Toward Industry Oriented Software Engineering Project Course: A Pilot Study

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Abstract

Software engineering has become a prosperous industry sector due to the widespread and successful applications of software products. Industry oriented software engineering education is necessary to bridge academic training and industry needs. To this end, this paper reports on a recent pilot study at Clarkson University where a professional industry advisor from a CMMI level 5 certified software institution was systematically involved in an undergraduate software engineering project course. The goal of this practice is to make a solid step toward providing students with a formal introduction to industrial soft-ware engineering processes and authentic professional experience in an academic environment. Informed by a pre-course survey of student needs, the advisor participated in the entire development cycle of the open source course projects and offered multiple key lectures addressing industry needs. We describe the textbook, the selection of course projects, and the workflow where students interacted with the instructor and the industry advisor. Our analysis of results from a post-course survey indicates that 91% students "agreed" with adding the industry advisor role and that they have built enough confidence for future career through our course. Good practice and the future improvement plan have been summarized to share with the broader software engineering education community.

1 Introduction

Nowadays, software engineering has emerged as a prosperous business due to the pervasive adoption of software products in almost all sectors of the economy. According to the United States Department of Labor, there were 1,256,200 software engineering jobs in United States in 2016, with an annual growth rate outlook from 2016 through 2026 projected to be at an amazing level of 24%, and the median annual salary of software engineers is reported to be $103,560 in 2017[1]. Consequently, universities must educate enough highly qualified junior professionals who are ready to take on these well-paid jobs with all the essential skills.

It has been a long-term issue that in addition to the increase in demand for software engineers, software companies have recognized that skills provided by exiting education do not completely meet their requirements

[1] Bureau of Labor Statistics, U.S. Department of Labor: https://www.bls.gov/ooh/computer-and-information- technology/software-developers.htm

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[Sai02].

Garousi et. al. pointed that the software engineering shortage is not a lack of individual calling themselves "engineers", but one of quality - a lack of well-studied, experienced engineers with a formal and deep understanding of software engineering [GGT+18]. Su, Jodis, and Zhang further pointed out that many of the challenges associated with software engineering education are due to our inability to provide students with the "real world", large-scale software development experiences in an academic environment [SJZ07]. Thus, industry oriented software engineering education has been called upon to bridge the gap between academic software engineering education and expectation and needs of software companies.

Clarkson University[2], founded in 1896, is located in Potsdam, New York, United States, with an enrollment of around 4,300 students, offering degrees ranging from Bachelor's to Doctorate's. A Clarkson education emphasises the tight and win-win relationship with the industry, and the university was ranked #8 among "Top Salary- Boosting Colleges" nationwide in 2015[3]. Therefore, the industry oriented education practice has always been highly valued at Clarkson. Clarkson's software engineering program, a collaborative effort between Computer Science and Electrical and Computer Engineering, provides students with the technical competence, knowledge and skills in software processes and project management, as well as teamwork and professional skills for a successful career in today's software industry[4].

This paper describes our efforts in piloting an industry oriented software engineering course in this relatively young program. The process of an industry oriented project course must be characterized by the involvement of industry oriented staff along with key learning outcomes [MM14]. To meet this expectation, we seek to investigate appropriate industry oriented practice in a software engineering project course *EE418* in the Fall 2018 semester, as follows:

1. A professional industry advisor from a Capability Maturity Model Integration (CMMI)5 level 5 (top level) certified software institution provides authentic personal experience to our students regarding showcase projects, technical skills, ethics awareness, and interview soft skills in software engineering;
2. Close interaction among students, the instructor, and the industry advisor in course projects is required for a formal introduction to authentic industrial software engineering processes and practice.

To the best of our knowledge, this paper is the first to report a comprehensive plan as well as its piloting to bridge the gap between software engineering education and industry needs through a course project based approach. A senior industry advisor was heavily involved in the entire development cycle of software maintenance, as well as offering lectures on important issues in a software engineering career.

This paper describes the course design, evaluation results, and an analysis for the practice of introducing an industry advisor role into *EE418*. The rest of this paper is structured as follows. Section 2 presents the related work. Section 3 describes our design and practice of *EE418*. Section 4 presents an analysis of the students' post-course survey results, and our future plan to address the findings. Lastly, Section 5 concludes this paper.

