Seeing the voice of the student: A pilot study of customer-driven courses

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Abstract — Context: Customer-driven courses have been a classic approach in teaching software engineering for over four decades at the Norwegian University of Science and Technology. The main goal of these courses is close collaboration between students and customers. However, in this scope of work, the intent was to evaluate students' perception of skills acquisition, startup formation mindset, and the introduction of external activities. Objectives: Several aspects were investigated, which include how collaboration with external customers affects student skills in a customer-driven course, how collaboration with external customers affects students' motivation in startup formation, and how students perceive the introduction of an external Innovation Bootcamp activity at the start of the course. Method: Twelve semi-structured focus group interviews were conducted with 86 students. Furthermore, an inductive thematic analysis was performed, which utilized open coding of the interview transcripts. Results: Students reflected an improvement in technical, soft, and project management skills. It was found that many of the customers' projects were not eligible for becoming startups due to the nature of the project niche scope closely related to the customer needs. Motivations in startup formation rely heavily on individual students' mindsets, and many of the teams had a weak perception about startup formation within the existing course context. The overall observation from the focus group interviews was that introducing external activities such as Innovation Bootcamp could assist in the process of startup formation and elevate the projects' relevance and quality. Contribution: The study's findings contribute to the course's future improvement while introducing external activity. The outcome could promote student innovation and active participation in customer project proposals and end-product features. Educators and researchers can benefit from the findings of our study in regard to making future updates to their customer-driven courses. There is also potential to increase practitioners' awareness of positive student input in their project proposals.

Keywords — customer-driven course, project-based learning, soft skills, technical skills, Innovation Bootcamp

I. INTRODUCTION

Education in a modern, knowledge-based society needs to compete with the increasing complexity of technology and science subjects. Engineering students require a profound conceptual understanding of subject topics and the ability to work with them in both a practical and creative sense [1]. Customer-driven project courses have been a successful example of a project-based learning approach [2,3] that provides in-depth knowledge to students, strengthened by authors who report positive outcomes from previous research [4-11]. The main characteristics of the course consist in (1) providing students with the opportunity to apply skills gained in other computer science and software engineering (SE) courses, (2) executing projects in large agile teams of 5-8 students, and (3) student teams developing a working prototype or minimum viable product (MVP) for real customers.

The main characteristic of the course is the close collaboration between students and external customers. Course instructors commonly take for granted the knowledge and competence students gain from the course. However, in this scope of work, the evaluation investigated students' perception about skills acquisition, startup formation mindset, and the introduction of external activities. These were all reasonably new concepts to the course setting. In summary, the following research questions (**RQs**) were formulated:

RQ1: *How does collaboration with external customers affect student skills in a customer-driven course?*

RQ2: *How does collaboration with external customers affect students' motivation in startup formation in a customer-driven course?*

RQ3: *How do students perceive the introduction of an external Innovation Bootcamp activity at the start of a customer-driven course?*

To address the **RQs**, 12 semi-structured focus group interviews were conducted with 86 students. Focus group discussions [12] are appropriate for (1) the generation of new ideas formed within a social context, (2) obtaining a deeper understanding of the phenomenon and new insights, and (3) gaining an understanding of students' expectations for the future. Utilizing this methodology, more educated guesses can be made as to how students will react to change, and this can be done before any actual updates are applied to the course. To obtain insights from the investigations, an inductive thematic analysis was performed using open coding of the interview transcripts.

Findings showed that students displayed an improvement in technical, soft, and project management skills. However, the course's primary impact was mainly on the students' technical and project management skills. It was found that most of the customers' projects were not relevant in becoming startups due to the nature of the project niche scope being closely related to the customer needs. Motivations in startup formation rely on individual students' mindsets, and many of the teams had a weak perception about startup formation with existing team members within the existing course context. The findings stemming from the focus group interviews showed that introducing external activities such as Innovation Bootcamp could assist in the process of startup formation and elevate the project relevance and quality.

The rest of the paper is structured through the sections below. Section II presents related work. Section III describes the course and Innovation Bootcamp settings. The study's design and methodology are both presented in Section IV. Section V presents the results and key findings. Section VI discusses the findings. Finally, Section VII concludes the study and identifies opportunities for future work.

