State students are notoriously generous with their time and involvement in community outreach. As pointed out previously, these events provide student coaches with excellent service learning experiences in educational planning and instruction.

Table 1 ISL Outreach/Inreach Activities

Event	*Activities*	*Grade*	*#P*	*#S*
1. Richvale Gate '04	2hr workshop - Mindstorms	6th-8th	30	8
2. Quincy Jr. High Gate '05	3hr workshop - Mindstorms	8th	9	6
3. Girl Scouts '05	45min workshop - Mindstorms	4th-6th	20	6
4. Wheel Encoders Workshop	building wheel encoders for class	UG	20	4
5. Color Sensor Workshop	building color sensors for class	UG	19	3
6. Country Day School	site visit w/demos - '05	K-1st	17	3
7. Career Workshop	site visit w/45min. present. & demo	HS	40	1
8. Minds in Motion '04, '05	info table, demos, hands-on	K-12	2000	6
9. Mesa Presentation	presentation & demos	HS	~30	3
10. Getting Connected '05	Chico State SoccerBots	Fresh.	4000	8
11. Fall Preview Day '04	info booth & demo	transfers	N/A	4
12. Math Club Seminar	1hr presentation & demos	UG	30	8
13. Summer Camp '04,'05,'06	week long – Mindstorms	6th-8th	12-22	10-15

The primary platform for workshops and summer camp has been the LEGO® Mindstorms®.[2] Exhibitions and demonstrations typically highlight the ISL research projects (see Figure 1). This is where the students get a chance to showcase their work and practice communicating about it at a novice level. It is interesting to observe how much a confidence builder this can be for the research team. All members participate in multiple events per semester. Although this is an expected part of their appointment to the ISL, students never have to be coerced or reminded, and are always eager to participate in outreach events.

[2]LEGO, Mindstorms, and Robotic Invention System are registered trademarks of the Lego Group.

Workshops

To date, the ISL has held five workshops (see Table 1.1-1.5). Two of these were requested by junior high Gifted and Talented Education programs (GATE). A third workshop was requested by the local chapter of Society of Women Engineers (SWE) for participation in Girl Scout Day, and the remaining two were sensor workshops associated with the college Robotics and Machine Learning class. In all cases, the research team was entrusted with designing and testing an appropriate curriculum/project for the short 45 minute to 3 hour workshop. With minimal advising, they investigated sample projects, brainstormed on ideas resulting from their own research and experiences, designed, tested, and settled on an appropriate lesson for each workshop. Typically, the lesson for each workshop incorporated some short presentation and discussion about robotics, intelligence in machines, and sensors. In each case there is always a hands-on component, where the participants build a simple robot. Finally, participants are introduced to the Robotics Invention System®, given a template program, and furnished instructions for developing their own solution. In all outreach workshop cases, the lesson plan was well prepared and executed, and the participants and their advisers were well pleased. We have had many requests for more workshops and have had to turn them away, due to time constraints. In the case of the two inreach workshops, the workshop itself went well, but the sensors being developed were not rigorously tested to ensure their future benefits for classroom projects. The experience of building and soldering was still considered by their peers to be a beneficial learning experience, but the end product was not as useful as had been anticipated. With more time and testing the authors hope that future workshops of this nature can be offered and provide greater benefits for the peer participants. Nonetheless, the research team has indicated on multiple occasions their eagerness to continue with such workshops.

Demonstrations / Exhibitions

A common request from the department, college, and campus organizations is for an ISL information booth and/or exhibition or demonstration. The ability to captivate an audience with new research and technologies is one aspect of robotics and intelligent systems that makes it so exciting to share. Unlike other areas of Computer Science, intelligent systems via autonomous robots represents a tangible artifact. Demonstrations by the lab typically include whatever projects the research assistants are currently engaged

Figure 1 Chico State SoccerBots!

in. Favorite demonstrations of the past have included the "Hallway Hummer" (see Figure 2), the "MechMoth", the "AntBots", and the AIBO™[3]. Prior to demonstration day the research team coordinates their presentations, determines who and what is being demoed and manage whatever preparations need to be done for the event. During the event, ISL team members take turns managing the ISL table, coordinating and running demos, and answering questions. The ISL has participated in seven demonstration days (see Table 1.6-1.12), some of which have been repeated over the three year period. Two of these events have been site visits, the remainder have been held on Chico State's campus. The Math Seminar event (Table 1.12) was directed toward a technical undergraduate audience, and focused on ISL research projects, and applications of mathematics to robotics research. The Getting Connected event (see Figure 1 and Table 1.10) was by far the largest event, with an exhibition of the Chico SoccerBots entertaining approximately 4,000 freshmen in the university gymnasium. The event was one of several meant to highlight various programs at the university.