2 Related Work

In recent years, software engineering educators started to realize the importance of connecting software engineering education with the industry needs. Saiedian emphasised the importance of bridging academic software engineering education and industry needs, and listed several key aspects of educating software engineering students in order to build this bridge, including education in risk management, software maintenance skills, etc [Sai02]. Recently, Garousi published results from a survey regarding closing the gap between software engineering education and industrial needs [GGT+18]. Through a review and comparison of a large number of papers published in 1995-2018 about the most important skills in the industry and the status of software engineering education, some knowledge gaps have been highlighted, which include software engineering professional practice, project management, software engineering processes, etc. Liebenberg discussed the industry's perception of the relevance of software development education through a mixed methods study, and then proposed some solutions, including involving people from industry into software development classes, hiring lecturers with industry experience, project

[2] Clarkson University: https://www.clarkson.edu/

[3] https://money.cnn.com/2015/04/29/pf/college/college-biggest-salary-boost/index.html

[4] Software Engineering Program of Clarkson University: https://www.clarkson.edu/undergraduate/software-engineering

[5] CMMI Institute: https://cmmiinstitute.com/

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based education, etc [LHM 3]. Long illustrated the critical need for software engineering education especially for the United States higher education system, indicating that this system did not follow the pace of the software industry evolution. Long emphasised the education innovation regarding this matter [Lon08].

Mishra investigated an industry oriented advanced software engineering education curriculum [MM14], of which the purpose is to respond to the industrial skill expectation.

Unfortunately, none of these publications have practiced and implemented their conclusions and suggestions. Maras is the first to report their practice of performing an empirical study on students with an industry-relevant topic taught by an industry expert in their software engineering course in Croatia [MU15]. However, during their practice, only a three-hour lecture has been offered by an industry expert from the Ericsson Corp[6], which is obviously not enough to bridge these key knowledge gaps identified by prior work.

3 Course Design and Practice

3.1 Course and Industrial Advisor

EE418 is a software engineering project course at Clarkson University where junior and senior students will participate in managing and executing the process of carrying out a significant software development effort from a conceptual idea through integration and testing of the new proposed features into an open source software. The focus of the particular *EE418* offering in Fall 2018 was software maintenance rather than new software development, a topic that has been often inadequately covered in software engineering education. For example, based on personal observation in his teaching career, Piere pointed out the educational difficulties with traditional greenfield projects is that they often produce poor project results [Pie92]. Buchta et. al. pointed out that developing small programs from scratch in the traditional software engineering course does not match industrial practice [BPPR06]. Saiedian also pointed out that training software maintenance skills is a way to build the bridge between academic education and industry needs [Sai02].

The industry advisor, who is a co-author of this paper, is from Motorola Solutions Inc.[7] with over twenty years' experience of software developing and management. More importantly, the author and co-author were co-workers in Motorola software design center for many years, and they once worked together to help Motorola to obtain the CMMI level 5 certification [GGK06] through a showcase software maintenance project. Thus, the industry advisor had great enthusiasm and capability for improving STEM education and was fully engaged in our course projects.

3.2 Textbook and Lectures

Rajlich's software maintenance textbook [Raj12] has been adopted as an ideal supplementary to our course projects. The chapters selected for *EE418* lectures are as follows: (1). History of Software Engineering; (2). Software Lifespan Model; (3). Software Technologies; (4). Software Models; (5). Introduction to Software Changes; (6). Concepts and Concept Location; (7). Impact Analysis; (8). Actualization; (9). Refactoring; (10). Verification; (11). Conclusion of Software Changes; (12). Introduction to Software Processes; (13). Final Stage.

In addition, the industry advisor has given two lectures, one on software job interviews and the other on ethics in software engineering. He has also contributed to the development of the course syllabus.

3.3 Course Projects and Grading

To determine the best practice for running this industry oriented project course, the instructor conducted a course expectation survey in the first class, where the students' expectation on the industry advisor were solicited. The results showed that our students expected the advisor to provide more industry insights (45%), feedback to the course project (30%), and interview tips (25%).