II. RELATED WORK

Krogstie and Bygstad [4] gathered empirical data from customer-driven courses at Universities in Norway. Their research focused on the understanding of the interaction between student groups, their university, and customers. The authors concluded that educators should place a stronger focus on stakeholder goals and project artifacts.

Sindre et al. [5] discussed the advantages of project-based learning regarding SE education's quality and educational objectives. The authors propose a framework for exchanging university experiences and supporting stakeholders and educators in their future choices and course design.

Similarly, Carver, Jaccheri, and Morasca [6] presented the value of empirical studies when combined with project-based education. Project-based education is costly in terms of educator, lab, and student resources; the authors suggested that empirical studies may encourage this kind of education in the future.

Bruegge, Krusche, and Alperowitz [7] indicated the value of involving real industrial clients in customer-driven courses. The main focus of the research was on methods to find sound customer projects. The authors presented their evaluation over the four-year period of their customer-driven course.

Similarly, Vanhanen, Lehtinen, and Lassenius [8] presented a customer-driven capstone course. The authors discussed their experience of the course design. The authors argue that the students' option to select from many project descriptions provided by the customers increases project selection quality. Furthermore, the filtering of the project topics is based on their coverage of SE aspects (requirement specifications, development, testing, etc.).

Paasivaara, Vanhanen, and Lassenius [9] analyzed customers' perspectives when participating in a capstone customer-driven project course. The authors investigated the customers' motivation in participating in the course. However, little evidence was presented regarding the course's impact on students' innovation mindset and skills.

Cico, Jaccheri, and Nguyen-Duc [10,11] previously investigated the distribution of societal topics within project proposals of a customer-driven course. The authors focus on mapping the project proposals to Sustainable Development Goals [13]. Although the authors stop the analysis at the paper's social aspect, it stems from exploring different software sustainability traits (e.g., technical, environmental, and economic) and recommend that both students and customers seize the opportunity to innovate within the course.

III. COURSE SETTINGS

A. The course

The customer-driven course at the Norwegian University of Science and Technology is a fourth-year master's degree course at the Department of Computer Science. The course aims to give the students practical experience in executing all phases of large development projects in SE. Students develop a realistic prototype of an information system on contract for a real-world customer. Moreover, students need to cover all the phases of a development project: preliminary studies, requirements specification, design, implementation, and evaluation, apart from maintenance. In most cases, teams deliver a system prototype known as the MVP because of resource constraints. Typical team size in the customer-driven course ranged from 5-8 members. Throughout the course, the students encountered situations that required the following:

1. Swift decision-making for the design and implementation of a large development project

2. Creative and collaborative problem solving, as opposed to the smaller and more well-defined tasks from students' earlier studies

3. Efforts coordination dictated by the effective distribution of work and responsibilities

4. Enacting successful project management, cooperation, decision making, follow-ups, and dispute resolution

5. Ability to handle unreliable and/or unavailable customers in non-ideal working situations

6. Structuring of requirements and specifications

7. Complete and well-structured documentation of project documents with focus on targeting the technical knowledge level of the customer

8. Proper defense of choices made on behalf of the customer, ensuring that all obstacles, overruns, and weaknesses are documented for future explanative and argumentative purposes

9. Presentation and pitching of the final MVP to the customer and the external examiner

B. The customers and project topics

Customers from different sectors such as research, telecommunication, financial, business intelligence, health, welfare, and city commune submitted their project proposals ahead of the course. Their role was to present problems that students can address through SE practices. Customer participation in the course was crucial for presenting students with practical industry-like projects. The course coordinator used his network to contact companies and collect relevant topic proposals.

Typically, the number of topic proposals is larger for our course than the expected number of teams. To ensure that the project proposals meet certain quality criteria, we perform a filtering process that assesses the projects' SE relevance. Some of the customers do not get a team for a topic they have prepared. Every year, we post the call for project proposals on social media, the University's official communication channels, and the course website.

