

Incorporating societal topics in software engineering education: A case study of a customer-driven course

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Abstract

Context: This full research paper presents a review of the project descriptions from a project-based course designed around close collaboration with students and external customers. Our master course is based on four decades of software engineering experience and teaching at Norwegian University of Science and Technology. In the scope of this work, we analyzed 45 customers' project proposals over the past three years.

Objectives: More precisely, we looked into 1) how many societal topics are present in project customers' descriptions? 2) Which sustainable development goals if any, are addressed from the customers? 3) How do the trends of societal topics addressing SDGs in customer projects change over time? 4) Which categories of individuals do project descriptions target?

Methods: We conducted a deductive thematic analysis utilizing open coding of the customers' project descriptions.

Results: We found that most project descriptions provided by the customers had a technical focus with a moderate portion of projects addressing societal topics for specific target groups.

Contribution: The study's overall outcomes contribute to the course's future improvement and informs customers about the prospective socially relevant project proposals.

I. Introduction

Modern engineering, from systems engineering, electrical and electronics engineering, marine engineering, to chemical engineering, affects almost every aspect of our society and engages a substantial set of the population in their implementation, operation and usage [1]. But what is the role of engineering in responding to society's needs as well as in shaping them? How well does engineering carry out that role? How engineering research and practice might reshape and otherwise affect the sustainable living conditions is an unanswered question. Several practical issues, for example, impacts of engineering activity: economic, social, cultural, environmental and sustainability, and professional responsibility of an engineer to society need a careful ethical reflection as early as in education programs. Improving education in sustainability would have a positive impact on changing attitudes, but empirical evidence from courses are needed to support the argument.

Education in a modern society of knowledge needs to cope with increasingly complexity of technology and science subjects. Students in engineering programs need a deep conceptual understanding of subject topics and the ability to work with them practically and creatively [2]. Customer-driven project courses have been a successful instance of effective educational initiative that offers deep learning for students [3,4]. Many positive outcomes have been reported from previous research [5-13] with benefits for both students and customers alike. It is worth mentioning that (1) the course provides students with the opportunity to try out, in practice, the skills gained on other computer science and software engineering courses; (2) projects are executed in large scrum teams

consisting of five to eight students; and (3) the course is developing a working prototype defined as a minimum viable product (MVP) for a real customer.

Projects with a societal focus is a good way to promote for reflection and ethical consideration in the context of engineering education. From our experience running a customer-drive project course at Norwegian University of Science and Technology (NTNU), relevant projects covering specific software engineering (SE) knowledge areas as recommended by the Software Engineering Body of Knowledge (SWEBOK). However, we observed little focus in evidentiating whether the projects are also addressing societal topics and United Nations (UN) Sustainable Development Goals (SDGs) [14]. Moreover, the research so far does not report which target groups are the projects proposed by the customers covering.

To this end, our research reviews the project descriptions from our customer-driven project course. Our master course is based on four decades of software engineering experience and teaching at NTNU. In the scope of this work, we analyzed 45 customers' project proposals over the past three years. More precisely, we, with our research questions (RQs) looked into the following:

RQ1: How many societal topics are present in project customers' descriptions?

RQ2: Which SDGs, if any, are addressed from the customers' project descriptions?

RQ3: How do the trends of societal topics addressing SDGs in customer projects change over time?

RQ4: Which categories of individuals do project descriptions target?

To answer our research questions, we conducted an inductive thematic analysis utilizing open coding of the customers' project descriptions [15]. The analysis of the qualitative data revealed that projects addressing societal topics are at modest percentage covering less than half of the total number of projects. Moreover, the coverage of the SDGs also remains at moderate levels with little more than half of the total number of SDGs addressed from the projects in recent years. Projects successfully address different groups based on age and work status; however, marginalized, culturally diverse, ethnic, and gender groups are not present in the project descriptions.

The rest of the paper is structured as follows. Section II presents related work. Section III describes the course, customer settings, and project topics. We present our study's design and methodology 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, B. and Bygstad [5] gather empirical from customer-driven courses in software engineering at two learning institutions in Norway. The focus of their research is to make sense of the interaction between three stakeholders: student groups, university and customers. The authors conclude that a stronger focus should be placed between stakeholder goals and project artifacts.

