Aligning Industry Training and Incubators with Learning Outcomes in Software Engineering Capstone Courses

Orges Cico[1]

[1]*Norwegian University of Science and Technology, Norway*

Abstract.

While teaching a software engineering course, we noticed a lack of technical skills within the course setting. Based on this observation, we decided to redesign the course, shifting from classical classroom lectures to a capstone project approach and exploiting student participation in industry training and information and communication technology incubators. We conducted semi-structured interviews and relied on observations and exploratory data gathered on student participation in training, incubation, and the course. In order to validate the teaching strategy, we developed the InnoTechSE model, where students migrate from company training to an incubation centre while developing a capstone project in their capstone course. As a result, we found a decrease in technical challenges when industry training and incubation naturally align with the learning outcomes of the capstone course. We state hypothesis and propose future recommendations to test the model further with quantitative longitudinal studies.

Keywords: Industry Training, Incubators, Innovative Model

1. Introduction

Facing industrial work continues to be a challenge for most software engineering (SE) students after their graduation [1]. Universities have tried to cope with this challenge by adopting different strategies [2-6]. Capstone courses have provided adequate challenge for students to become acquainted with industry-related skills at the end of their curriculum. A strong emphasis on capstone courses has been adopted for the final year of bachelor or master students in regard to boosting their employability in the industry [7]. Two years ago, we redesigned our capstone course, which previously focused on waterfall approaches, with a shift from the classical classroom lecture approach to agile and Scrum methodology and by exploiting industry training, focusing on technical aspects, and information and communication technology (ICT) incubation participation, focusing on soft skills development. Since then, we have provided students a concrete learning outcome to emphasize the relevance of acquiring technical skills through face-to-face industry training and soft skills through a lean start-up model adopted within ICT incubators.

Important to us is what students specifically learn and the usefulness of the exposure to two external entities (one international software company and one incubation centre) within the context of their newly designed capstone course. Therefore, we formulated the following research question (RQ):

RQ: *How can we align student participation in industry training and incubators with learning outcomes in software engineering capstone course, to improve students soft and hard skills?*

For this purpose, we propose a model (Innovation Technology Software Engineering (InnoTechSE)) to align learning outcomes among the two external entities (company and incubator) and the course. Constructive alignment [8] has been applied in a range of fields in SE courses for teaching concurrency [9], introducing programming [10], etc. Moreover, we designed a qualitative survey with semi-structured interviews for the beginning, during, and end of the industry training incubation process and observed the quality of the project delivered within the capstone course. The scope of the investigation is to evaluate student perception related to the participation in activities outside the course and how it affects their skills and learning outcomes. The dimensions chosen for the evaluation are categorized as (1) technical skills (code development and software technology comprehension, project planning, and quality) and (2) soft skills (teamwork, communication, presentation, negotiation, and innovation).

Through interviews conducted at different phases of their project development, we found a noticeable increase in student confidence toward solving technical challenges as well as a major improvement in the soft skills.

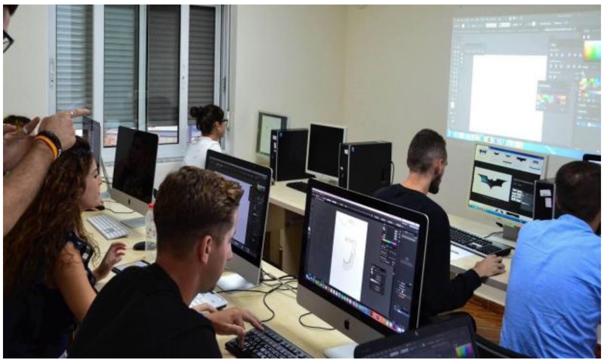
We concluded that our model (InnoTechSE), based on the alignment of industry training and incubation, directly contributed to learning outcomes for the SE course and affected students final assessment as well as their level of confidence in technical and soft skills.