IV. METHODOLOGY

To address the aforementioned **RQs**, semi-structured focus group interviews were adopted [12]. Focus group discussions are appropriate for the generation of new ideas formed within a social context, and given that the course was project-based, the study sought to collect the attitudes and opinions of the students in a social context. The focus group interviews also presented the opportunity to obtain a deeper understanding of the phenomenon and gain new insights. Focus group interviews can help create an understanding of student expectations for the future, thus providing more insights on how they will react to change.

A. Interview design and data collection

The study was performed during the autumn semester of 2020. Several semi-structured interviews were conducted with student teams preceding the final project presentations to the customers. The interview process took place in two parts, as reflected in Table 1. In the first part, the interview questions primarily addressed background information about the student team, which lasted 5-10 minutes. The second part concentrated on the students' skills, startup formation motivation with regards to existing team members and the developed project, and the introduction of an external activity to the course, which lasted 40–50 minutes.

Although all the student teams in the course were invited for an interview, only 12 out of 17 teams responded to this request. Each focus group interview lasted around 60 minutes. Student participants could not only voice their opinions in focus groups, but they could also procure new thoughts and ideas from each other. In total, 86 students took part in the interview, distributed into teams of 6 to 7 students each.

TABLE I.   STUDENT INTERVIEW TEMPLATE

Interview part	Question
Part 1 – Background Questions	1. What are your team members' study backgrounds? 2. What customer project is the team developing? 3. What motivates you to participate in the customer-driven course? How did you benefit from the interaction with the customers?
Part 2 – Specific Questions	1. What technical challenges did you and your team face during the project development? What technical skills did you learn during the course? 2. What soft skills did you and your team obtain during the course? 3. What project management approaches did you adopt during your project or learn from the customers? 4. How did you use the acquired project management skills to develop your project? 5. To what extent did your customer participate during the project development? 6. What motivations to create a startup during/after the course based on the project you are developing can you mention? 7. Would you involve your team members in future startup formation? 8. What do you think about introducing an external activity such as (Innovation Bootcamp, Hackathon) during the first three course days?

B. Data analysis

First, data was carefully transcribed to obtain significant evidence that would assist in answering the aforementioned research questions. The thematic analysis approach was subsequently used [14,15]. This coding process consisted of identifying recurring patterns and themes within the interview data. The steps to conducting the systematic analysis consisted of the following:

1. **Reading the transcripts** – this step involved an initial quick browsing and correction of automatically transcribed data from the audio recordings. Later, the transcribed data was reviewed through a thorough line-by-line reading.

2. **Coding** – during this step, focus was put on choosing and labeling relevant words, phrases, or sentences, and this also included even larger text fragments or sections related to student skills, startup formation, and Innovation Bootcamp activity.

3. **Creating themes** – after gathering all the codes, the decision was made on which were the most relevant ones, and different categories or themes were subsequently created based on this.

4. **Labeling and connecting themes** – relevant themes were chosen, and appropriate names and relationships for these themes were defined.

5. **Drawing the results summary** – after deciding on importance and hierarchy of the chosen themes, a summary of the results was generated *(cf. Section V)* and discussed in relation to previous studies *(cf. Section VI)*.

V. RESULTS

To answer the **RQs**, the impacts of the course were presented in relation to students' technical skills, soft skills, project-management skills, startup-formation mindsets, and the possibility of incorporating an Innovation Bootcamp activity into the course.

A. Answering RQ1

A thematic analyzation was carried out to examine students' perceptions of technical, soft, and project-management skills acquired during the course, as shown in Figure 1.

