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Facilitating Entrepreneurial Experiences through a Software Engineering Project Course

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***Abstract*—Skills and competencies in entrepreneurship, such as the ability to generate innovative ideas and the courage to engage with stakeholders and society, have gained importance in engineering curricula. In this case study paper, we report on how we have integrated entrepreneurial experiences into a software engineering project course and made the creation of value and reflection on the application of a structured process the heart and soul of the course. Based on current research on entrepreneurship education as well as the definition of entrepreneurial competencies used by the European Union, we show how the learning objectives, the teaching moments, the integration of external stakeholders, and the assessment work together to create an entrepreneurial environment in which students are encouraged and rewarded to work in an entrepreneurial way. Based on data from reflection reports, course evaluations, and interviews we discuss the pros and cons of our approach and how the student perception and expectations often run counter to the motivations of the course design. We thus contribute guidance for other teachers based on our own experiences in relation to the findings of our peers.**

I. Introduction

We are currently in a time of transition, where engineering education is being rapidly redefined to not only cover the traditional core subjects of the engineering domain, but to also encompass new competences such as sustainable development [1] and ethics [2] as well as generic engineering competences like communication and project management [3]. It is usually acknowledged how engineers need "T-shaped" competences or "21st century skills" [4], so that their deep domain specific knowledge is complemented with skills ranging from being collaborative team members, managing projects as well as embracing life-long learning while acting in a responsible way. Lately, entrepreneurship has been added to this list and thus to the backlogs of institutions and teachers.

In contemporary entrepreneurship education, entrepeneurial skills relate to both the ability to set up a small enterprise [5] and to more generic skills valuable in any career — such as opportunity-seeking, taking initiative and self-awareness [6]. Accordingly, in integrating entrepreneurship into educational offerings universities can take a narrow or broad approach [7]. The latter shifts the focus to support students and their future employers to be adaptive and flexible in a technical and economical landscape under an increasing rate of change, reminiscent of agile methodologies [8]. The "best way" to teach entrepreneurial skills is, however, not yet clear and many different approaches exist, all with advantages and drawbacks [9].

While all this seems fair and reasonable it still poses a number of questions for teachers and program managers about how to manage the transition. And while entrepreneurship in engineering education and STEM education is a burgeoning research topic, there seems to be very little work focusing on the pros and cons of the particularities of introducing entrepreneurship in software engineering education, in particular also taking into account the student experience. We therefore set out to explore:

RQ1: How can software engineering education facilitate entrepreneurial experiences?

RQ2: How are entrepreneurial experiences in software engineering perceived by undergraduate students?

We answer the first question by outlining the design of a software engineering project course and how it maps to the broader definition of entrepreneurship. To this end, we report on the course structure and how the different elements are connected, e.g., showing how integration of external stakeholders can be an important aspect in ensuring that external value creation is considered. Further, we discuss how agile processes in software projects can facilitate focus on the creation of customer value and on constant feedback from the customer, but do not have a strong emphasis on ideation.

The main contribution of this paper is thus a description of how to operationalise entrepreneurial experiences that focus on taking action and managing resources in an agile software project, so that other software engineering educators may relate the perspectives put forth to their own practice, or even adopt specific course design aspects. In relation to previous work on how agile processes can be leveraged to help students develop entrepreneurial skills, we propose an alternative approach to stakeholder involvement, where a specific customer is defined at the outset of the course and acts as product owner.

We evaluate the approach from the student perspective derived from interviews, reflection reports and course evaluations gathered over two course instances. While we see that a majority of students enjoy working with external stakeholders, they also struggle with adapting their academic credentials to a real-world setting, specifically when transferring technical skills gained from labs to professional technology chains.

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II. Entrepreneurship – A Primer

In a broad definition of entrepreneurship, value can be defined in terms of creating change in a given context [10], [11], [12]. Change here concerns differences for individuals or organisations, and for the environment in which the process has taken place. An entrepeneur is then a person who is capable of creating change in the surrounding environment [10], [11]. Hindle states that *"The new value may take many forms: economic, social, monetary, ecological, mental, physical, etc."* [13] so that value can be measured as dollars or yens but also represent a positive change in an individual's health or empowering minorities in democratic processes. A complimentary definition focuses on the creative process, the ability to assess the current situation in terms of goals and resources, plan a relevant interaction with other people, carrying it out and evaluate the outcome in terms of new resources or new goals [14], [15]. In order to conceptualise the capacity of students to create change in their surrounding environments, the EU has defined 15 entrepreneurial competencies, divided into three major building blocks; *Ideas & Opportunities*, *Resources*, and *Into Action* (see Figure 1, taken from [6]). The 15 competencies are not orthogonal but interrelated and interconnected and should be seen as parts of a whole.

Ideas & Opportunities covers competencies for identifying opportunities to create value in terms of better solutions to new or existing challenges, formulating and adhering to a vision as well as being capable of assessing the possible values of ideas from various perspectives while acting responsibly. *Resources* regards skills such as reflecting on the needs of different stakeholders, acquiring new resources and using existing ones in an efficient way, developing economic know how and ensuring the collaboration of relevant stakeholders to be able to deliver value. *Into action* refers to the ability to initiate processes, tackle challenges and create short-, medium- and long-term objectives. It also involves defining priorities, adapting to unforeseen changes and making decisions based on partial or ambiguous knowledge in an evolving context. Competencies such as networking and collaborating with others are essential, together with the skills necessary to apply a structured process to test and evaluate ideas and prototypes while reflecting on and learning from both success and failures.

