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Lean Software Startup Practices and Software Engineering Education

Orges Cico†
Department of Computer Science
Norwegian University of Science and Technology
Trondheim, Norway
orges.cico@ntnu.no

ABSTRACT

In the modern economy, software drives innovation and economic growth. Studies show how software increasingly influences all industry sectors. Over the past 5 decades, software engineering has also changed significantly to advance the development of various types and scales of software products. Software engineering education plays an essential role in apprising students of software technologies, processes, and practices popular in industries. Furthermore, approaches to teaching software engineering are becoming more interdisciplinary and team-centered, comparable to startup contexts. In this PhD work, I want to answer the following research questions: (1) To what extent are software engineering trends present in software engineering education research? (2) What set of common software engineering practices employed in lean software startups is transferable to the software engineering education context? (3) What is the impact of lean startup practices on software engineering students and curricula? I utilize (1) a literature review, (2) mixed-methods approaches in gathering empirical evidence, and (3) design-based research. In the first phase of the research, I pinpoint the relevance of the lean startup in software engineering education through an extensive literature review. I gather empirical evidence on lean startup practices and assess their potential transferability to software engineering education during the second research phase. I demonstrate that the lean startup is an emerging trend in software engineering education research. I demonstrate that students can acquire soft, hard, and project management skills in a more realistic context in the introduction of the growth phase of lean startup practices throughout external course activities. I expect software engineering curricula to benefit from the model and framework that I propose and validate, thus facilitating lean startup practice transfer to software engineering curricula.

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CCS CONCEPTS

• General and reference → Empirical studies; • Social and professional topics → Software engineering education.

KEYWORDS

Software Engineering, Lean Startup, Empirical Studies, Software Engineering Education

1 Introduction

Over the past 5 decades, software engineering education (SEE) has continued to evolve while focusing on preparing software engineering (SE) students for future careers [1,2]. International organizations such as the Institute of Electrical and Electronics Engineers, Association for Computing Machinery [3], and the Computing Curricula of 2020 [4], encourage integrating industrial perspectives in SE curricula. Despite this support, addressing industrial demands remains an open question in SEE. Educators provide fundamental programming knowledge and skills that help students adapt to and work quickly with new technologies in industrial environments. SEE strives to meet this goal through lengthier design of courses, and it relies on teaching strategies such as project-based learning and capstone courses to enable skill practicing in relatively realistic project environments [1,5]. Systematic reviews [2,6,7] have revealed that educators successfully convey relevant SE knowledge to students by using these approaches.

Moreover, education for software engineers should prepare students to stay current in the face of rapid change. Existing studies have reported educational challenges that exceed fundamental skillsets. For example, reports have addressed how to support students regarding communicating effectively with customers in an Agile project [8] and how to work with other developers in a geographically distributed setting [9]. The underlying assumption of these reports is that students are already aware of the necessary state- of-the-art software engineering trends. Such topics are essential for educators when building appropriate curriculums and selecting suitable teaching methodologies [10].

Seeking to prepare students for future computing, as illustrated by the Computing Curricula 2020 project [4], I recognize the

necessity of reviewing SEE to ensure education outcomes relevant to the software industry in the mid-2020s and beyond. Studies have highlighted the importance of SEE collaborating on common education goals and remaining current with SE trends [7,11]. In particular, trends in current SE curricula from previous decades require revision. In this project, an SE trend is a commonly adopted software development approach that includes a set of practices, working methods, associated toolsets, and frameworks. For example, lean startups is an industry SE trend attracting interest in SEE [12]. How SEE responds to this trend may be crucial for future student cohorts. Unsurprisingly, the main collaboration scenarios between industry and education stakeholders involve lean software startup formations. However, the lean software startup trend is underrepresented in the SEE context. Difficulties faced while applying it are related to (1) SE students' mindsets when developing innovative ideas, and (2) delays in adopting innovative technologies, tools, and SE practices. I argue that the main cause for the gap is the lack of a conceptual model and framework that would facilitate lean software startup research in becoming part of SEE courses. To this end, I formulated the following hypotheses:

- **H1:** Lean Software Startup paradigms are part of SE Trends presented in SEE research.
- **H2:** A set of common software engineering practices among lean software startups is transferable to the SEE context.
- **H3:** The adoption of lean software startup practices and settings can positively affect students' skills and startup formation motivation in the SEE context.

To corroborate my hypotheses, I have posed three primary research questions (RQs) and corresponding sub-questions for my study's research objectives, discussed in Section 2. To answer the RQs and verify the hypotheses, within my research scope (Section 3), I have designed a research methodology relying on a mixed-methods approach in empirical investigations, described in Section 4. I discuss the study's expected contributions in Section 5 and the results obtained thus far in Section 6. I have carefully planned the timeline for evaluating the research; see Section 7.