1) Technical-skills acquisition and challenges. The students' efforts in MVP development were among the most positively perceived technical aspects. The students state as follows that the course offers ample technology learning:

Overall, I think there is a lot of learning potential within the course as you're almost no matter what forced to use something **[Technology]** *that you haven't used before… [**Team 4**]*

Specifically, students acquired <u>new technical knowledge during the course</u>. Two student teams reported the following:

*It was also a very steep learning curve because we didn't have too much like experience with C programming that was quite new … And also, we had to do some things in the cloud, like with the AWS Amazon Web Services. I think that was new for most of the group. So, we had to try and learn that as well… [**Team 2**]*

*I had less than average experience with web design and web frameworks. So, when I started this project, I was really interested in learning modern web frameworks such as Django for the back end… [**Team 8**]*

Similarly, another focus group interview revealed the following:

*In the beginning, we used a lot of time to learn the new technologies. That's everything from frameworks for making a mobile application to backend hosting services and databases… [**Team 11**]*
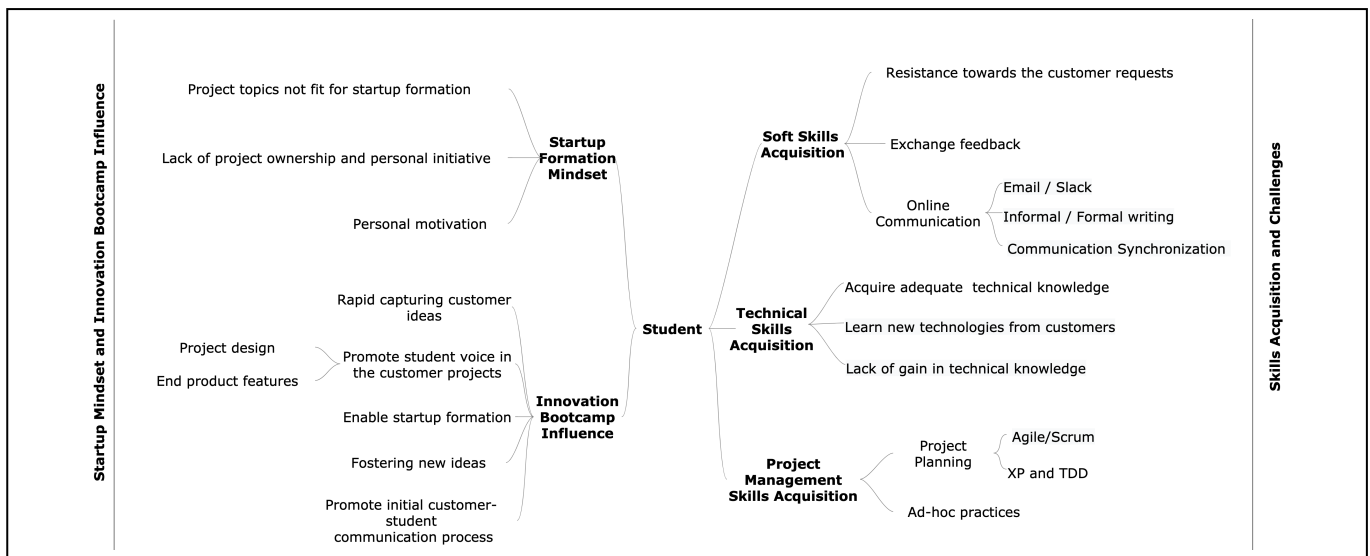
Fig. 1. Student skills and startup motivation and Innovation Bootcamp activities thematic analysis.

In the same vein, another team interview said:

*These are – for me – new technologies. I've never worked with Django and I don't have a lot of experience with them back in programming in general. So yes, there have been challenges and we have been required to learn a lot of new stuff... [**Team 14**]*

In one particular case, the underline customer did not have any specific technology requests for the team. This allowed the team to make their own choices when it came to the MVP development, as stated in the following quote:

*In our specific case we were able to choose freely, what kind of technology we want to use. We've created the system from scratch... [**Team 16**]*

The same team proved however to have underline gained adequate knowledge while developing the product:

*I think we used a lot of time in the beginning just learning how things work since it was – for a lot of us – new technology. So that was definitely a technical challenge ... [**Team 16**]*

One particular student team reported the underline lack of gain in technical skills because of the customers' non-technological background and the technologies requested to develop the project:

*There is not a lot of programming and the company was not a software development company...we have used technologies that were known to us before, but those technologies were also click-and-drag technologies that fourth year computer students should be making instead of using... [**Team 1**]*

2) Soft-skills acquisition and challenges. The students learned to become more underline resistant towards the customer. Two student teams report the following in their collaboration process:

*I think like he [**one student from the team**] said, stand our ground to the customer because the customer is always pushing the development team and telling them, "we can do this and this", but also let them know when they're pushing too hard... [**Team 1**]*

*The only kind of challenge we had was that it was sometimes hard to understand what the client wanted to implement ... and the kind of assets we were going to deliver... [**Team 2**]*

Communication within the students' teams was mainly smooth, however there were some underline challenges due to the remote setting students often had to work in. Student teams reported the following observations:

*I think the general consensus of the group is physical attendance and meetings are better than the original digital ones... [**Team 3**]*

*You need special equipment and hardware to be able to develop the application. So, we have to come up here to campus, just to use computers here ... One can we try to like not have everyone coming, but that's just limiting our development massively ...[**Team 7**]*

*We do like a split between meeting here and working remote ... but it can be challenging sometimes to update each other on how things are rolling in and who is working on what and at what times when communicating remotely... [**Team 8**]*

*We have also worked a lot remote and we had some challenges at the beginning when we started working remote it was not as productive as the physical working environment...that was a bit challenging to have the remote work at the beginning, but I think it's better... [**Team 16**]*

Students deemed it important to *communicate* with the customers and *exchange feedback* while acquiring relevant information to develop their projects. Some of the teams report the following:

*...during the pandemic it is quite important to often go with the customer and ask them ... so we are keeping as much communication as possible, either physically or online... [**Team 8**]*

*It was me that discussed with the group about design, and we showed it to the customer and they gave feedback. So, they were pleased with it... [**Team 11**]*

I think we've got some comments from the customer and then we updated the requirements…we sent the sketches to the customer, and they showed it to other municipalities and came back to us with feedback and we're updating the parts they had feedback on… [Team 15]

Perspectives were positive regarding <u>online coordination and communication</u> among the team members via Slack. One student mentioned:

…we tried to keep the communication open with Slack, and we met Mondays and most Wednesdays as well… [Team 2]

Another focus group interview reported the following:

Yeah, we have a Slack workspace to coordinate our sprint and also with the customer. So, we are in free-flowing, continuous communication with them… [Team 8]

3) Project-management skills acquisition and challenges. Project management was essential to developing the final products. Students acknowledged the benefit of using <u>agile methods like Scrum, extreme programming (XP), pair programming, and test-driven development (TDD) in project planning</u>. The following was reported in the interviews:

we have learned to combine Scrum and at least pair programming from XP… [Team 2]

…more professional, and the thing with Scrum is it sort of varies from team-to-team, and you learn new ways to do things, maybe better things. So, it's just more training in Scrum, basically… [Team 11]

…from the lecture on project management and just holding meetings, I think I've learned quite a bit…we used some XP elements as well, and we have also used some pair programming, by sharing our screen… [Team 9]

So, we have learned technologies, and apart from that we have also gotten a lot of experience with Scrum and communicating with the customer in a professional way… [Team 15]

Students mention <u>challenges related to rigorously adopting the Scrum framework</u> and all of its ceremonies:

…we had some sort of issues in the beginning because we tried doing Scrum very strictly…but when we realize that we should be more pragmatic because we didn't have time for it … since we're getting late deliveries … there was like no time to basically do Scrum… [Team 7]

Another team reports the lack of need to use Scrum or other similar agile project management methodologies. This particular case can be considered as an outlier since only one team reported using <u>ad-hoc practices</u>:

*… I don't really think that [**Scrum**] was something we needed so I really feel like the working of methodology [**ad-hoc**] that we've chosen works really well for our team…. [Team 4]*

B. Answering RQ2

The student interviews showed that many of the <u>project topics were not fit for forming future startups</u>. Reasons vary from project scopes being limited to prototypes, proof of concepts, and toy projects without any real market value. Several teams actively repeat the following statements:

I mean, as far as this project in particular is not very well fit for a startup… [Team 8]

*…we all feel like it [**the project**] doesn't really fit startup. Because it's so dependent on the customer, and also doesn't really have a way of market value… [Team 11]*