The instructor designed the following process for selecting the course projects. First, students attending this course were grouped into three teams, and each team chose an open-source software from the Github in the areas of machine learning and artificial intelligence. Then, each team proposed three new features, and proposed one feature for each of other teams. The industry advisor working with the instructor proposed one additional feature to each team. He also gave feedback to the other new features based on his industrial view. Therefore, each team worked on six new features in their project. The requirements of each feature were negotiable in the requirement phase. All new features proposed were voted for acceptance by all stakeholders including all team leaders, the instructor and the industry advisor. Open source software selected and sample features proposed by stakeholders are shown in Table 1.

[6] Ericsson Inc.: https://www.ericsson.com/en

[7] Motorola Solutions Inc.: https://www.motorolasolutions.com/

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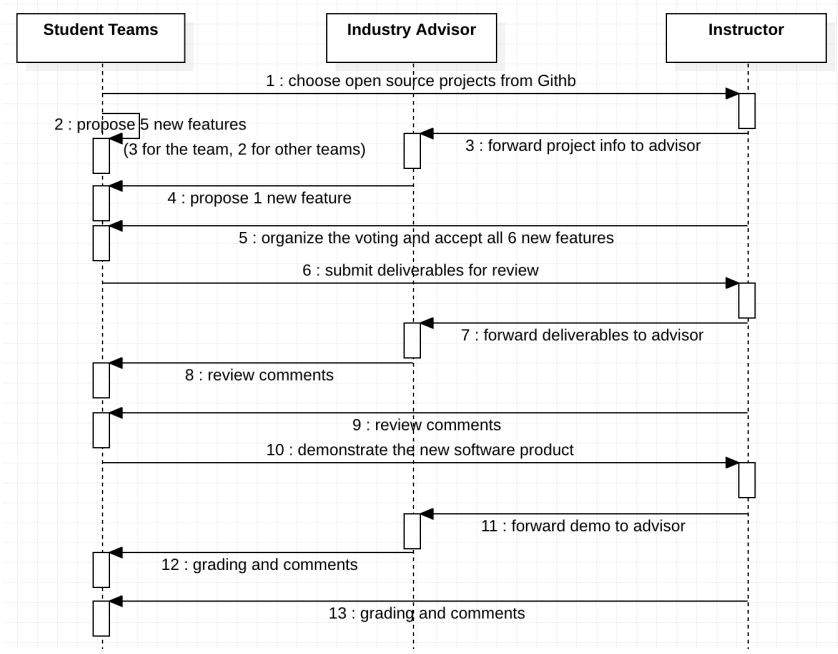

Figure 1: The interaction workflow among *EE418* students, the instructor, and the industry advisor.

The justification for our choice of open source projects on the theme of machine learning and artificial intelligence is as follows. Recently, open-source projects are increasingly being used in software engineering education for their benefits of easy and free source codes accessing and active development community [CK03, PBOP07, NGHL08]. Team based software engineering course projects are believed to be important for facilitating learning, fostering student motivation as well as obtaining a successful project outcome [DAHB18]. In addition, machine learning and artificial intelligence are the future of the industry, and are even called "the fourth industrial revolution" [Theil].

Table 1: Course Projects and Sample New Features.

Project Name	Description	Sample Feature
DeepLeague[8]	A deep learning and computer vision application to analyze minimap recordings from League of Legends	The system shall take .csv file as input to the UI portion
DeepXplore[9]	A white-box testing framework of deep learning systems by introducing visual augmentations in images	A heatmap feature shall be added to track the areas augmentation placed
Magenta[10]	A tool to make music and art through machine learning based on Tensorflow	Classical, modern, and rock specific output shall be generated depending on pre-trained datasets

To best meet students' expectation, the instructor designed the workflow among students, the instructor, and the industry advisor (Figure 1). As advised by the industry advisor, each team member was assigned a role in the team in the project kick-off meeting, including project leader, configuration manager, test leader, quality engineer, and project website administrator. These are the common roles in the software development team in Motorola Software Centers. Besides these roles, all team members were both developers and testers. The project leader was responsible for project management plan and requirement book, the configuration manager setup the version control system to manage the source codes, the test leader finished the test plan and test report, and the quality engineer was to ensure quality, providing the quality data in the test report and maintaining traceability matrix between requirements, design, coding, and testing. The industry advisor also participated in the review activities of all the deliverables, including requirement book, design document, test plan, test cases and report, and the final product demonstration, providing feedback from the perspective of industry needs. At the end, all stakeholders (team leaders, the instructor, and the industry advisor) worked together to grade each new feature. Although the benefits of group projects are well known, grading team projects is not an easy undertaking, with many inherent challenges [HLP03]. To achieve fairness and consistence, we followed Hayes' best practice of grading haye. First, the projects