2. Course, Training and Incubation Settings

The course. We redesigned the course at the Canadian Institute of Technology in Tirana so that the primary learning outcome focuses on both technical and soft skills in equal measure. This required external stakeholders who could provide realistic challenges for the students. The updated syllabus aimed to develop technical and soft skills through an early capstone course in the curricula. This helped in fully exploring all dimensions—technical development, project management, teamwork, communication gap challenges, presentation, negotiation, and innovative mind-set. The course has a duration of 90 hours distributed throughout one 15-week semester. However, teams are expected to have a practical overload of 8–10 person hours every week dedicated to training and incubation.

The company training. During the course, students participate in company training to explore different technical aspects (programming and technology). The training provides hands-on experience and boosts technical confidence through a rapid prototyping approach. The training portfolio of the collaborating company mainly addresses web, mobile, and cloud application development as well as graphic design for portfolio development. The training usually consists of 30 face-to-face hours. Students can choose from several training modules [11] and participate in training classes (Figure 1).

Figure 1: Company training session [12]



The incubation process. We have run the Metropolitan Incubator (MI) for over two years, with approximately 18 start-ups following a well-planned pipeline (Figure 2). The process involves three months of incubation where students undergo a soft-landing period. The participation is open to a plethora of external entities (professionals, business developers, experts, and students from different backgrounds and academic levels). Start-ups follow a lean canvas model, relying on product testing with external customers. Applications are handled from an in-house cloud-based system [12].

The teams. Teams are commonly composed of students with an entrepreneurial mind-set. The main characteristic is the inter- and multi-disciplinary composition of each team. Every team makes the effort to come up with an innovative idea upon which they agree. The team size varies from 3–7 individuals. Self-structuring is common and a balanced environment for making decisions helps with team sustainability.

The projects. The projects for the course are commonly decided after the first two weeks. SE students at our university have the chance to brainstorm and explore their own innovative ideas. Mainly, the number of projects is determined by the overall number of teams. The projects follow a value-driven approach focusing more on the project contribution. Whenever the team members feel a lack of technical competencies, they are encouraged to follow training sessions based on their role in the project. Mandatory agile practices, such as Scrum burndown diagrams [11], are performed within the classroom context as well as in the incubation center for project management.

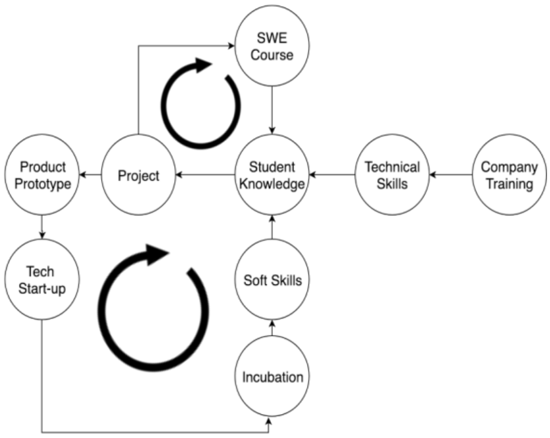
Student evaluation. The students receive individual grades based on the midterm, final, and delivered project. However, the project makes up 50% of the overall assessment and has a unique mark for the whole team. The evaluations are of a different nature, and they take place at each sprint review, commonly with 4–5 sprints per semester, for the project [13]. Midterm and final exam addresses theoretical and practical knowledge obtained during the classes.

Figure 2: Incubator team work [14]

3. InnoTechSE Model

In order to align the learning outcomes among the three entities—(1) capstone course, (2) software company training, and (3) incubation centre, we propose the InnoTechSE model. We propose that students' learning should orient more toward innovation and start-up as well as adopted technology in software companies so that they acquire the tech and soft skills required for the new breed of software engineers. Figure 3 presents the proposed model to integrate innovation and company training into Software Engineering courses. From the model, we can observe that starting either from an incubator or company training can directly contribute to the students' knowledge, which is then further translated into the delivery of a course project or into a product prototype that can create the basis for a start-up formation. Both iterations can be observed from the model loop arrows.