*…I feel like the customer proposal is small, and also that the customer is not really trying to sell the solution to their operators… I don't really see a huge potential for trying to start a startup based on it [**the project**… [Team 16]*

…it's not necessarily a product that actually makes sense in the real world, it's just a toy showcase project… [Team 2]

Reasons vary but some worth mentioning are <u>lack of project ownership and personal initiative</u>, as mentioned below:

…We don't have a lot of ownership to the product we like, you know?… [Team 8]

*…I don't feel like if I were to profit from it [**the project**], that would be enough for me to want to put in the work to make this a startup… [Team 14]*

<u>Personal motivation</u> is the key factor in startup formation. Some of the students showed their personal interest in startup formation. However, the course had little impact on the overall student mindset:

I already have a lot of motivation for starting new startup. I'm quite involved in the innovation environment and so I think that has made a bigger contribution than this course… [Team 14]

…if you could make interesting projects, then sure, if you line it up with the course so that students could make it into startup that way. I think that would be a cool concept… [Team 11]

C. Answering RQ3

The Innovation Bootcamp activity has the potential to enable an <u>early start to a project process</u> by rapidly <u>capturing customer ideas</u>.

*An Innovation Bootcamp could be useful to better understand the customer problem or get a better grip on what they [**customers**] want.… [Team 3]*

Get started much quicker because we wasted almost two first weeks because we didn't have enough information from our customers… some groups are still in trouble with getting documentation and planning with their customer… [Team 8]

*…I think it [**Innovation Bootcamp**] would probably help a lot to gather domain knowledge and to understand the problem …initially you don't know what the customer wants, and we found that we had spent a month, not knowing what to do…. [Team 9]*

The project requires some exploration on our part and a lot of communication with the customer, and that might have been accelerated by a more intensive start to the course with a Bootcamp… [Team 11]

*It was quite difficult for us to comprehend the needs and really understand the task in the beginning. And we spent a lot of time trying to figure out what the customer actually wanted. So, I think if we had like a workshop or something like that [**Innovation Bootcamp**] in the beginning that would be really helpful… [**Team 15**]*

The <u>Innovation Bootcamp also allows students to have a say in the project design, end product features, and startup formation</u>:

*…They [**students**] think that they'll have a say in how the product ends up. But in the end, or after the course some of them [**students**] feel like they didn't really have a say even if they thought they did in the first place. So, it could be cool to try it [**Innovation Bootcamp**] out and see if one can actually affect the product… [**Team 2**]*

*…if you could make interesting projects, then sure, if you line it up with the course so that students could make it into startup that way. I think that would be a cool concept… [**Team 1**]*

In the same vein, one student who touched on his previous experience in similar events reported that an <u>Innovation Bootcamp could potentially enable startup formation</u>:

*…I was at a hackathon recently and I had a lot of fun and the product that we made in the hackathon we've considered trying to make a startup…that [**Innovation Bootcamp**] would definitely bring the startup mindset… [**Team 6**]*

Another student team in particular deemed the <u>Innovation Bootcamp and its fostering of idea exploration</u> to be more relevant than the final report writing:

*…Figuring out the solution to the problem would be interesting for us students…more interesting than having to work with pregiven information, and report writing would enable us to develop a more real-life project… [**Team 9**]*

According to one student team, the <u>Innovation Bootcamp could also promote a good initial communication process</u> with the customer that would be the kick-start for smoother project development:

*If you have this sort of Bootcamp, you'll get a good kick start, and you get lots of communication with the customer and the group… [**Team 3**]*

Key Findings

1. *Technical, project management and soft skills.* The course provides adequate knowledge in technical, project management and soft skills, with few significant challenges that students can speak of.
2. *Startup-formation.* Projects proposed from the customer were not fit to create future startups. In addition to this, students lack initiative in startup formation due to lack of ownership or personal initiative and in most cases motivations to form startups are based primarily on students' personal motivations.
3. *Innovation Bootcamp.* The Innovation Bootcamp activity introduced at the beginning of the course can positively affect the start of the project process, capturing customers' ideas, student voice in the project, fostering of new ideas, startup formation, and student-customer communication.