At our university there is currently an initiative to expose more students to entrepreneurial experiences during their undergraduate studies. The project is supporting an educational shift from telling the students what they need to know in the future to engaging them in value-creating processes now. The initiative follows the EntreComp model where *Into Action* is defined as: through interaction with other people understand their needs and wishes to create an artefact representing value for them; *Ideas & Opportunities* is realised through an iterative process to generate, implement, evaluate and package an idea in a relevant context to ensure value for others; and *Resources* is the ability to identify and use both your own and other's resources, the courage to handle uncertainty, using a reflective mindset, with the objective to create value for others.

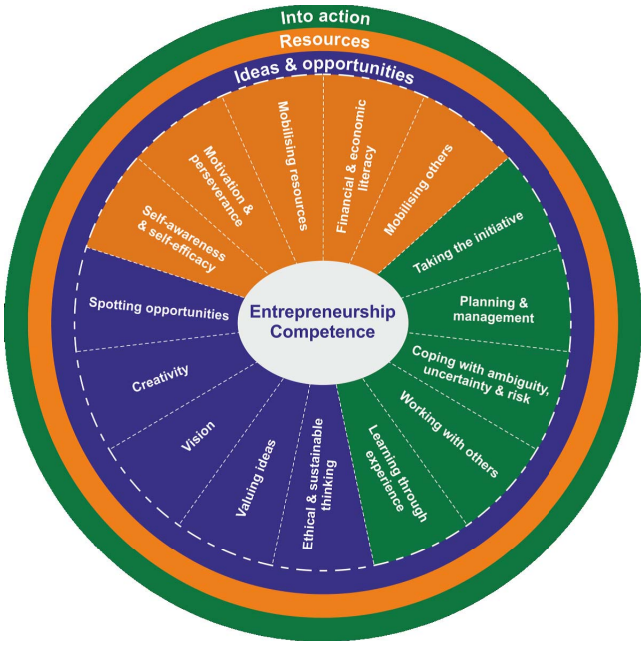

Figure 1. The EU representation of entepeneurial competencies [6]

Thus, the University ambition is not that all students should become business developers, but rather to expose a majority of the students to entrepeneurial experiences by participating in activities that *create value for someone else*, *through a structured process* that transforms an idea into perceived value *while reflecting* on the use of resources, how uncertainty has been managed, and the own ability to act.

III. Related Work

Following a shift in entrepreneurship education research from viewing entrepreneurship narrowly as venture creation to instead focusing more broadly on value creation, the approach suggested in entrepreneurship education research for developing entrepreneurial skills in students have shifted from teaching *about* or *for entrepreneurship to* teaching *through entrepreneurship* [16], a matter of engaging students in entrepreneurial experiences. In general, it has been suggested that such an educational format should be active, start from student's previous experiences, that students should act autonomously and take responsibility for actions and their impacts, and should create and implement ideas and artefacts towards specific audiences [12], [17], [18].

The question of how entrepreneurial experiences can be facilitated specifically in software engineering has attracted interest in later years, with growing recognition of the importance of entrepreneurial skills among software engineers [19]. Specifically, authors have pointed to many similarities between contemporary perspectives on entrepreneurship and agile methodologies, both focusing on iteration, flexibility and stakeholder interaction in the face of uncertainty and unfolding creative processes [20]. In terms of teaching, most authors

advocate engaging students in *project work* in autonomous teams using structured processes, towards the solving of *real problems*, involving *real stakeholders* (customers or experts) both during the process and at final presentations [21], [22], [23]. We also follows this approach, but ensure that students always interact with *the same* external stakeholders.

From applying such a format, Fernandes et al. [24] argued that while these ambitious approaches seem successful for promoting entrepreneurial skills among software students, they do come with a difficult trade-off between market aspects and technological aspects. In their study, a number of student teams ended up focusing more on technical aspects and developed their ideas according to their own views, rather than really taking into consideration the views of potential customers, even though externals were invited to regularly provide feedback on student projects. Beyond the development of entrepreneurial skills, a reward of achieving a proper balance between customer and technology focus seem to be that projects can result in extended professional networks, job offerings and even start-up capital for students [8], [24].

IV. Methodology

We use a deductive and qualitative approach [25], [26] to answer our research questions since we strive to clarify the relationship between course elements and possibilities for entrepreneurial experiences. Thus, we use the definition of entrepreneurship as described in Section II as our theoretical framework for analysing our course on software engineering and the students' perception of their participation.

The data for the course elements were accessed through the course syllabus and course descriptions for the spring of 2017 (58 students divided into 10 teams) and 2018 (88 students in twelve teams). The students taking the course were in their last term in three different bachelor programs – business management for IT, software engineering and computer science. Students worked in teams of five to seven (three in one case) and were asked to develop a demonstrable software prototype that delivers stakeholder value as part of their project work. In total the workload represents 7.5 ECTS or 200 hours per student. Seven out of ten weeks are dedicated to the project.