Figure 3: InnoTechSE model



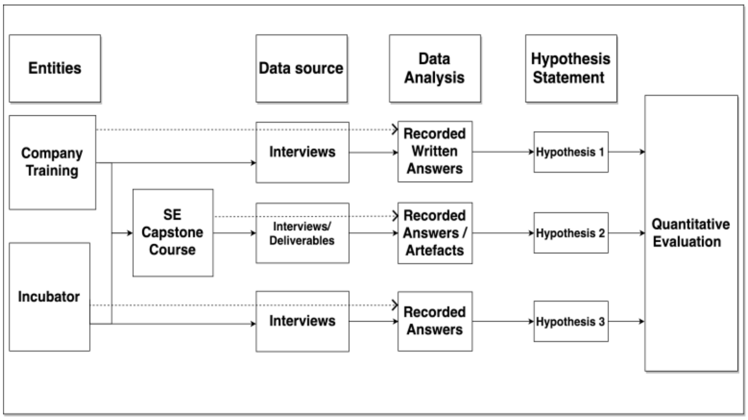
4. Qualitative Survey

We guided our investigation based on the RQ. The survey involves semi-structured interviews with students participating in parallel in the training, incubator, and course and is divided into soft and technical skills acquired from incubation processes and company training.

4.1 Survey design

The conducted survey was designed based on the model in *Figure 4*.

Figure 4: Qualitative survey design methodology



Company training survey model. Students were interviewed before the training based on a set of open-ended questions that focus on their study background, technical skills, and technical challenges. The interview lasted 15–20 minutes [15]. At the end of the training, another interview and presentation took place related to the participants' confidence level and the prototype developed [15].

Incubation survey model. During the incubation process, candidates took part in several activities and were routinely asked questions related to team development and balancing, communication issues, product presentation, negotiation skills with the customers, clients (venture capitalists or investors), and contribution to innovation. These were all conducted in the form of semi-structured interviews on a weekly basis. A sample of the questions related to project managers is found in [15].

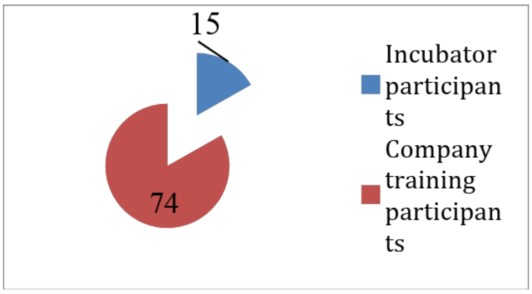
SE course survey model: Students were asked about their perception of the challenges regarding the chosen dimension under investigation at the beginning of the course upon team formation and at the end of the course upon final presentation.

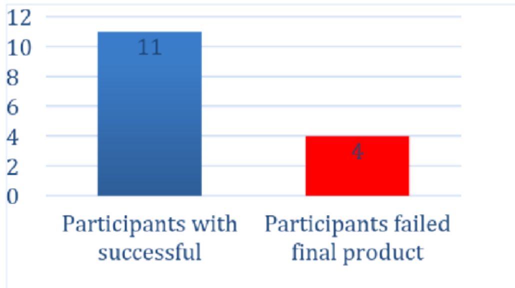
4.2 Data collection

We conducted the study for two academic years starting in 2017–2018. At the beginning of the course, students were asked to group into teams of 3–7 members, each having a particular role (e.g., one project manager, two developers, two testers, one product designer, and one configuration manager). In total, we had 15 students and four teams participating in both company training and incubation. Projects were mainly oriented toward hybrid mobile application development and websites. **UniTask** involves proposing a solution to excessive mobile phone usage among students during their study time. A mobile application was developed to help students focus on their tasks by blocking the phone and helping individuals concentrate while dealing with tasks. **Street Digital Reporting** provides guidance and reports road issues. The aim is to help citizens, tourists, and government decrease the number of street accidents and increase safety on the streets. **My Career** is a portal developed to guide high school students in choosing their university study program. It involves sharing experiences from professors and experts in various fields. The **Medical Care system** provides medical advice at different levels, such as medical graphics, animations, symptom checker, and hospital locator.