Moreover Sindre et al. [6] discuss the advantages that project based learning can produce in the quality and in the educational objectives of the software engineering education. The authors aim at the proposal of a framework for exchanging experiences among universities and assisting national stakeholders and educators on their future decisions and plans.

Similarly, Carver, Jaccheri, and Morasca [7,8] discuss the value of empirical studies when combined with project-based education. Since project-based education is costly in terms of educator, lab, and also students resources, the authors suggest that empirical studies may be seen as a way to promote this kind of education in the future.

Bruegge, Krusche, and Alperowitz [9] emphasize the importance of conducting customer-driven courses with real industrial clients. The authors address the research question on how to find reasonable customer projects. The authors present their evaluation over the past four years of their multicustomer course. The course mainly focuses on the tools and methods on how to conduct the course, but little implications are presented on societal aspects of the projects proposed by the customers.

Paasivaara et al. [10] present a capstone course based on close customer interaction with the students. However, the research is based on a mixed-method approach that focuses mainly on the soft and hard skills that students have acquired and their attitudes in the course, rather than on the type of projects the customer proposed.

Similarly, Vanhanen, Lehtinen, and Lassenius [11] present a customer-driven capstone course. The authors present their experience of the course design. It is noteworthy that there is a large variety of project descriptions and the students interact and select the projects from the customers, which according to the authors increases the overall project selection quality. Again, the filtering of the project topics is based on their coverage of software engineering aspects (requirement specifications, development, testing, etc.). However, the authors do not state whether the projects cover any societal topics.

Yet again, Paasivaara, Vanhanen, and Lassenius [12] analyze the customers' perspective when participating in the capstone customer-driven project course. Emphasis was placed on the motivation the customers had in participating in the course. However, little evidence is presented regarding whether the project proposals cover any societal issues.

Another relevant work from Nguyen-Duc et al. [13] investigate the gender issues within student team in software project courses. While they do not explicitly address societal issues as the course objective, their research process involve students and promote the idea of gender equality and diversity.

III. Course, Customer Settings, and Project Topics

The course

X is an MSc degree course based on a project-based learning approach. The goal of the course is to learn—by working in groups—software engineering skills in the context of a development project to make a realistic prototype of an information system “on contract” for a real-world customer. Through the project, all the phases of a typical software project were covered (e.g. project management and planning, pre-study, requirements, design, programming, testing, evaluation, and documentation), but no “maintenance” was done. Due to resource constraints, the focus was on delivering a system prototype called the minimum viable product (MVP). A typical team size in customer-driven course ranges from five to eight members.

During the course, the students experience situations that require:

1. Fast decision-making for the design and development of a relatively large and complex system.

2. Creative and collaborative problem solving. Earlier in their studies, the students' tasks will be smaller and more well-defined. In this project, there are (conflicting) decisions to be made with short time limits.
3. Coordination of efforts and distribution of work and responsibilities.
4. Project management, cooperation, decision-making, follow-ups, and dispute resolution.
5. The ability to adapt to non-ideal working situations. This will be particularly relevant in 2020 with respect to the COVID-19 situation.
6. Planning and execution of plans. This involves the creation of project plans and registration, and monitoring of effort and resource usage.
7. Handling customers who might be unreliable and/or unavailable and have high expectations. An important part of this course refers to managing the group project so that the results match the customer's needs, even though the situation may turn difficult.
8. Structuring of requirements and specifications.
9. Documentation. The projects' documents must be complete, well-structured, and target the technical knowledge level of the customer.
10. Defend decisions that are taken on behalf of the customer. You should document all delays, overruns, and weaknesses so that they can be explained and argued for. Ideally, all decisions should match the conditions coming from the customer (the customer has the right to complain about any aberration that is not his/her fault).
11. Presenting (and selling) the final product for the customer and the external examiner. Under the final presentation and demonstration, it is important to give the customer a complete and good impression of the system delivered.