In both instances the external stakeholder was a consortium collaborating on a new platform for data-sharing to optimise port calls. As a motivating example, in a scenario such as berthing, the vessel, the pilot and the tug boats need to be at the agreed upon meeting place at the same time while the mooring personnel should be at-hand when the vessel approaches the docks. This is coordinated by sharing timestamps for planned, commenced and completed actions through a shared messaging format implemented by the consortium. In 2017 each student team was assigned to create an application that would help a specific actor (such as the captain of the vessel, the tug boat operator or the pilot) to participate in the data sharing. Each team then visited their end-user at their work place to see the end-user needs and held weekly meetings with three consortium representatives who acted as the teams' Product Owners (PO). The same setup was used in 2018 but with a new version of the platform and a generic Android application. The assignment was then to tailor the application to meet the needs of the designated end-user. Thus, in both instances the student teams had an external PO as well as an external end-user. At the same time the teams were also required to negotiate with the other teams in order to receive data relevant for their own application and submit data needed by others.

We analysed two major blocks of data, one block relating to the course organisation and one block to the student perception. The data regarding the course was analysed by determining for each course element if it corresponded to one or more entrepreneurial concepts. Data regarding the student perception was obtained through interviews, the teams' reflection reports for the course instances and the standardised course evaluation forms sent out to each student after the course was completed. We also used data from the course evaluation of the course instance in autumn 2018 as a complementary data source. Ten formal interviews with volunteering students were conducted between one and four weeks after the course ended and lasted between 45 and 60 minutes. The participating students were rewarded with a cinema ticket. The author responsible for interviews and field observations is not a teacher in the course but participated in multiple activities as an observer in the spring of 2017. The interviews were recorded and later transcribed. They were complemented by informal interviews during course activities where notes were taken. The informal interviews were used to get the students' *reflection-in-action* [27], while the formal interviews served to understand the students' *reflection-on-action* [27] on collaborating with an external PO and end-user.

The reflection reports were written as part of the assessment (see Section V-D) and obtained from the teams' repositories after the last scheduled course activity. The course evaluations are managed by the student administration of the university and include both questions that are answered on a Likert-scale and free-text comments. The individual replies are anonymised and summarised into a report distributed to the teachers and made public through the university web page.

The student data was analysed by relating statements to entrepreneurial experiences. For the course evaluations we only included the free-text comments, disregarding the numeric values due to the low response rates (below 35%). Just as for the other textual data, the comments were compared to the entrepreneurial concepts as a complimentary source to the interviews and reflection reports. Here it is worth pointing out that since the course design is for a software engineering course, the students are not asked to use the terminology or the theory of entrepreneurial experiences as introduced in Section II. They thus do not apply this terminology in their reflections either. This meant that we went through the texts in a *deductive fashion* [25], [26], looking for evidence where the students describe entrepreneurial experiences which we then grouped according to the three themes of *Ideas & Opportunities*, *Resources* and *Into Action*. The outcome in relation to the course organisation is detailed in the next section while the student perception can be found in Section VI.

V. Designing for Entrepreneurial Experiences

In this section, we describe how the course's pedagogical concept, the intended learning outcomes, the teaching moments, and the assessment in the form of reflection reports are connected to EntreComp's entrepreneurial competencies.

A. Pedagogical Concept

The course design is focused on teaching students a systematic way to deliver stakeholder value. We use a *project-based learning approach* in which the students are asked to deliver value to an *external stakeholder*, usually a company but sometimes also a research project or institute. As such, the project is a simulation of product development in reality. The students are asked to work with a high degree of autonomy and teach themselves critical technical skills such as new tool-chains and programming languages. Depending on the concrete product, the technical solution uses existing elements that need to be mastered by the students. The students receive limited technical support, usually through the organisation that is represented by the external stakeholder. Teaching itself focuses on the development process and project management skills. In particular, we use Scrum to structure the project in an iterative-incremental fashion with one week sprints, a product and sprint backlog, and sprint reviews as well as sprint retrospectives as prescribed ceremonies.

Since learning takes place as part of a project, a real-world problem motivates students to produce and reflect on a series of artifacts that address the questions related to the original problem [28]. Krajcik states that in such environments *"communities of students, teachers, and members of society collaborate on questions or problems* [where] *the result is a series of artefacts or products that address the questions or problems"* [29]. Processes and procedures can also be part of the intended learning outcomes since process-oriented projects can *"help students acquire science-process skills such as the ability to pose a researchable question, identify and formulate a hypothesis, design and conduct an investigation, collect and analyze data, draw valid conclusions, and document and report findings"* [30]. Subsequently, project-based learning is one recommended approach for teaching entrepreneurial experiences, (cf., e.g., [31]).

Due to the presence of the *external stakeholders*, students are engaged in providing a demonstrable result to the PO every week. The students also need to handle conflicts between products and process and negotiate scope [32].