2 Research Objectives

This thesis aims to contribute to the ever-evolving development of industry-relevant teaching strategies, focusing on software startups. Thus, I have designated the following research objectives: (1) Identify industry- and academia-based SE trends; (2) Identify lean startup practices when transitioning from early to growth phase; (3) Identify the extent to which lean startups are presented in SEE research; (4) Identify primary stakeholders involved in the introduction of lean startups in SEE curricula; (5) Evaluate how external activities involving internal and external stakeholders foster innovation and lean startups within SE curricula; (6) Evaluate how lean startup paradigms, practices, and settings can affect students' skills and startup formation mindsets; and (7) Propose a model and framework facilitating lean startup practice transfer within SEE curricula.

Concurrently, I wish to contribute to the scientific development of lean startup SE and SEE research. I want to demonstrate the present relevance of lean startups in the SEE context. My research inquiry contains the following RQs in connection with the research objectives:

- **RQ1:** To what extent are SE trends present in SEE research?
  – **RQ1.1:** Which industry models, processes, and methods are embraced in SEE research?
  – **RQ1.2:** What industry-relevant teaching approaches are presented in SEE research?
  – **RQ1.3:** Which stakeholders work together, as presented in SEE research?
- **RQ2:** What is known about lean software startup practices?
  – **RQ2.1:** What are common engineering practices in lean software startup companies?
  – **RQ2.2:** What discrepancies are present in software practices when lean startups transition from the early to the growth phase?
- **RQ3:** What is the impact of lean startup practices on SE students and curricula?
  – **RQ3.1:** How do external lean startup-focused activities impact students' learning in experience-based courses?
  – **RQ3.2:** How do external activities/stakeholders affect student motivation regarding startup formation within SEE curricula?
  – **RQ3.3:** What model and framework can facilitate lean startup practice transfer to SEE curricula?

RQs 1, 1.1, 1.2 and 1.3 relate to positioning the lean startup in SEE while scoping the literature. I want to evaluate how startup characteristics have been integrated into SEE. RQ2 and its corresponding sub-questions focus on the knowledge from the state of the art in the lean software startup context. I then evaluate the transferability of software startup practices into SEE (including project-based learning courses such as customer-driven project and multidisciplinary courses, such as experts in teamwork). Finally, RQ3, RQ3.1, RQ3.2, and RQ3.3 evaluate potential impacts for existing SE curricula and SE students in collaboration with other disciplines. I follow the research methodology outlined in Section 4 to answer the RQs.

3 Research Scope

The scope of the PhD project is related to students participating in Norwegian University of Science and Technology (NTNU) SE-related master study courses (e.g., Experts in Teamwork and Customer-Driven Project).

The project will also contribute to Lean Startup research by gathering empirical data on SE practices from growth-phase software startups. The project will focus on (1) contributing to learning approaches for SE-related courses by adopting software startup, Lean Startup methodology, and minimum viable product prototyping approaches and tools;

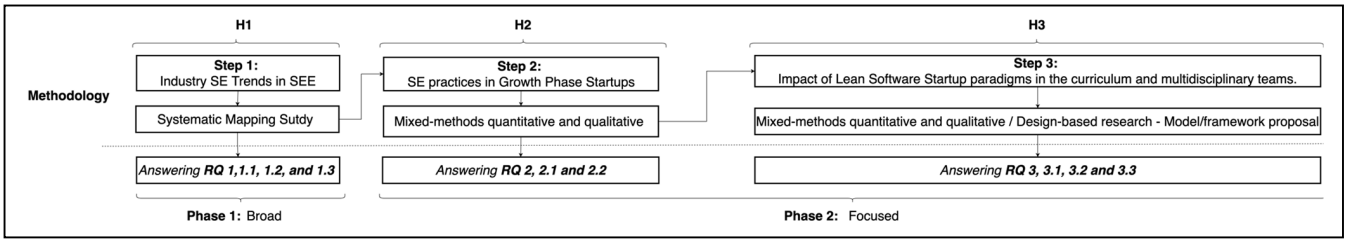

Figure 1: Methodology Design

(2) promoting innovation and software startup models that allow students to become future tech innovators; and (3) potentially adding to knowledge of SE practices in growth-phase software startups.I will limit the study to the lean software startup paradigm and SE practice transfer within the SEE context. Moreover, early-stage software startups will be outside the research scope, as they have been extensively evaluated by the research community. Data collected from growth-phase startups would be more meaningful and provide a better overview of how equivalent growth achievements could be achieved in the education context. Notably, software startups have constituted a large part of the most lucrative and rapidly growing businesses over the last decade.