The customers and project topics

The customers belonged to different sectors and delivered their project proposals ahead of the course. Their role is to present students with problems that could be addressed through SE practices. Participation in the course is key to presenting students with realistic industry-like projects. Some of the sectors the customers represent include telecommunication sectors, research centers, financial, business intelligence, health, welfare, and city commune sectors, to name a few.

The teacher and course coordinator collected topic proposals from the companies using their networks. Typically, there are more topic proposals than there are teams. A filtering process is performed to ensure that the project proposals meet quality criteria from a software engineering perspective. The downside is that many customers do not get a team for a topic they have prepared. Every year, we post the call for project proposals on the course website, and customers provide a 1-2-page description of their project proposal.

IV. Methodology

We designed a case study following the qualitative approach described by Borrego et al. [15]. We gathered data from the customers' project descriptions while performing a thematic analysis of the projects. The data was gathered via an EasyChair where each customer could submit their project. In evaluating the projects, we performed the steps presented in Figure 1.

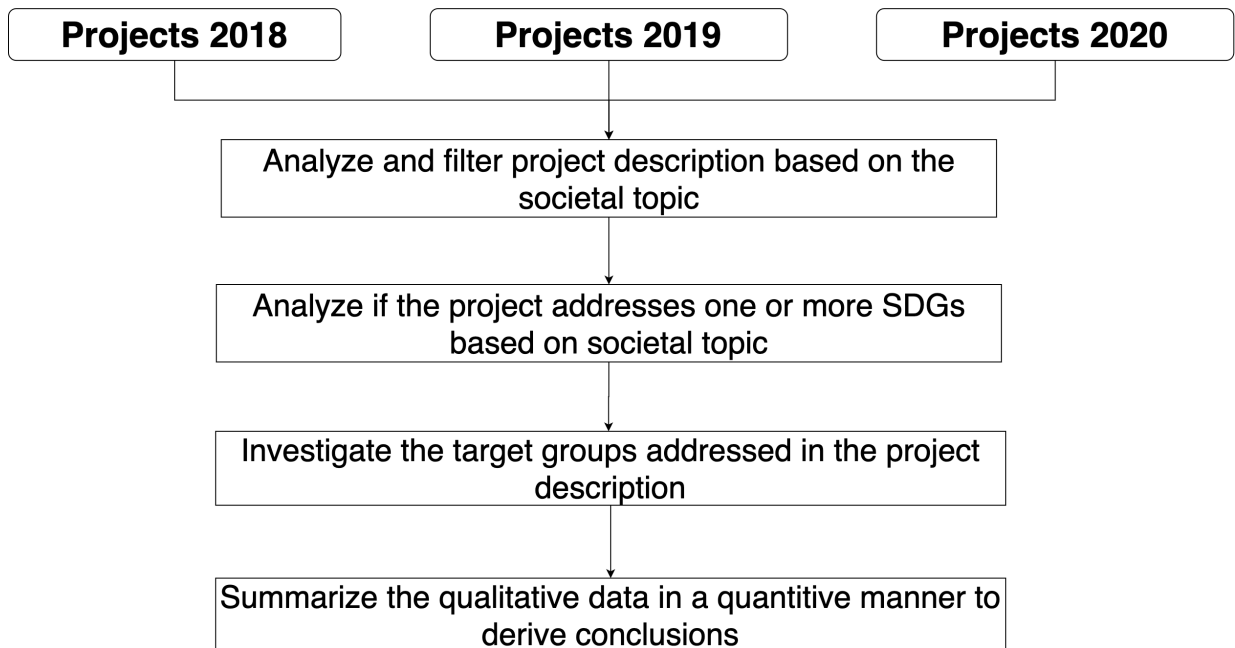


Figure 1. Methodology steps

Data Collection

We conducted the study during the autumn semester of 2020. We collected data from the project descriptions submitted in the last three years.

Each customer-submitted their project proposal via EasyChair, so the data was continuously stored in the past years. A review process took place before the project was accepted. In 2018 and 2019, only 14 projects were chosen out of 28 and 22 submissions, respectively. Similarly, in 2020, 17 projects were chosen out of 25 submissions.