B. Intended Learning Outcomes

The current intended learning outcomes are the result of an evolution from a focus on the product, over a focus on the process, to a focus on value. This evolution was a reaction to the insight that students tend to focus on the delivery of a project and in doing so neglect learning outcomes that are connected to their use and reflection on the development process [33]. However, a focus on the process alone is insufficient: if there is no value created within the process, it becomes an end to itself and students will not understand the purpose of the process. Entrepreneurial skills are being fostered since the students deliver value in their project [10], [11] and follow a process that includes ideation, planning, interaction, implementation, and evaluation [14], [15]. To achieve this focus, we have revised the learning objectives to clarify that the students are intended to learn about creating value for various stakeholders, including their own development team. After the completion of the course, the student should be able to:

1) describe the relationship between stakeholder, product, and process
2) specify, implement, and evaluate a system based on what different stakeholders perceive as valuable
3) learn tools and APIs which are relevant for the project in collaboration with the other team members
4) apply a structured software development process as a member of a team
5) reflect on the own and the team's learning strategies

Apart from the first intended learning outcome which lays the foundation for the work in the course, all others can be directly tied to entrepreneurial competencies as defined in Section II. The *Resources* competency is covered by item 3, in particular w.r.t. *mobilising resources*. *Into Action* is addressed by item 5, in particular w.r.t. *learning through experience*, *working with others*, and *planning and management*. Item 4 also addresses *working with others* and *planning and management* but also covers *taking the initiative*. Finally, the *Ideas and Opportunities* competencies are addressed by item 2, in particular w.r.t. *spotting opportunities* and *valuing ideas*.

C. Teaching Moments

While the intended learning outcomes have changed in order to clarify the relation to value, the teaching moments have been relatively stable over the years. A breakdown of the teaching moments, a description, and their relation to entrepreneurship can be found in Table I. The course starts with two intense weeks of introductions in the form of lectures and workshops and then switches to a project format in which the students apply the Scrum project management methodology with sprints of one week. During the seven week project phase there is no additional theory, but students are asked to apply their knowledge and develop their skills through continuous reflection which is supported by the weekly supervision.

D. Assessment through Reflection

All assessment is based on reflection reports around a number of pre-defined topics. Smith states that reflection is "assessment of what is in relation to what might or should be and includes feedback designed to reduce the gap" [34] which can be boiled down to describing:

- the current situation or "what is" (A),
- what you want the situation to be or "what might or should be" (B), and
- a plan for getting from where you are to where you want to be or "feedback designed to reduce the gap" (A $\rightarrow$ B).

We encourage a reflective and explorative mindset in the course by letting the students reflect every week, both on an

Table I. The different teaching moments of the Software Engineering Project course and how they relate to entrepreneurship.

Week	Moment	Description	Relation to Entrepreneurship
1	Introduction to Software Engineering	Brief introduction to software engineering (SE) that motivates SE as an engineering discipline and outlines some fundamental aspects such as software quality and the need for a systematic approach to develop software, including iterative-incremental development, agile principles and practices, definition of done, and basics of software testing. We mention design documents and their relation to requirements as well as how they can be used to steer acceptance tests.	*Resources*: students acquire skills necessary to evaluate the value they create *Into Action*: a structured process and a way to address uncertainties is introduced
	Continuous improvement with a Kata exercise	We use the Kata to Grow exercise [36] to put students in the mindset of continuous experimentation with new ideas and their continuous improvement. Student groups are asked to complete a simple puzzle in minimal time, then reflect on their experience, devise a new strategy, and do it again. During the six iterations, the teachers change the rules (e.g., the puzzle needs to be face down) to challenge students to generate new problem solving strategies. With the help of a form, students track goals for each iteration, the changes they made as well as the solving times and are able to reflect on which changes had the most impact on their solution times.	*Ideas & Opportunities*: students develop and test new ideas to create value more efficiently *Into Action*: a systematic (iterative and incremental) process to plan, execute and reflect in order to become more productive, learning through experience
	Lego© Scrum simulation	We introduce the notion of creating value for someone else with potentially divisive ideas about what is valuable in a Lego© Scrum simulation following the guidelines in [37]. Over the course of the simulation, students begin to understand the notion of value and how their actions influence if value is created or not. It also teaches them to negotiate with the PO and thus provides them with the necessary courage to, e.g., speak up against unreasonable changes. The students also learn very basic requirements elicitation skills that allow them to focus the scope of the product and to elicit the information they need. Students reflect on the experiences from the simulation and their meaning for their later project work after the simulation.	*Ideas & Opportunities:* students need to understand the stakeholder's vision and assess the value they create *Resources*: available resources have to be used efficiently and stakeholder cooperation has to be established *Into Action*: Creating value for and acquiring ability and courage in interacting with the PO
2	Project introduction	The project introduction is the first time the students are exposed to the external stakeholder (i.e., the "customer") who they will create value for and marks the beginning of the ideation process. The PO presents a vision of what they want to achieve, usually in rather broad terms, but sometimes also in more specific ones.	*Ideas & Opportunities*: the PO's context and vision serves as a foundation for the teams' ideas
	Technical introduction	The underlying technical platform, representing one of the important *Resources* in the project, is introduced by a developer representing the external stakeholder. The students are then given a motivation for the platform design, an introduction to what the platform provides in terms of resources and a working example for how the platform can be used. After the introduction there is time to discuss what additional resources the students can use and the impact of the technical framework on the type of value they can create. A common question is if it is allowed to use other data sources, such as maps or simulated GPS data. The availability of technical support is also discussed.	*Resources*: students learn about available technical resources, discuss possible additional resources and which skill and knowledge gaps need to be addressed *Into Action*: students reflect on the impact of the technical framework on the value they can create, planning
	Elephant carpaccio exercise	Translating novel ideas into actionable requirements that deliver value for a potential customer is a challenge for students. Therefore, the course dedicates a lecture and an exercise to agile requirements engineering in order to allow students to put value creation *Into Action*. The lecture introduces vertical slicing of user stories as a means to ensure that customer value is delivered with each story and each task. We introduce the INVEST [38] criteria for user stories and the SMART criteria [39] for tasks. The students then get to apply their new knowledge and develop skills by applying Alistair Cockburn's *Elephant Carpaccio* exercise as adapted by Henrik Kniberg [40] to create as many vertical tasks (or slices) as possible for a shipping cost calculator. Importantly, each task needs to create a bit of customer value. Students struggle with creating sufficiently small and vertical tasks. Based on the suggestions of the students, we discuss that tasks that focus only on one architectural layer (e.g., user interface) do not deliver customer value. We also discuss the value of delivering small pieces of functionality such as the ability to only set the price, but leave the number of items and the country fixed as well as the value (or lack) of embellishments.	*Into Action*: students learn how to write requirements and plan with them to maximise the delivery of customer value and the creation of team value, tools for decomposing large ideas into manageable tasks
3–7	Project work in team	Students work in teams of five to seven to create stakeholder value throughout the project part. In iterations of one week, they use the user stories they created based on stakeholder input to develop an increment that they can demo to the PO to receive feedback. A Slack channel allows students to exchange information with other teams, with technical support, and — in a limited way — with the PO. The teachers are available on Slack to answer questions related to the process or the course as a whole. During the project work, the students need to plan and manage their work and their work environment, continuously learn both in terms of the product as well as in terms of the technical infrastructure they use, use the resources at their disposal to create value the best way and to address the uncertainty and the risk inherent in the project. We also encourage them to share their experiences and help and mobilise others to achieve the best overall outcome. These aspects are also picked up in the weekly reflection (cf. Section V-D) which is usually performed as part of a sprint retrospective.	*Ideas & Opportunities*: valuing ideas, opportunities for creativity, spotting opportunities; *Resources*: optimal use of resources to create value within the given time frame *Into Action*: creation of value for the team and other stakeholders through a systematic process