4 Proposed Approach

The research methodology is based on a triangulation of quantitative and qualitative methods [13] that will explore researchable facts through various types of investigation. Figure 1 outlines the methodology and connections between the research methods and RQs. In the first phase, knowledge and insight will be acquired through a literature review (RQs 1, 1.1, 1.2 and 1.3). The second research phase will have two directions. First, I will conduct investigations into SE practices in the growth phase of lean software startups (RQs 2, 2.1, and 2.2). Second, I will gather empirical evidence on how lean software startup practices can affect students' skills and startup formation mindsets (RQs 3.1 and 3.2) while introducing external activities to intensive SE project-based courses with multidisciplinary teams. In the final step to the investigation, I will address transferring lean startup practices to SEE curricula (RQ3.3) while proposing a model and framework, utilizing design-based research approach [14]. Design-based research relates to educational action research and design science, but it emphasizes educational improvement. Each iteration seeks to improve the previous artifact based on collected empirical evidence. The evaluation of the model and framework is outlined in Section 7. The data collected during these two parallel investigations will be both quantitative and qualitative and be analyzed in systematically and theoretically. For instance, a grounded-theory approach will be used to analyze the exploratory data, while other well-documented methods will be employed for surveys and literature reviews [13,15].

5 Expected Contributions

With the project, I expect to produce contributions to existing SE teaching and learning approaches and to fill gaps between industry and academia. There is a need to expand our understanding of SE trends. This study's literature review identifies a software startup practice gap within SEE. Startup formation may be a more pragmatic approach for master's students learning SE practices compared with present project-based learning and capstone courses.

Using a multidisciplinary setting and external stakeholder participation (e.g., during bootcamp activities) should also bring real-life scenarios into the software startup formation context. I expect that students will succeed in careers in SE startups. I intend also to contribute a sustainable model and framework fostering startup formation in the SEE context, one that can be developed to assist educators, researchers, and practitioners in making educated decisions regarding startup-oriented approaches for SE courses.

6 Results Presently Achieved

6.1 Software Engineering Education Trends

An overview of the evolution of SE trends in SEE is presented in Figure 2, which is taken from a more extensive literature review of SEE trends [12]. Agile software development was the primary SE trend investigated in SEE. Two other trends, emerging in 2013 and 2016, respectively, are global software engineering and lean software startups. Interest in the lean software startup SE trend has increased since 2016.

I have identified important dimensions of lean startups in SEE related to project-based learning—often combined with experience-based learning—lean and agile practices and tools, and multi- and interdisciplinary contexts. I have also observed a plethora of interactions among students, educators, practitioners, and researchers within the lean software startup trend.

6.2 Startup-driven SEE model

I used design-based research [14] to propose a model, Figure 3, unfolding dimensions underlying domains, sustained by empirical evidence collected from two consecutive iterations in our experience-based SE course at NTNU [16-21].

I propose in the model that both technical and soft skills are critical to the success of a student team. Students' prior competencies are the primary source of technical skills (**nodes 1 and 2**); team diversity makes teaching technical skills unrealistic, but soft skills can be taught effectively. An experience-based course builds good team dynamics with the active participation of teaching assistants and course leaders (**node 3**), while learning outcomes are defined from the beginning so that I have a precise understanding of the course's team benefits (**node 4**).

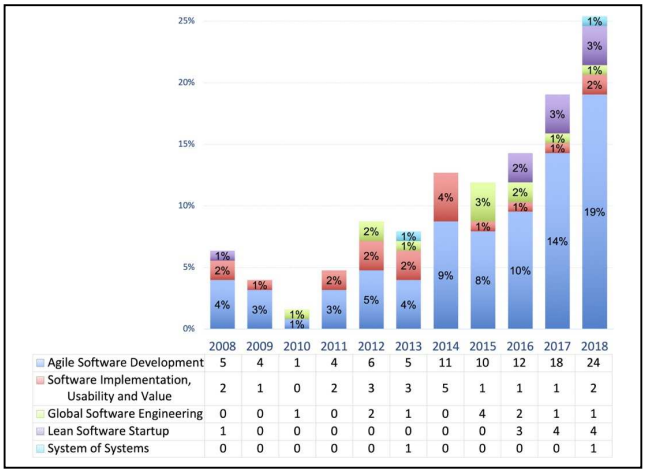

Figure 2. Focus of SEE research on SE Trends in time [12].

