2-2020

Experiential Learning Framework for Smaller Computer Science Programs

Zachary A. Kissel
Merrimack College, kisselz@merrimack.edu

Christopher S. Stuetzle
Merrimack College, stuetzlec@merrimack.edu

Experiential Learning Framework for Smaller Computer Science Programs

2 authors:

Zachary A. Kissel
Merrimack College

Christopher Stuetzle
Merrimack College

Experiential Learning Framework for Smaller Computer Science Programs*

Zachary Kissel[1], Christopher Stuetzle[1]
[1]Department of Computer Science
Merrimack College
North Andover, MA 01845
{kisselz, stuetzlec}@merrimack.edu

Abstract

Experiential learning (EL) permeates the Computer Science discipline. This work seeks to codify EL practices for computer science pedagogy into five key pillars. These pillars have been successfully applied at a small to mid-sized college within the heavily competitive Boston area. This paper further describes how a computer science department may effectively implement the pillars in their own curriculum.

1 Experiential Learning in Traditional Pedagogy

The benefits of EL practices in higher education are well established [4, 9, 10]. Research has shown that students learn most when they are more engaged in the experience rather than as passive participants [14]. The Association for Experiential Education (AEE), founded in 1977, regards experiential education as "a philosophy that informs many methodologies in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities." [1] Traditionally, this has manifested in student internships and the use of case studies. While computer science students have traditionally been encouraged to seek internships and co-ops, and have been overall successful in attaining them, there are skill competencies that these experiences are not guaranteed to provide, such as communication, team/self management, or service learning.

Computer science, by its nature, is rife with experiential opportunities inside the classroom. First and foremost, the hands-on aspects of courses in the discipline (project-based learning, in-course labs, internships-for-credit, and practical quizzes and tests) are common in university curricula and important for the overall growth of the students. These have also been universally-adopted by the community as a whole. We take these EL components as given for a computer science curriculum. However, from years of discussing program requirements with CIOs and hiring managers from several industries seeking recent graduates in computer science, as well as environmental scans of the local industry, this is no longer seen as sufficient by employers and graduate schools. Students need more well rounded experiential opportunities during their time as undergraduates.

This has been supported by the literature. Previous work has argued the importance of developing soft skills in computer science, through the use of service learning [16], modification of students' theories on self [2], and a form of gamification [17]. Previous work, except [2], placed soft skill development late in the curriculum, normally in a capstone experience. We assert this delay in soft skill development reduces the potential impact on student development.

There are several ways that schools introduce additional EL opportunities into their curricula. A near ubiquitous EL technique is the use of "hackathons," which have been adopted into formal instructional processes by authors such as Gama et al. [5]. Hackathons can increase student engagement and enhance team based learning outcomes. Hackathons are sometimes incorporated into curricula as either a prep course, or as part of a larger programming course. Along similar extracurricular lines are external experiences such as the NASA Robotic Mining Competition [7]. The authors of this work believe this is not sufficient for well-rounded graduates of computer science undergraduate programs.

1.1 Background of Institution and Department

Our institution is a Catholic college, in the Augustinian tradition, located outside of Boston, Massachusetts; an area of heavy competition in higher education. It currently enrolls 3500 undergraduate students and 700 graduate students. The computer science department graduates between 15 and 20 majors each year, and has roughly doubled in size since 2012.

Prior to 2012 the computer science department's use of EL was drastically different. While there was a capstone experience and some project oriented courses, there was a dearth of independent studies, public and in-class presentations, or formalized soft-skill development. Moreover, the curriculum lacked cohesion around the use of EL practices. Starting in 2012, the faculty initiated an organized effort to introduce consistent use of EL throughout the curriculum. The resulting curricular decisions are captured as a five-pillar framework.

1.2 Contribution

EL curricular frameworks have been presented in several disciplines, such as Marketing [13], Management [11], Medicine [12], and Foreign Language [8], for example. Additionally, authors have provided frameworks for particular aspects of EL curricula, such as scaffolded reflections [3] or working in teams [6]. To the best of this work's authors' knowledge, no framework for experiential learning curricular guidelines for small- and mid-sized computer science undergraduate programs has been explored in the literature.

This paper presents a formalized framework for EL in small- to mid-sized undergraduate computer science curricula that has been effectively deployed in the authors' computer science department. The framework is broken into five pillars which are emphasized throughout the curriculum. Although we recognize the fact that many of these curricular aspects are present and even ubiquitous throughout many institutions' undergraduate computer science curricula (specifically an emphasis on internship opportunities and a project-based curriculum), our work attempts to codify these notions into a sustainable framework that can be applied to institutions similar in size to our own.