Continued on next page.

Week	Moment	Description	Relation to Entrepreneurship
	Supervision	During regular supervision sessions, the PO discusses the product and its value with each individual team, giving feedback on what has been achieved in the past sprint and providing input to the planning of the next one by evaluating the next user stories and giving priority to them. Most teams run their sprint retrospectives or conduct a Scrum of Scrums during that time. The sessions allow students to apply and refine their abilities to discuss the product and its value with the PO, in particular in negotiations about the scope of the next sprint and the priorities in which different user stores will be tackled. The discussion with the teachers revolves around how the individual team's process influences their ability to create value. Students are encouraged to explore different alternatives in the way they define their process and evaluate whether these alternatives have an influence on their performance, similar to the Kata to Grow exercise. Students, e.g., experiment with different key performance indicators to measure their performance, try pair programming, test-driven development or other paradigms. We make it clear that — as long as students reflect on their experiences — there is no "failure" in this regard. However, we emphasise certain aspects such as the importance of effort estimations and defining velocity and how students work with these concepts to ensure that students adhere to the main ideas of the Scrum method and develop an appreciation of planning their work and improving their related skills.	*Resources*: interaction with stakeholders to scope the project and ensure that existing resources are used optimally, discuss acquisition of new resources, valuing alternatives when desired resources are not available (i.e. when the required data is missing, should they stub the interface, simulate a system or generate random values?) *Into Action*: reflection on process implementation and value creation, decision making under uncertainty, planning and executing interactions with external stakeholders and other teams in order to define and create value
4	Guest lecture	The guest lecturer is a former agile coach and PO at a large Swedish company in the music industry and is currently the CTO of a start-up that brokers micro-loans. The lecture focuses on the *Resources* aspect of entrepreneurship, in particular how the internal organisation of a company influences its ability to create value and how the individual development team, their ceremonies, and their mindset can influence this ability. Anecdotes from the lecturers personal experience support these arguments. Concrete suggestions for the students include developing a common vision with the PO and an emphasis on rapid feedback.	*Resources*: relation between process, organisation and ability to create value
7	Concluding lecture	The final lecture in the course is used to tie the experiences of the students together with entrepreneurial skills and the learning objectives in general. This is the first time that the students are explicitly exposed to entrepreneurial concepts and we connect their experiences and the intended learning outcomes to the different components of entrepreneurship as described in Section II and outlined in this table. We also outline how the intended learning outcomes are connected to entrepreneurial competencies and which elements of the course have contributed to the development of these competencies. We then discuss with the students how this new insight influences their retrospective experience. As part of the concluding lecture, students also get the opportunity to incorporate aspects of entrepreneurship into their reflections and to receive feedback on their thoughts surrounding how they have worked with this topic.	*Ideas & Opportunities*, *Resources*, *Into Action*: relate course syllabus and experiences in the course to entrepreneurship
8	Final presentation	During the final presentation, each team demonstrates their application to the other teams, the POs, the end-users, and other external stakeholders with a focus on *Ideas & Opportunities* and the value created. Other interested parties from the consortium attend these presentations and provide additional feedback. The students do run-throughs of a typical port operation and demonstrate their products and receive feedback on the value that has been created. This is also an opportunity for students to present themselves as future employees and for the consortium members to look for potential recruits.	*Ideas & Opportunities*: Demonstrating the value of the created product for the PO, the end-users, other external stakeholders, and the other teams, obtaining feedback *Into Action:* Planning and carrying out interaction with external stakeholders
9	Reflection reports and supporting artifacts	The course is examined with *individual reflections* and *team reflections*. The former focus on how the student created value for other students in the own team or in other teams and for the external stakeholders. Specifically, the students are asked to address a number of questions, using the A, B, A $\rightarrow$ B reflective loop described in Section V-D: what do I want to learn or understand better; how can I help someone else or the entire team to learn something new; what is my contribution towards the team's application of Scrum; what is my contribution towards the team's deliveries. The questions focus both outwards ("someone else", the "entire team") and inwards ("what do I want to learn"). Students are thus asked to think about the value they create for themselves as well as for others, reflect about their abilities, and identify the opportunities they have by reflecting on their own contribution to this external value. By thinking about ways to contribute repeatedly, students are also encouraged to scrutinise and challenge established practices. The *team reflection* also happens on a weekly basis and most teams use topics defined by the teachers as a kind of agenda for the retrospective meetings.The category *Value and Scope* focuses on the creation of value and how the team measures its success in delivering this value, thus addressing *Ideas & Opportunities*. It also addresses how the value is translated into actionable requirements that the team can then implement, thus addressing *Into Action*. Within *Social Contract and Effort*, the students relate the *resources* they have at their disposal in terms of their work hours with the rules they use to ensure that value is created in every sprint (*Into Action*). In the category *Design Decisions and Product Structure*, students relate their practices for the creation of the product to the value these practices create, both for the team as well as for the PO. They thus reflect on the *Resources* at their disposal and how they put them *Into Action*. Finally, the category *Application of Scrum* discusses how the students have used the process to manage uncertainty, split up work, and incorporated new input into the process. These issues refer to *Into Action*.	*Ideas & Opportunities*: Valuing ideas, relating vision to delivered value; *Resources*: Describing and motivating the developed resources so they can be used by someone else *Into Action*: reflection on process implementation and value creation, decision making under uncertainty