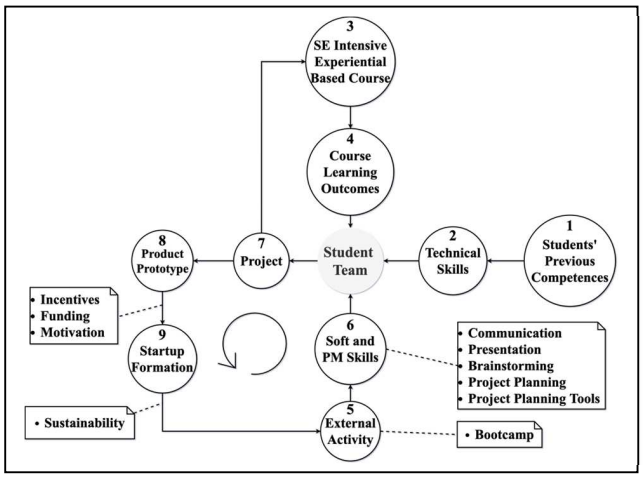

Figure 3: Our proposed startup-driven model [16].

External activity is key to developing realistic soft and project management skills (nodes 5 and 6). Teams are to deliver a worthwhile project (node 7) that is part of the course evaluation (node 3) or developed further into a functional product prototype (node 8). I observed greater interest in startup formation after the innovation bootcamp activity (node 9). Startup formation motivations can be amplified by (1) incentives, (2) funding, and (3) personal motivations. The course leader should (1) incentivize startup formation within the course, such as with networking with external stakeholders, and (2) provide applications for local funding opportunities.

6.3 Startup-driven SEE Framework

Our framework relies on dimensions from our previously proposed student team-centered model [16], our growth-phase startup research [22–26d], and opinions gathered from renowned experts in startup education. Figure 4 provides a graphical representation of the proposed framework characterized by its domains, with corresponding dimensions categorized into conceptual and practical areas. I categorized the course domains into four distinct parts, each with corresponding dimensions. The

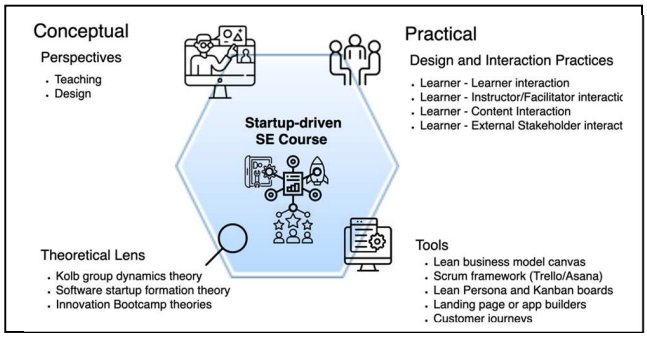

Figure 4: Our proposed startup-driven framework.

domains are a consequence of studies on lean software startups for education identified in our initial literature review [12] and throughout our empirical investigation in growth phase software startups. I later adopted similar approaches aggregated with our unique course design relying on particular dimensions. Specifically, course teaching and design perspectives are connected tightly to students' technical, soft, and project management skills.

7 Research Evaluation and Dissemination Plan

The research plan is divided into two phases. The phases are sequential, moving from a broad understanding of the research (Phase 1 – Figure 1) toward more specific knowledge that addresses the lean startup research gap in SEE (Phase 2 – Figure 1). The second phase is intrinsically connected to the first and involves further empirical evaluation. I have completed Step 1 and the empirical investigation covering Steps 2 and 3 in Figure 1. To propose a viable model and framework, I use SE-intensive experience-based project courses under the theoretical umbrella of project-based learning and growth-phase startup SE practices to enable student teams to create startups, supported by an innovation bootcamp external activity.

To assess the validity of the proposed model and framework, I have collected feedback from students in another popular SE project-based course at NTNU (Customer-driven Project). I have also used a Delphi method to validate the dimensions defined in the framework, relying on feedback from SE course leaders in several institutions. To further evaluate the proposed model and framework, I intend to conduct semi-structured interviews with SE course leaders in various institutions and lean startup practitioners. Lastly, I will apply the proposed model and framework to one or more conventional SE project-based courses.

Most of the research has already been disseminated [16-22], with 2 or 3 publications in journals such as *IEEE Access* and *IEEE Transactions on Education* before June 2022.

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REFERENCES

[1] Almi, N.E.A.M., Rahman, N.A., Purusothaman, D. and Sulaiman, S., 2011, March. Software engineering education: The gap between industry's requirements and graduates' readiness. In 2011 IEEE Symposium on Computers & Informatics (pp. 542-547). IEEE.