2 Experiential Learning Framework

The following five pillars of our framework describe a formalized pedagogical approach to incorporating EL into undergraduate students' curricular and co-curricular experiences. In the following paragraphs, the incorporation and focus of each of these pillars will be discussed. Each discussion is followed by a description of how the pillar is implemented at our institution, though these are not the only ways in which they can be incorporated into the curriculum or department student outcomes. It's important to note that, while each pillar can be discussed separately, they all inform each other and as such create a web of EL opportunities.

- **Soft Skills -** Focus on soft skills through reinforcement and repetition
- **Real-World Focus -** Consistent and constant real-world curricular tie-ins

- **Group Work -** Group work with an emphasis on tools such as source control, test-driven development, and real-time collaborative development
- **Student Empowerment -** Student empowerment through choice and ownership of learning
- **Dissemination of Individual Work -** All novel or substantial work is disseminated to the broader community

2.1 Soft Skills Pillar

To incorporate soft skills into the curriculum our experiences have demonstrated that emphasis, at all levels, should be placed on both written and oral communication and self promotion. In both forms of communication, strong technical and non-technical communication should be fostered; paying special attention to communicating with audiences of various technical backgrounds. Oral communication should be honed through frequent projects incorporating presentations whose length is proportional to the scope of project. For theoretical courses and capstone experiences written skills should be fostered, in addition to oral skills. The key factor for building good communication skills is repetition. For this reason it is recommended that a concerted effort be made to include communications skills in a majority of the curriculum. Self promotion is most amenable to co-curricular activities, generally through the form of interview and internship preparation. We also recommend involving any career center on campus to participate in a portion of these co-curricular activities.

At our institution soft skills are present in almost every class and co-curricular opportunity. In our curriculum oral communication skills are practiced through course final projects in which presentations are required. Without exception, students are provided with a rubric to help focus the presentation and determine the instructors' weight on certain components (generally including clarity and professionalism). In independent studies and the capstone experience, communicating with varying audiences has been practiced through college wide poster sessions. The capstone experience additionally provides a communication opportunity that simulates direct interaction with a client, as well as a heavy seminar and discussion component where students can engage with each other and their faculty in debating current important topics, such as net neutrality or algorithmic transparency. Soft skills are incorporated into other coursework as well, such as public debates, the value of which has been previously demonstrated [15].

To ingrain in students the idea of self promotion the department runs seminars, in cooperation with the career center, in the last course of the introductory sequence. These seminars include writing a good resume, discussions of elevator pitches, and how to perform well in a code interview. These are often re-emphasized during informal meetings, such as office hours with either the faculty of the computer science department or advisers from the career center.

This pillar maps well to our student outcome goal of graduating students with *"an ability to communicate effectively with a range of audiences"*.

2.2 Real-World Focus Pillar

An emphasis should be placed on how skills and ideas learned through curricular and co-curricular means are necessary and valued by the industry and graduate school community. This emphasis takes many forms. Instructors should make an attempt to map in-class project topics to real-world applications. Where applicable, course content should encourage students to engage with important topics of the day and think about these topics in ways beyond a traditional computer science curriculum, such as from ethical or service perspectives. Faculty should not only allow this exploration, but encourage it through course content and informal discussion. Faculty should require a degree of professionalism from students when communicating through e-mail or in person.

Departments should encourage students to seek internships as soon as practically possible. Not only are internships arguably the most traditional of EL avenues, but they are an invaluable resource for students to experience first-hand application of the skills and ideas they acquire through course work. Departments should also be flexible in allowing students to engage with co-ops and study abroad opportunities, though this is a challenge as programs continue to grow. Additionally, departments should track internships taken on by their students, and encourage thoughtful formal reflection on their experiences.

Faculty should encourage and teach aspects of entrepreneurship. Students should understand intellectual property, knowing who owns the work they produce at school and in their internships. The environment they work in should foster creativity and encourage initiative, so that students believe what they create is valued and may be successful.

In our department we work closely with our institution's career services center in a variety of ways. First, all internships can be registered through the center and reflection papers are required for the institution to formally acknowledge the internship as part of the student's experience while in school. The department encourages students to register all internship and co-op experiences with the career center. Secondly, the career center regularly attends our classes and hosts workshops on resume building, interview tactics, and other career preparation topics.

Courses in the major present project opportunities that map directly to real-world applications. In some courses, such as Artificial Intelligence or Computer Graphics, this is straightforward. However, even in courses where the mapping might not be as obvious, such as Operating Systems, students write shells and implement and utilize thread pools to construct web servers and content filtering proxies, all tied back to the algorithms and concepts taught in the course.