individual as well as a team level [35]. The reflection addresses many aspects such as stakeholder value, the use of resources, and the students ability to interact with the stakeholders as discussed in Section II. The details about both the individual reflection and the team reflection are described in the final row of Table I. Only the final report — in which previous reflections are summarised — is graded.

To address the intended learning outcome "reflect on the own and the team's learning strategies", the students each week write down what they have achieved in relation to last week's ambition, what they would like to achieve for the next week and how to make the change happen. We let them address different issues each week as long as they motivate the change and evaluate the outcome of the previous week (e.g., by describing the current situation). This reflects the progression in the course where, in the beginning, technical challenges and learning new frameworks is, e.g., the initial challenge while defining the scope becomes more relevant later on.

Overall, the individual and the team reflection focus students on different aspects of an entrepreneurial project: the individual contribution to the value within the team and the value created for others. The second aspect is achieved through the team reflection in which students discuss how the decisions of the team have influenced the perceived value from different stakeholders' perspectives, how they have used the resources at hand or gained access to new resources, how they managed the uncertainty in using new tools and technologies as well as defining what they are supposed to be able to deliver as their understanding of the environment and the needs of the end-user become more clear. The ability to act and take responsibility is emphasised during supervision. The product plays a crucial role since a product increment is essential to receive feedback from the PO and to understand the process. Without action, there are no experiences (entrepreneurial or otherwise) to reflect on [41].

VI. Student Perceptions and Experiences

We report the student perceptions in accordance to the three competencies defined by EntreComp (cf. Section II and [6]. In terms of *Ideas & Opportunities*, we found that breaking with what students were used to seemed to initially cause unease and confusion among the students as to how their preconceptions mapped to their factual experiences. For example, one student pointed out that:

> "It took me a while to figure out that it was not as much about producing something, but rather about the process of producing something" (Student interview)

While some students think that "*the focus of the project should be clearer*" (Course evaluation Spring 2017) some students do appreciate the realistic nature of the course and that not all issues had clear answers provided by the teachers. However, students also felt a sense of frustration about the fact that the finally delivered product is not part of their assessment:

> The learning outcomes had no connection with the deliveries in the project. This made it difficult to decide if focus should be on pleasing the POs or the examiner. Combine their interests in order to drive the students.
> (Course evaluation spring 2018)

That said, several students report that they were motivated by getting the opportunity to create value for someone else. They expressed a sense of meaningfulness in being able to create a positive difference with the respect to the external stakeholders' ongoing practice:

> It felt like we could actually contribute with something, when we showed our solution to them they were actually happy with it. It felt much better coming from someone who is not a teacher. I mean, these people are knowledgeable and have an outside perspective. (Student interview)

Which leads us into *Resources*. While the course has been running for several years and has been continuously improved over the years, the course evaluations vary quite a bit over the different course instances. There seems to be a correlation between the overall assessment of the course in the course evaluation and how closely the technical platform is aligned with the knowledge and skills the students already have:

> I didn't have enough programming skills, the step from simple labs in Java, which pretty much is what we have done in earlier courses, to running a project with new languages and at the same time trying to use Scrum was too big.
> (Course evaluation spring 2017)