[2] Marques, M.R., Quispe, A. and Ochoa, S.F., 2014, October. A systematic mapping study on practical approaches to teaching software engineering. In 2014 IEEE Frontiers in Education Conference (FIE) Proceedings (pp. 1-8). IEEE.

[3] Force, A.J.T., 2013. Association for Computing Machinery (ACM) IEEE Computer Society; 2013. Computer Science Curricula.

[4] Clear, A., Parrish, A.S., Impagliazzo, J. and Zhang, M., 2019, February. Computing Curricula 2020: introduction and community engagement. In Proceedings of the 50th ACM Technical Symposium on Computer Science Education (pp. 653-654).

[5] Kuang, L.Q. and Han, X., 2012. The research of software engineering curriculum reform. Physics Procedia, 33, pp.1762-1767.

[6] Beecham, S., Noll, J. and Clear, T., 2017, May. Do we teach the right thing? A comparison of GSE education and practice. In 2017 IEEE 12th International Conference on Global Software Engineering (ICGSE) (pp. 11-20). IEEE.

[7] Garousi, V., Petersen, K. and Ozkan, B., 2016. Challenges and best practices in industry-academia collaborations in software engineering: A systematic literature review. Information and Software Technology, 79, pp.106-127.

[8] Lethbridge, T.C., Diaz-Herrera, J., Richard Jr, J. and Thompson, J.B., 2007, May. Improving software practice through education: Challenges and future trends. In Future of Software Engineering (FOSE'07) (pp. 12-28). IEEE.

[9] Herbsleb, J.D., 2007, May. Global software engineering: The future of socio-technical coordination. In Future of Software Engineering (FOSE'07) (pp. 188-198). IEEE.

[10] Bass, M., 2016, April. Software Engineering Education in the New World: What Needs to Change?. In 2016 IEEE 29th International Conference on Software Engineering Education and Training (CSEET) (pp. 213-221). IEEE.

[11] Beckman, K., Coulter, N., Khajenoori, S. and Mead, N.R., 1997. Collaborations: closing the industry-academia gap. IEEE software, 14(6), pp.49-57.

[12] Cico, O., Jaccheri, L., Nguyen-Duc, A. and 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, p.110736.

[13] Borrego, M., Douglas, E.P. and Amelink, C.T., 2009. Quantitative, qualitative, and mixed research methods in engineering education. Journal of Engineering education, 98(1), pp.53-66.

[14] Anderson, T. and Shattuck, J., 2012. Design-based research: A decade of progress in education research?. Educational researcher, 41(1), pp.16-25.

[15] Kitchenham, B., Brereton, O.P., Budgen, D., Turner, M., Bailey, J. and Linkman, S., 2009. Systematic literature reviews in software engineering–a systematic literature review. Information and software technology, 51(1), pp.7-15.

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

[17] Cico, O., Jaccheri, L. and Duc, A.N., 2020, October. Towards Designing an Experience-based Course around Innovation Bootcamps—A Cohort Study. In 2020 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE.

[18] Cico, O., Duc, A.N. and 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.

[19] 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.

[20] Cico, O., Duc, A.N. and 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.

[21] Cico, O., Jaccheri, L. and Duc, A.N., 2021, October. Seeing the voice of the student: A pilot study of customer-driven courses. In 2021 IEEE Frontiers in Education Conference (FIE) (pp. 1-8). IEEE.

[22] Cico, O., Duc, A.N. and Jaccheri, L., 2020. An Empirical Investigation on Software Practices in Growth Phase Startups. In Proceedings of the Evaluation and Assessment in Software Engineering (pp. 282-287).

[23] Cico, O., Souza, R., Jaccheri, L., Duc, A.N. and Machado, I., 2020, November. Startups transitioning from early to growth phase-A pilot study of technical debt perception. In International Conference on Software Business (pp. 102-117). Springer, Cham.

[24] Cico, O., 2019, November. Technical Debt Trade-off-Experiences from Software Startups becoming Grownups. In International Conference on Software Business (pp. 413-418). Springer, Cham.

[25] Cico, O., Besker, T., Martini, A., Duc, A.N., Souza, R. and Bosch, J., 2021, November. Toward a Technical Debt Relationship with the Pivoting of Growth Phase Startups. In International Conference on Product-Focused Software Process Improvement (pp. 265-280). Springer, Cham.

[26] Kazemi, G., Cico, O., Nguyen, Q.T. and Nguyen-Quang, A., 2021, December. Risk Exposure and Management in Software Development–A Survey of Multiple Software Startups. In International Conference on Software Business (pp. 98-104). Springer, Cham.