Data Analysis

After collecting the customer project description data, we then applied a thematic analysis approach [16] to identify recurring patterns of societal topics (issues and challenges). We deduced the potential SDGs and target groups being addressed based on deductive analysis of the projects that address societal topics.

The steps we followed to conduct the thematic analysis were as follows (overview in Figure 2):

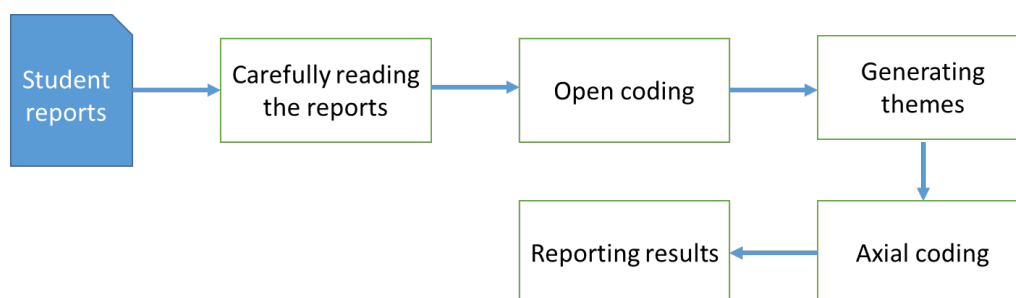


Figure 2: The coding process

- (1) **Reading the transcripts.** This step initially involved quick browsing and correcting the transcribed data from the audio recordings. Later, we reviewed the transcribed data more carefully by judiciously reading line by line.
- (2) **Coding.** During this step, we focused on choosing and labeling (coding) relevant words, phrases, and sentences. The labels revealed more about perceptions related to Bootcamp activities. The coding process is illustrated by Figure 3.
- (3) **Creating themes.** After gathering all the codes, we decided on the most relevant ones and created different categories (themes) and dropped or merged many of the initial codes from the previous step.
- (4) **Axial coding (Labeling and connecting themes).** In this step, we decided which themes were most relevant and defined appropriate names. We also attempted to identify relationships among the themes.
- (5) **Summarizing the results.** After deciding on the themes' importance and hierarchy, we presented our results in the next section. We used the thematic coding tool NVivo 12 [17] to fulfill the five steps.

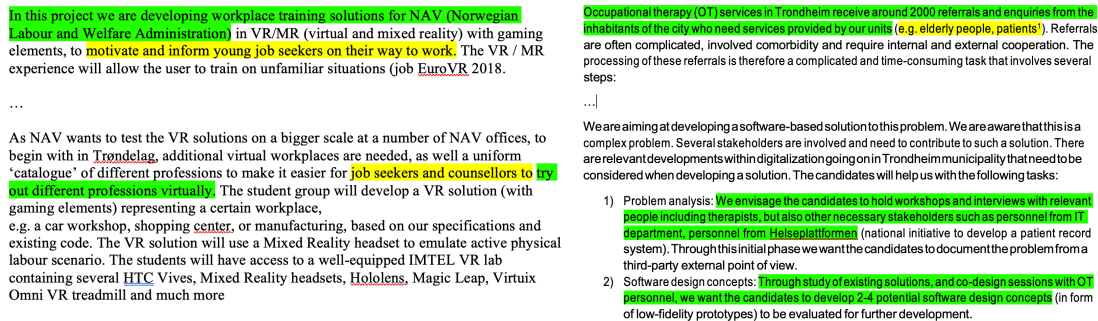


Figure 3. Two samples of analyzed customer project descriptions (color coded: green – societal topics; yellow – target groups addressed).

V. Results

To address our RQs, we present the findings concerning the presence of societal topics, targeted UN Goals, categories of individuals, and the evolution of topics over time within customers' project descriptions. The results target the thematic analysis of the qualitative data gathered over the past three years.

Answering RQ1: How many societal topics are present in the customers' project descriptions?