In general, the students are ambivalent about the teaching approach and the level of uncertainty introduced by an external stakeholder and an open problem. In these regards, the course breaks with the student expectations and what the students are used to. While some students appreciate that and comment positively on this in the evaluations, there are also those that complain bitterly about it. This also means that students cannot apply their successful learning strategies from previous courses and need to invest resources to develop a new approach. This can cause significant anxiety, in particular for students that feel a high pressure to receive top grades:

> The problem is that everyone wants a good grade. When we get a task that contains the need for so much knowledge we still have not be taught in, we are getting super stressed. The people who don't have the knowledge get sad, angry and are feeling unneeded (and every person wants to feel needed). Those who have the knowledge are angry because they do 90% of the work and are getting stressed about getting a good grade.
> (Course evaluation autumn 2017)

An argument can be made that students are able to create more value if they are familiar with the technical foundation they need to apply. However, it is an explicit aspiration of the course to move students out of the comfort zone of their "*simple labs in Java*" and let them apply the resources they have acquired in those labs to an open problem. After all, as engineers the value they can create is limited if they are only prepared for simple labs. Another student argued how creating value for someone else had helped him in identifying what he already knows and what he had learned in the program and thus providing him with an opportunity to reflect on his self-awareness.

Regarding the structured processes as a resource for creating value, many students appreciated learning about the Scrum methodology as a tool to organize their projects:

> The practical setup and "trial and error" approach. You learn better from making mistakes, rather than doing it right the first time. (Course evaluation spring 2017)

However, some students were anxious about adopting Scrum "the right way" and were not sure whether they had managed to do so.

> [What is missing is] a way to verify that we are implementing scrum in a correct way (Course evaluation spring 2017)

Finally, in terms of *In Action*, the students appreciated how their own ability to work in a structured way influenced whether or not they could create stakeholder value:

> Learned a lot about handling a big team in a semi chaotic project, just like in working life. (Course evaluation autumn 2017)

Students also appreciated the possibility to train their teamwork skills and the relative freedom of defining the process and they see the relation to reality:

> It was fun, felt like a real workplace and we really got to work with group dynamics, work delegation and trying to find out about our own preferred ways of working. (Course evaluation autumn 2017)

As an example of how the students experience the *interaction between the three dimensions of entrepreneurship* we have chosen the following quote:

> Towards the end, the group's knowledge of the development environment improved and the group could more efficiently provide new functionality demanded by the product owner and end user. The group had thus come across a small threshold, which led to a greater understanding of their own limitations. As a result, the scope continued to scale down, and the prioritization scheme set by the product owner was used as a template to gradually deliver a little bit of what was demanded by end users and product owners. (Reflection report spring 2018)

Here we can see how the understanding of what ideas to pursue ties in with the mastering of the resources and collaboration with the PO. The quotation also serves to remind us that the three competencies are not orthogonal and clearly distinguished but interlinked and dependent on each other.

VII. Discussion

In relation to **RQ1:** "How can software engineering education facilitate entrepreneurial experiences?", we believe that the described course illustrates that applying agile methodologies in project-based courses creates opportunities for entrepreneurial experiences in software engineering courses, since they can be readily applied in student projects to take ideas into action.

Our project course puts a strong emphasis on the creation of value, both for an external stakeholder as well as for the team and other students. It thus focuses on the entrepreneurial competencies *Into Action* and *Resources*. This emphasis is engrained in the intended learning outcomes and we achieve it through the teaching moments, the integration of an external stakeholder in the crucial parts of the course, and an assessment focusing on reflections about what value is created for whom.

The introduction of external stakeholders gives some framing and direction for students' ideation processes, which is not provided by Scrum itself. In contrast to previous work on entrepreneurial experiences in software engineering, which have outlined how externals can be invited as guests, panelists or be sought out by students to provide customer feedback [8], [22], [24], we have detailed an approach using an external stakeholder as PO. This ensures that students need to manage the reality of stakeholder feedback, and do not end up primarily developing solutions according to their own views.

However, as a consequence of introducing a specific PO, ideation and opportunity search is less supported by the course setup. In contrast to a course design in which students generate ideas in an unconstrained environment [24], students tend to stick to relatively conservative ideas, potentially in an attempt to minimise the risk of the project. This is not a problem in itself, but limits the usefulness of the course to address the *Ideas & Opportunities* aspect of entrepreneurship. It is an open question how much focus can be put on such an aspect in a course in which some tangible outcome needs to be produced within a limited period of time. Even though the product is not being assessed by the teachers, it is a necessary part of the course to show students how a structured way of working influences their ability to create value in the product. Shifting focus away from product creation and towards ideation would thus negatively impact those aspects of the course that are the most important w.r.t. the intended learning outcomes.

In carrying out a challenging Scrum-based project, students need to explore opportunities for action, gather and responsibly manage resources (e.g., knowledge, time), and mobilise these to create software that delivers valuable functionality. Through such experiences, students need to develop and use many of the entrepreneurial competencies outlined in the EntreComp framework [6]. The teachers provide scaffolding for this by discussing systematic requirements engineering and how to talk to external stakeholders. We also find that the iterative-incremental cycle of Scrum and the focus on reflection is well-suited to the development of entrepreneurial skills, a conclusion also drawn by Tolfo et al. from asking software teachers and practitioners about their impressions [42] and by Read, Derrick and Ligon [8] based on their own course design. Further, since there are external stakeholders that pose demands on student products, the teachers can shift their attention from product to process. This also moves the learning focus away from technical details and closer to students' abilities to organize software engineering processes and projects in general, e.g., transversal skills. However, students do not necessarily react positively to this shift and express frustration with the fact that the product as such is not part of the assessment.