VI. DISCUSSIONS

A. "Seeing the voice of the student"

The qualitative results reported in Section 5A, 5B and 5C provided thorough insights about students' perceptions on skills acquired, startup formation mindset, and Innovation Bootcamp impact on the course. A gathering of unique perspectives was orchestrated on how students see the course, as well as how they perceive interventions to it. Utilizing focus group interviews became an instrument that brought forth new insights and a deeper understanding of the phenomenon. Furthermore, by gaining an understanding of students' expectations for the future, more educated guesses can be made in regards to how they will react to change. Finally, attitudes and opinions can be socially formed and articulated in a more social environment. Another key point is students' active claims of needing to have a voice in the final projects proposed by customers.

Indeed, students argued that they learned extensive technical and project management skills in the course setting without overlooking soft skills. More precisely, students learned new technologies and learned to manage their projects despite lacking relevant prior experience. Agile methods like Scrum were also key to project management activities. This learning opportunity demonstrated that the course was mature with long-standing experience over the past four decades in teaching project-based SE.

Startup formation is a relatively new concept to the course, with students having mixed perceptions on how the startup formation intervention would benefit them personally, as well as how it would benefit their teams. It is understood that the course does not promote the startup formation concept, but the fact remains that students do not totally discard the concept. At times, they even view the idea as positive, and this is very promising for future interventions.

When bringing up the Innovation Bootcamp as a new instrument promoting startup formation and innovation within the course, students voiced their need to be part of the decision making in the customer projects.

This research argues that the innovation ground bolstered by external Innovation Bootcamp activities is still in its infantile stage, but it holds promise for updating future customer-driven courses. Both teachers and customers have continually overlooked the need to have students participate in the decision-making aspects of the customer project, and they neglect to make students feel included as a part of the stakeholders. Having students participate in the decision-making process and contribute or share ideas with the customers has the potential to increase project relevance, ease development, and elevate the final product quality. Metrics such as relevance, ease of development, and product quality are drivers for potential startup formation.

B. How can educators, researchers, and practitioners use these findings?

This study contributes to educators by helping them do the following:

1. Understand the necessity behind updating the course while focusing on innovation and activities that would

promote startup formation, thus improving project quality and relevance.

2. Introduce external activities such as Innovation Bootcamp early in the course, which would help kick-start projects and provide smoother development.

3. Give students an active role in the customer projects by allowing them to express their voice and become actual stakeholders.

Researchers can use this study for the following actions:

1. Conduct further investigations on how Innovation Bootcamps or similar activities (e.g., Hackathons and Innovation Workshops) can improve the overall student acceptability of the customer projects, increase end product quality, and motivate students to create future startups.

2. Augment the dimensions to investigate aspects such as innovation mindset of the students, students' active participation, end product quality, and others while utilizing the current findings.

Finally, practitioners – or in this case, customers – should use this study to complete the following steps:

1. Understand the value of participating in Innovation Bootcamp activities.

2. Utilize students' inputs and ideas to bring value to their present project proposals.

3. Be open to startup formation opportunities during and after the course setting.

C. Hypotheses

Conducting focus group interviews on a large sample provided for a thorough view of students' true perception, demonstrating their intense need to have a "voice" in the customers projects. This is what composes the core of the course. Attempts to mitigate the bias of the obtained results were also carried out, however fully eliminating the researcher bias was not possible *(cf. Section VI.D)*. On the basis of these results, four hypotheses were drawn, thus completing the first half of the investigation.

Hypotheses:

H1: *A customer-driven project course positively affects students technical, project management, and soft skills. (cf. Section V.A)*

H2: *Students become thoroughly interested in the startup formation and innovation perspective of the customer projects if educators introduce an Innovation Bootcamp or similar external activities at the beginning of the course. (cf. Section IV.B)*

H3: *An Innovation Bootcamp positively affects project kick-start, relevance, development process, end product quality, and student active participation in customer-driven project courses. (cf. Section V.C)*

The intention behind this study was to corroborate the aforementioned hypotheses by conducting questionnaire surveys with other similar SE project-based courses and performing triangulation with artifact analysis of our present findings.