[8] DeepLeague: https://github.com/farzaa/DeepLeague/
[9] DeepXplore: https://github.com/peikexin9/deepxplore
[10] Magenta: https://github.com/tensorflow/magent

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were graded as a team base, and then each team member got the same score based on the team performance. Second, we allowed team members to evaluate the contribution of each other to a certain percentage of the entire project grades. Third, the attendance of group activities in class was checked and it took some points of the final grading.

4 Evaluation and Analysis

A post-course survey with eight questions was conducted in the last class. These questions and their key measures are shown in Table 2. The survey results and relevant analysis are presented in Table 3. On average, 85% students were satisfied with this industry oriented teaching innovation, and 70% students were very satisfied. Thus, based on the survey results, we can conclude that the basic goal of this education innovation has been achieved. Also, the analysis shows that it is the right decision to involve the industry advisor into the software engineering course (Q1), and that students believe that their interview skills (Q5), knowledge and confidence for software engineer jobs (Q2-Q4, Q6), and teamwork skills have improved (Q8).

Table 2: Survey Questions and their Key Measures.

Questions	Key Measures
Q1: How is your understanding about the industry advisor role value	Industry advisor awareness and value
Q2: How do you think the value of industry knowledge and practices for your job interview	Industry knowledge value
Q3: How is your preparing for your job hunting	Preparation for job hunting
Q4: What is your confidence in IT job interview	Confidence for job interview
Q5: Do you think you have enough technical competence and soft skills in IT job interview	Enough technical competence and soft skill
Q6: How do you feel what you will learn from this course is useful in the real-world	Value of this course in real world
Q7: How do you feel your course project can be used as a show case in your job interview	Course can be a show case
Q8: How is your commitment to working in a team to develop the software project	Commitment of working in a team

Table 3: Results and Analysis of the Post-course Survey.

Questions	Analysis	Satisfied/Agreed	Strong Satisfied/Agreed
Q1	Right decision to introduce industry advisor role into this course	91%	64%
Q2	A very good start, and also an opportunity to adjust the future practice	91%	82%
Q3	Students have obtained knowledge to do better preparation	91%	82%
Q4	Students have built more confidence for their future career	91%	55%
Q5	Students have gained stronger competence and skills	100%	82%
Q6	Room to refine the course to be more practical	82%	64%
Q7	Need drill down more to prepare better show case with proper scope	55%	45%
Q8	Good teamwork has been done, and it is very useful for their future career	82%	82%

Although 55% of students thought that their course project can be used as a good showcase for their future career in software engineering, we did observe that one of the three teams had unsatisfying performance in their course project and their project was not good enough for a showcase (Q7). In addition, the evaluation indicates that we have a good start (91% students "agreed" with the industry advisor role and they have built enough confidence for future career), but we also have the opportunities to improve our practice in future semesters (only 64% students "strongly agreed" with this role (Q1), and 55% of them "strongly agreed" that they had built enough confidence (Q4)).

Our planned future actions are listed as follows:

1. Course projects will be provided by the industrial advisor to reflect the real needs of industrial software product development (Q7);
2. All lectures will be revised by the industry advisor to follow the technical trends in the real-world (Q4&Q6);
3. Multiple guest lectures will be offered to share more authentic industry experience, and the topics span the entire software development cycles, such as risk management and budget planning (Q4&Q6).

5 Conclusion

We report on a preliminary practice and an analysis of an industry oriented software engineering educa innovation at Clarkson University. A senior professional industry advisor from a CMMI level 5 certified softw institution has been deeply involved in a software engineering project course to introduce our students to authe industrial software engineering processes and practice. Our analysis of a post-course survey indicates

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91% students have “agreed” with adding the industry advisor role and believed that they have built enough confidence for future career through such a course. We have also identified the opportunities and actions for future improvement.

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