The fact that students learn entrepreneurial skills and competencies is not made explicit during the course from the outset. However, since our University is now actively encouraging bachelor students to gain entrepreneurial experiences we have chosen to make the relation explicit. This was not a change requiring substantial effort as entrepreneurial competencies motivated the existing course organisation, the required change was to discuss the connection in a dedicated lecture towards the end of the course to give students an additional perspective and tie their experiences to the University's ambition. Since the first weeks of the course are very intense and students need to quickly grasp several novel concepts and attitudes, we decided against emphasising the relationship earlier or through more teaching moments and thus to reduce the cognitive load.

With regards to **RQ2:** "How are entrepreneurial experiences in software engineering perceived by undergraduate students?", we observe that students are motivated by creating value for others. However, the educational focus on project management, stakeholder interaction, as well as defining and negotiating value can leave students with too many challenges to solve independently. Since the definition of what is valuable is driven by an entity outside of the student body and even the university, students perceive the course differently, in particular if the external stakeholder represents an organisation that is attractive as an employer. This can, on the one hand, lead to additional stress for the students due to a pressure to succeed, but can also increase motivation and engagement [32]. Managing such challenges while being introduced to a rather new and different perspective on software engineering might cause excessive cognitive load. Here, appropriate scaffolding techniques need to be prepared and put into action when needed.

Further, the technical challenges of the project course affect how students perceive the course. On the one hand, it should be expected that students who know Java are able to pick up Javascript quickly and efficiently — on the other hand, the course in its current form offers little scaffolding for that and leaves the students alone with their technical issues. Partially this is due to teaching resources and partially by design: there is an intended learning outcome that states that students should develop skills on their own and apply them. This meta-cognitive aspect [43] is, however, not well-scaffolded either. Robinson and Hall identify the same conflict between student expectations around choice of programming languages and what works best in the given environment, but they do not recount the student perception nor strategies for handling the dilemma [44]. Read, Derrick, and Ligon suggest to include mentoring as a way to introduce students to new technologies [8].

According to Piperopoulos and Dimov [45], a course focusing on entrepreneurship can "*steer students toward attaining the possible versus containing the probable*". The study of Nabi et al. [9] also confirms that "*experiential pedagogies*" provide a higher impact. We believe that our course adheres to these ideals. As of now, we do however lack sufficient data to make conclusive statements about this aspect for our own course. A positive effect that can be observed in most students is the development of team-work skills and competencies. As witnessed by the statements in Section VI, students appreciate the work in their teams and how the team dynamics change once the problem is more open and explorative work is required.

Based on our findings in relation to **RQ1** and **RQ2** we see that by introducing an external stakeholder who owns the definition of value, we enforce the learning of the abilities related to *resource* management and acquisition as well as the courage and skill to move *into action*. Due to the relatively fixed scope defined by the external stakeholder, this setup will not, however, provide the students with the same opportunities for exploring *ideas and opportunities* as in the case where the students define their own project. Regardless of approach, a course targeting entrepreneurial competencies should provide technical support since students often lack the skills necessary to transition from labs to working with professional tool chains. It also needs to manage the cognitive load of the students carefully and provide scaffolding for key process aspects.

VIII. Conclusion

We set out to explore to what extent our own software engineering project course relates to entrepreneurship. We identified a number of opportunities for the students to have entrepreneurial experiences while applying agile software processes. Agile software development and entrepreneurship have a number of similarities, such as using a structured, iterative and incremental process to refine and implement an idea to deliver value for one or more stakeholders while dealing with uncertainty and change in relation to scope and resources. We detail how we combine these two worlds in a concrete course design. We have proposed a way of organizing entrepreneurial experiences involving an external stakeholder as PO. While this shifts focus away from ideation, it pushes students to go *into action* in their projects and manage their own and others' *resources* while doing so. Such an approach offers unique opportunities for students to develop, e.g., initiative-taking, perseverance, and ability to cope with ambiguity and uncertainty — valuable skills for any software engineer.

In an educational context, one challenge lies in finding appropriate stakeholders with whom the students can collaborate and who are able and willing to invest the necessary resources [32]. From the teachers' perspective, we found it challenging to prepare the students for working in a real-world context. Specifically the students' technical skills are unaligned to the skills needed for the tool-chains used by professionals. As a response to our findings we are currently involved in creating a learning sequence among the courses in the relevant programs so that the students get introduced to realistic tool-chains while they take their introductory programming courses. That said, our students appreciate the challenge of collaborating with an external stakeholder since it gives them the opportunity to interact with people who have real needs and demonstrate their own capability to create value today. They also remark positively on the ability to develop teamwork skills and develop a process that worked for them. A possible way forward here is to investigate further how the teams can act as value creators for each other, so that each team develops a system which consumes the output from another team's system while providing input for someone else system.

In summary, we conclude that project courses with a strong emphasis on agile processes are apt to integrate entrepreneurial experiences in engineering education while the students will find the difference compared to traditional courses both unsettling and rewarding, a challenge that will require a structured process for course development and collaboration across courses at programme level.

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