This pillar maps to our student outcome goal of graduating students with *"an understanding of professional, ethical, legal, security and social issues and responsibilities"*.

2.3 Group Work Pillar

Whether in an industry setting or a graduate school setting, students will eventually spend significant portions of their lives working in groups toward a common goal. This clearly presents a large set of challenges. An EL-rich education should afford students as many opportunities as possible to work in groups. They will not always have a positive reaction to these opportunities, but they are important experiences. However, the curriculum should also strive to provide students with the tools to thrive in group settings, by providing the tools to enhance students' workflows and by providing the necessary emotional ground work for the challenges they may face when in group settings.

Faculty should encourage the use of group workflow tools for their group projects. This includes version control software (such as git), collaborative development tools (such as Google Docs), and project management tools (such as BitBucket's issue tracker). Embedding these ideas throughout the curriculum allows students to overcome their learning curve and get used to them, but also provides additional directly-applicable skills that can be added to resumes.

Arguably the most prolific complaint from students regarding group work is the unfair workload that emerges from working as a team. Faculty should put countermeasures in place to combat this workload imbalance. Allowing students to weight each members' contribution is a classic example of this, but there are others. Incorporating an issue tracker and weighting the projects based on issues closed is a more transparent method.

At our institution, group work is a focus of many upper level classes, and all include an emphasis on these team management tools. Groups present, produce deliverables, and disseminate together. Our capstone experience especially provides a heavy emphasis on group work, and includes units on group dynamics and inter-group communication. Groups are required to provide both individual and group-written deliverables and group contribution is weighted based on the number, weight, and priority of issues closed and bugs squashed.

This pillar maps directly to our department student outcome goal of graduating students with *"an ability to function effectively on teams to accomplish* *a common goal"*.

2.4 Student Empowerment Pillar

We, like others, have observed that students who feel empowered with choices in a class often achieve a deeper learning experience. It is recommended that, when possible, students should be provided choice in projects. Whether that choice is through a list of potential topics, a free form choice approved on a case-by-case basis, or a combination of the two.

It is important to foster a culture of independent studies within the department. Independent studies empower students to take control of their learning by adapting the curriculum to their aspirations. In order to build a successful culture of independent studies, the faculty must engage in practices that highlight the value of independent studies to the students. A substantial percentage (36.5%) of our student population engages in independent studies and thus mold the curriculum towards their interests. In our view, a culture of independent studies has formed over the past seven years, the time period where this framework was in place. This growth was energized by the faculty through announcement of potential topics in courses, where appropriate, as well as through curation of a student accessible list of potential topics of faculty interest. This culture has created a sense of a community of learners.

At our institution thirteen of the eighteen courses offered to computer science majors beyond their first year have presentations based on a project of the student's choosing. Some of these classes use group work while others utilize individual projects. Independent studies consist solely of student chosen work, in consultation with a supervising faculty member.

Finally, a component of course reflection by students is empowering. This may be achieved through the use of a post-course survey asking key questions such as: what they feel they learned, what changes to the course they would like to see implemented, what topics they feel they benefited from the most, etc. These questions may be used by the faculty to potentially modify courses, thus empowering students to enact changes in their learning environment. Thus the curriculum moves from prescriptive to adaptive. The faculty at our institution have implemented student course reflection using the questions described above, as well as additional questions. The feedback has been used to modify curriculum, which has not gone unnoticed by the students. The most change is normally enacted in the upper level electives as they are most malleable.

This pillar maps to our department student outcome goal of graduating students with *"recognition of the need for and an ability to engage in continuing professional development"*.

2.5 Dissemination of Individual Work Pillar

There are two ways in which dissemination should be formalized in the curriculum. First, all research projects, independent studies, and applicable final projects should be presented to the broader community. This can be accomplished through poster sessions, presentation symposia, or in-class project presentations. Second, faculty should emphasize and provide opportunities for students to present work at local and regional conferences. Even if student work is not accepted, the process and abstract writing that usually accompanies application procedures to conferences is valuable as it forces students to distill, summarize, and visualize their work for audiences with variable technical backgrounds.

Work dissemination ties together several of the other pillars while providing additional benefits for students. There are clear benefits with regard to soft skill development, as it forces students to communicate, through both written and oral means, with audiences of varying technical skills and backgrounds. Students who are given a choice as to what and where to disseminate are empowered to own their work, and this can often lead to requests to continue work on a project past the end of its allotted time. Additionally, work dissemination gives students a sense of belonging to a larger society of academics, both at their institution and beyond, boosting morale and improving retention.