Clear-cut answers are not offered in this study, and it may even raise more questions than it answers. That being said, it is still possible to form assumptions *(hypotheses)* worth investigating by the research community.

D. Threats to Validity

Based on recommendations from Maxwell [16] on qualitative research and Breen [12] on focus group research, validity threats to the study and how they were addressed are as follows:

1. **Content validity** – analysis was done on dimensions (soft, technical, and project-management skills) that are widely accepted by the research community in SE literature. Studies overlapping with SE practices were also considered, and these studies rely on a project-based learning approach. Relying on focus group interviews further assisted in obtaining and providing a deeper understanding of the phenomenon under investigation.

2. **Criterion validity** – several previous studies (cf. Section II) have achieved results such as the ones mentioned in this study, but they relied on different methods, such as a survey (pre- and post-test) with a Likert scale. These previous studies, however, did not perform focus group interviews to gather qualitative data for the purposes that this study utilized them for. Through these focus group interviews, it was possible to better understand established dimensions, as well as explore new ones like startup formation and the introduction of Innovation Bootcamp.

3. **Descriptive validity** – although attempts have been made to gather as much information as possible, there are admittedly some aspects that may not have been adequately covered. To mitigate this threat to validity, audio records were used to verify the descriptive data back in time, and the rest of the data was stored electronically. Transcription results were also confirmed with the interviewed samples to ensure that their statements had been correctly interpreted.

4. **External validity** – this is related to the sample size and limited context under consideration. Validity was upheld by choosing a sample of SE students. Admittedly, this research is but a pilot study based on one course. A large sample size is required to generalize the results. To mitigate this threat to validity, the intended plan is to recruit more samples from other similar courses via follow-up interviews and questionnaires.

5. **Internal validity** – internal threats to validity in qualitative studies were related to data extraction and analysis. An attempt to mitigate this was done by carefully coding and categorizing the transcriptions, as well as gradually whittling down to the most significant data.

6. **Interpretation validity** – written perspectives of the individuals being researched were carefully kept track of to ensure that their unique perspective was considered instead of imposing meaning from interpretational perspective.

7. **Researcher bias** – it was crucial that gender, culture, or academic bias did not affect the study. The only possible bias was the interviewing of SE students, however this did not undermine the study, as SE was the primary focus of the study.

8. **Construct validity** – the sample used in the study is admittedly quite small, and for this reason, further experimentation must be done to fully assess the construct validity of our quantitative data. For now, however, the results are fairly consistent with the qualitative data.

VII. CONCLUSIONS AND FUTURE WORK

This customer-driven course was designed to allow students to interact with external customers through realistic projects, and it sought to evaluate whether or not students were gaining adequate skills and had an active role in the projects proposed from the customers. Students were introduced to potential interventions, such as startup formation and Innovation Bootcamp activity, that could help students become stakeholders alongside the customers in the projects. To answer the research questions posed early on in the study, semi-structured focus group interviews were conducted. A thematic analysis of the gathered data was performed. After a meticulous investigation, it was concluded that it is necessary to (1) elevate the student role and participation in the customer project, and (2) introduce external activities (e.g., Innovation Bootcamp, Hackathon, and Innovation Workshop) as drivers in innovation and startup formation to ease project development and increase product quality and relevance.

The course requirements should also better emphasize the student "voice" in the project proposed from the customers. It should facilitate innovative ways of learning software engineering that go beyond toy and niche projects with little to no impact after the course's end.

In the future, the intention is to address the issues found in this investigation. The aim of this is to improve the quality of customers' project descriptions based on an active student role enabled by Innovation Bootcamp activity and startup formation mindset. Based on the present findings, the intent is to continuously experiment and update the course. The future plan for this course also includes conducting questionnaires and further semi-structured interviews with both customers and students, focusing on the present findings and proposals.

On this note, other educators and researchers are encouraged to analyze the skill dimensions within their own SE project-based courses. It is also worth mentioning that methods in which students can have a more active role should also be considered, chiefly via Innovation Bootcamp activities at the beginning of the course.

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