Summer Camp

Perhaps the highlight of the ISL outreach program is the Summer Robotics Camp. This camp has been hosted by the ISL for three years, and is run entirely by the ISL, with funding support from NSF, the College of ECC, the Department of Computer Science, and a few local companies. The camp is restricted to young women at the junior high level. The goal of this camp is in keeping with NSF's commitment to bringing more women into the fields of science and engineering. The camp is designed to introduce young women to the fields of Computer Science and Mechatronic engineering by providing them with a unique opportunity to participate in a FREE week long day camp, filled with fun, interesting, and educational activities. It is very much a hands-on camp, with plenty of opportunity for social activities, athletics, challenging mind exercises, teamwork, building of structures (see Figure 3), problem solving and coding, showcasing solutions, prizes for all, college experience, and pizza!

Figure 2 Minds in Motion

The ISL team members are aware of the disparaging number of women in science and engineering disciplines, and are seemingly eager to do their part to encourage young women into these disciplines. Each year of the camp all the ISL team members contribute to the planning and running of the camp, with the addition of three to four student volunteers. The camp director is one of the authors and lab PIs, but the Head Coach for the camp each summer is selected by the PIs from the pool of ISL research assistant candidates. Two of the three years of the camp the Head Coach has been a female, and one of those females was an undergraduate.

The summer camp has brought some challenges for the team. One such challenge came about this year with the team's desire to change the curriculum, having not fully tested it. The result was the building of a gear box that was too complex and served only to frustrate the campers. The coaches helped them through it, came back the next day with a simpler design, and all was well. The lesson learned for the team was the importance of testing prior to deployment. Another challenge that came about this year was a lack of regard by at least one coach, for some of the camp policies laid out by the advisers and Camp Director. When one coach wanted to challenge the necessity for policy, the director had to step in and insist on following protocol. The team learned in the end the importance of policy, and a lesson in protocol and trust for authority in matters of experience.

The coaches of the summer camp must be applauded for their commitment to service. They begin preparing for the camp weeks in advance, spend countless hours building new environments for the final competition, drawing up diagrams and instructions for the curriculum, testing designs, and finalizing presentations. During camp, they show-up every morning by 8:00am, spend an entire day with 15-22 junior high girls (see Figure 4), send them off by 3pm, and

[3]AIBO is a trademark of the Sony corporation.

Figure 3 Building an Egg Tower

then sit around with the team for another hour to reflect on the day's events. Oftentimes, the team continues on into the night if there remains building to be done for the final day's event. The final day of camp is a whirlwind of assisting campers with finalizing their solutions, testing in the exhibition arena, final competition, parents, media, awards, and everybody saying their final goodbyes to newfound friends and favorite coaches. The coaches are amazingly still smiling at the end of the day.

Assessment

Participant satisfaction with the summer camp is formally assessed with the completion of anonymous camp surveys, as are the 2-3hr workshops. Positive feedback for the summer camp and other outreach activities also comes back in the form of informal letters and thank-yous from participants, parents, teachers, and faculty. All such indicators have been positive.

The mechanisms for assessing ISL Team member experience have been through weekly meetings and progress logs. These meetings served as a valuable format for reflecting on past events, preparing for future events, providing progress status, and sharing ideas.

ISL has received only positive feedback from all recipients of outreach and inreach events. Unfortunately, the lab cannot accommodate all requests to host an event, as the lab is also committed to curriculum and research. The goal of the lab is to provide one to two outreach events per semester. The remaining effort should be directed toward research activities.

Summary, Conclusions, Recommendations

Through their involvement with community outreach and campus inreach, the ISL graduate and undergraduate research assistants gain valuable service learning experience. These experiences in lesson planning, preparation, presentation and demonstration afford them opportunities to develop their technical skills, as well as public speaking and interpersonal skills. They serve to refine communication and team building skills, foster patience, tolerance, and leadership, while learning social responsibility and contributing something of value to the community. Through their involvement with the ISL, team members and volunteers receive small tokens of appreciation provided by our corporate sponsors and patrons, including hats, T-shirts, and positive recommendations from faculty advisers.

Figure 4 Summer Camp 2005

The ISL currently has no formal mechanisms in place for gathering member perceptions from service learning experiences, outside of team meetings. The authors would like to incorporate some type of self-reflection and program evaluation survey for assessment and analysis. Presumably this should be anonymous to encourage honest reflection. However, administering and collecting anonymous surveys upon student separation from the lab may prove difficult. It has also become apparent through this study, that documentation of the ISL team experience during many of these events is lacking, as the focus is typically on the participants. The authors will work to rectify this deficiency in future semesters.

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