At our institution, the computer science department hosts a symposium at the end of each semester. All students who take part in independent studies during that semester are required to present their work in formal 15-minute presentations to the department faculty and students, regardless of whether their semester included original research or not. Additionally, our institution hosts a campus-wide poster session each spring semester, and students present their work to the broader college community. Beginning with their sophomore fall semester, thirteen out of eighteen courses offered to computer science majors require a significant oral presentation component, and department faculty are invited to view these presentations. Students are regularly encouraged to present their work at local conferences by their faculty, and the department funds these presentations.

3 Conclusion

Informal reactions to several portions of this framework have been overwhelmingly positive. Student survey answers have praised aspects of the curriculum that focus on soft skills, such as: public debates, in-class seminars, and end-of-semester presentations. Student learning has tracked with student reactions. Faculty have observed both greater engagement and deeper understanding of course material. Independent studies have led directly to graduate school and career path choices, as well as an active culture of student work dissemination. Many of our students have received offers for full time post-graduation employment as a result of their internships.

Faculty and staff workload considerations are important as well. It has been our experience that the initial investment of time and energy is steep as course curricula are adjusted and faculty work to include students in multiple aspects of their reseach. However as with any cultural shift, this investment levels over time.

Almost all institutions face limited resources and must work to prepare students as best as they can for employment with vertical mobility in spite of those limitations. The presented framework has allowed our program to flourish within these limitations. In particular, evidence suggests that the framework, described above, has resulted in an increase in opportunities for graduates as well as greater satisfaction with their undergraduate experience.

The institution is working to establish a database of alumni positions and opportunities. Our immediate future work is to assess each pillar individually using feedback from the alumni and their employers and adjust our curriculum accordingly.

References

[1] What is experiential education. `https://www.aee.org/what-is-ee`. Accessed: 2019-07-25.

[2] Mikko-Ville Apiola and Mikko-Jussi Laakso. The impact of self-theories to academic achievement and soft skills in undergraduate cs studies: First findings. pages 16–22, 07 2019.

[3] Debra Coulson and Marina Harvey. Scaffolding student reflection for experience-based learning: a framework. *Teaching in Higher Education*, 18(4):401–413, 2013.

[4] J. Dewey. *Experience And Education*. Free Press, 1938.

[5] Kiev Gama, Breno Alencar Gonçalves, and Pedro Alessio. Hackathons in the formal learning process. In *Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education*, ITiCSE 2018, pages 248–253, New York, NY, USA, 2018. ACM.

[6] Brenda S. Gardner and Sharon J. Korth. A framework for learning to work in teams. *Journal of Education for Business*, 74(1):28–33, 1998.

[7] A. Heiney. Nasa lunabotics engineering competition. `www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html`. Accessed: 2019-07-28.

[8] Viljo Kohonen. *Experiential Learning in Foreign Language Education.* Routledge, 2000.

[9] David Kolb. *Experiential Learning: Experience As The Source Of Learning And Development*, volume 1. 01 1984.

[10] David Kolb. *Experiential Learning: Experience As The Source Of Learning And Development*, volume 1. Pearson FT Press, 01 2014.

[11] Makoto Matsuo. A framework for facilitating experiential learning. *Human Resource Development Review*, 14(4):442–461, 2015.

[12] Greg Ogrinc, Linda Headrick, Sunita Mutha, Mary Coleman, Joseph O'Donnell, and Paul Miles. A framework for teaching medical students and residents about practice-based learning and improvement, synthesized from a literature review. *Academic medicine : journal of the Association of American Medical Colleges*, 78:748–56, 08 2003.

[13] Ed Petkus. A theoretical and practical framework for service-learning in marketing: Kolb's experiential learning cycle. *Journal of Marketing Education - J Market Educ*, 22:64–70, 04 2000.

[14] Patricia Sendall, Kristin Stowe, Lisa Schwartz, and Jane Parent. High-Impact Practices: An Analysis Of Select University And Business School Programs. *Business Education and Accreditation*, 8(2):13–27, 2016.

[15] Christopher Stuetzle. Public debate format for the development of soft skill competency in computer science curricula. *J. Comput. Sci. Coll.*, 30(6):32–37, June 2015.

[16] Joo Tan and John Phillips. Incorporating service learning into computer science courses. *J. Comput. Sci. Coll.*, 20(4):57–62, April 2005.

[17] Bojan Tomić, Jelena Jovanovic, Nikola Milikic, Vladan Devedzic, Sonja Dimitrijevic, Dragan Đurić, and Zoran Sevarac. Grading students' programming and soft skills with open badges: A case study. *British Journal of Educational Technology*, 06 2017.