A summary of statistics related to the participation of students from various disciplines in the different company training can be found in [15]. Around 20% of trained participants, mostly students who were part of the capstone course, took part in forming multidisciplinary groups for the training and the incubation center during the period of 2018 (*Figure 5).*

Figure 5: Participants in incubation and training during / Participants' success rate for incubated projects





4.3 Data analysis

We tried to derive conclusions from observations and reported interviews, presentations, and delivered projects. We payed attention to the dimensions chosen for the investigation. Main findings based on the qualitative survey are as follows:

Training. One student in SE reported during the interview before the training, *"I would like to learn more about technologies and want to be able to develop mobile applications as part of my professional life. However, I am afraid about whether I can digest the whole program within 30 hours of training. Will I be able to develop a functional app?"*

After training, the same student reported in writing, *"I am satisfied that I was able to build an app serving the business of my father in coordinating field security agents during their work. I wished I could have added more features to the app, but I surely feel more confident to do so independently utilizing the learned technologies."*

Another SE student reported during the interview before training, *"I want to develop a website for my local gym. Do we start from scratch? I have already some knowledge about HTML and CSS."*

The same student reported after training, *"I didn't think that I would be able to learn so fast the new technologies, and I am very happy to have been able to actually develop the website, and I feel far more confident in working with web technologies"* [15].

Incubation. Teams participating in the incubation process reflected upon aspects leading toward their product development, challenges faced in making trade-offs, avoiding and negotiating drop-outs, as well as fostering innovation. They faced tight communication with external stakeholders and presented the products developed. After discussions with the staff and startups, experienced external evaluator T.E. (who has more than 20 years in developing incubators) reported, *“In Metropolitan Incubator, they have structured programming through the incubator. They take companies through programming that is administered via the exec director and program managers. They do some market validation. They track the milestones given to each start-up via an online tool, [and] give new milestones as others are achieved. They currently have five companies being incubated. Many are ideas that have a chance of commercial success”* [15].

Course. One of the project managers for a team developing Medical Care stated, *“After taking the course and being able to develop the project outside of the classroom setting has helped me and my team complete a fully functional prototype. We feel very confident in finding a job.”*

5. Results

Based on an analysis of the collected data, we developed the following hypothesis about technical skills dimensions: **H1:** *The perceived difficulty of addressing the technical challenges drops after after following the InnoTechSE model.* **H2:** *The perceived difficulty of addressing project management drops after after following the InnoTechSE model.* **H3:** *The software project quality increases after following the InnoTechSE model.* Based on the collected qualitative data, we were able to state an important hypothesis related to students’ hard skills. Although we tried to cover most of the relevant data, there is still a large set that needs to be analyzed. According to the recommendation of Maxwell [16] who identified five threats to validity in qualitative research, we report the following for our study: (1) Descriptive validity: Although we have tried to gather as much information as possible, we admit that some aspects might not have been able to be recorded. In most cases, we used audio and video recording, although this does not completely remove the threat for unrecorded situations. (2) Interpretation validity: We carefully kept track of the written perspectives of the individuals being researched. Open-ended questions were used to allow the participant to elaborate on answers. (3) Researcher bias: We were careful not to put any bias related to gender, culture, etc. The only bias is related to interviewing software engineering students. However, this did not affect the study because it pertained to the primary focus. (4) Theory validity: We made sure to collect all data reporting both success and failure with respect to our examination. (5) Reactivity: On most occasions, the interviewer was careful not to influence the outcome of the interview. This hypothesis can be unfolded for all the different dimensions and analyzed further through longitudinal quantitative studies.

6. Conclusions

Based on our study, students get better exposure to technical skills through company training and incubation processes. We also wondered if knowledge obtained among the two external entities are aligned with the course learning outcomes. To answer this question, we propose a model called the Innovation and Training Driven Software Engineering Courses (InnoTechSE) be adopted during the course, and we conducted a qualitative survey based on semi-structured interviews. We found that students' perception of technical challenges significantly dropped after the training and incubation, and their confidence in delivering a final working prototype grew significantly. The delivered projects and products were highly improved at the end of the course, with a lower failure rate of the students not participating in the model. We concluded that industry training and incubation naturally align with learning outcomes for the SE course and impact students final assessments as well as their level of confidence in tech skills. Moreover, we propose that the stated hypothesis should be tested through empirical investigation with quantitative data gathered through longitudinal studies. Other investigations can be conducted to evaluate if the model has further influence on the soft skills acquired especially during the incubation process. Moreover, we think that the InnoTechSE will help to foster more collaboration among academic and industry instructors in helping students develop better technical and soft skills and overcoming the academic and the industry knowledge gap.

References

Dunlap, J. C. (2005). Problem-based learning and self-efficacy: How a capstone course prepares students for a profession. Educational Technology Research and Development, 53(1), 65-83.

Cico, O., Jaccheri, L., Nguyen-Duc, A., & Zhang, H. (2021). Exploring the intersection between software industry and Software Engineering education-A systematic mapping of Software Engineering Trends. Journal of Systems and Software, 172, 110736.

Cico, O. (2019, November). The Impact of IT Bootcamp on Student Learning-Experience from ICT Enabled Experiential-Based Course. In International Conference on Software Business (pp. 430-435). Springer, Cham.

Cico, O., Jaccheri, L., & Duc, A. N. (2021, April). Facilitating learning and startup formation in experiencebased courses—A team-centered model. In 2021 IEEE Global Engineering Education Conference (EDUCON) (pp. 599-608). IEEE.

Cico, O., Duc, A. N., & Jaccheri, L. (2020, April). Software Startup Formation in an Experiential-Based Course-An Empirical Investigation of Students' Motivations. In 2020 IEEE Global Engineering Education Conference (EDUCON) (pp. 1278-1285). IEEE.

Cico, O., Duc, A. N., & Jaccheri, L. (2021, October). The development and validation of a framework for teaching software engineering through startup practice in higher education. In 2021 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE.

Buffardi, K., Robb, C., & Rahn, D. (2017). Tech startups: realistic software engineering projects with interdisciplinary collaboration. Journal of Computing Sciences in Colleges, 32(4), 93-98.

Chen, CY and Chong, PP (2011). Software engineering education: a study on conducting collaborative senior project development, Journal of Systems and Software. Vol. 84, No. 3, p. 479-91.

Biggs, J and Tang C (2003). Teaching for quality learning at university (new edition)., Society for Research into Higher Education & Open University Press.

Brabrand, C (2008). Constructive alignment for teaching model-based design for concurrency. In: Transactions on petri nets and other models of concurrency I, Springer, Berlin, Heidelberg, pp. 1-18..

Gaspar, A, and Langevin, S (2012). An experience report on improving constructive alignment in an introduction to programming, Journal of Computing Sciences in Colleges, Vol. 28 No. 2, pp. 132-40.

Dominusoft. https://www.dominusoft.com/en/

MI: http://mincubator-al.appspot.com/join/ (U/I: test@mnt.com/test)

Facebook: https://www.facebook.com/pg/Dominusoft-Training-367966920033759/photos/

Facebook: https://www.facebook.com/pg/metropolitanincubator/photos/

https://tinyurl.com/y9syo3r5

Maxwell, JA (2012). Qualitative research design: an interactive approach, Sage Publications.