The societal topics we identify from our thematic analysis are presented in Table 1. We observed fewer societal topics addressed in 2019, namely only five out of 14 project descriptions. In 2018 and 2020, we discovered six project descriptions addressing societal topics. However, in 2020, the total number of project descriptions was 17 compared to 14 projects in 2018. Figure 4 presents the distribution between projects addressing societal topics over the total number of projects per year. We observed that in 2018, we had a larger percentage of projects directly targeting societal topics. Moreover, the total number of projects addressing societal topics over the past three years remains moderate, representing less than half of the total projects.

Table 1. Societal topics per project year.

Project Year	Societal issue addressed in the project description
2018	<ol style="list-style-type: none"> 1. Carbon emissions and air quality 2. Government challenges 3. Fish farm production 4. Smart buildings and Internet of Things (IoT) 5. Energy markets 6. Children's education platforms
2019	<ol style="list-style-type: none"> 1. Interaction among health stakeholders 2. Population growth and protein demands 3. Underwater products and boxing materials (e.g., fish boxing with polystyrene and fish farming) 4. Social work and job seeking 5. eHealth solutions
2020	<ol style="list-style-type: none"> 1. Smart devices and IoT for the environment 2. Social work and job seeking 3. Environmental, social, and governance data 4. Sport activities for students 5. Health data sharing 6. Air quality

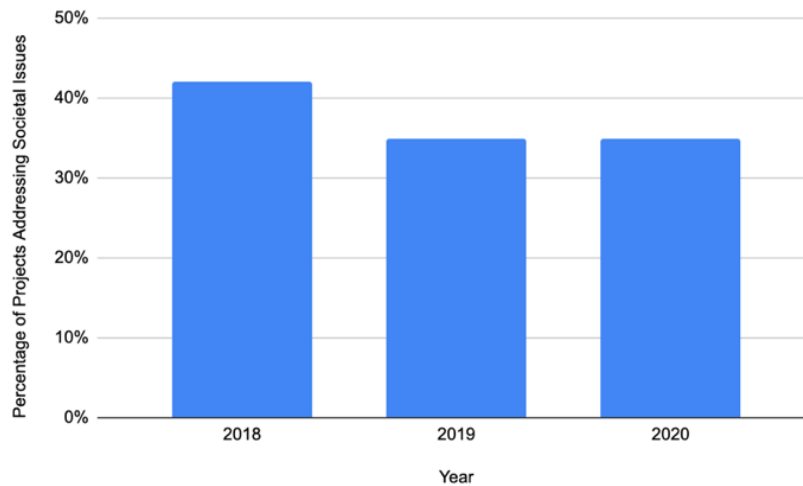


Figure 4. Percentage of projects addressing societal topics per year.

Answering RQ2: Which SDGs, if any, are addressed from the customers' project descriptions? **Answering RQ3:** How do the trends of societal topics addressing SDGs in customer projects change over time?

We identify no explicit evidence of SDGs being mentioned from the project descriptions. However, from our analysis of project goals, we can map the project descriptions to the corresponding SDGs, as shown in Table 2. Moreover, Figure 5 presents the distribution of the SDGs and the relation to the societal topics over three years of analyzing project descriptions. We observed that only two SDGs were addressed more than two times, namely the SDGs number three and eleven. The rest of the SDGs were addressed only one or two times. Similarly, we observe that projects in 2018 focused on only one SDG, and only in 2019 and 2020 can we identify some projects targeting two or more SDGs. Moreover, little more than half of the total number of SDGs (10 out of 17) are part of the three-year project descriptions. The coverage of the SDGs remains at moderate levels, but we observed an increase in the number of SDGs addressed in 2020.

Table 2. Societal topics and SDGs per project year.

Project Year	Societal issue addressed in the project description	Corresponding SDG
2018	Carbon emissions and air quality	SDG 13: Climate action SDG 3: Good health and well-being
	Government challenges	SDG 16: Peace, justice, and strong institutions
	Production of fish farms	SDG 12: Responsible consumption and production SDG 14: Life below water
	Smart buildings and IoT	SDG 11: Sustainable cities and communities
	Energy markets	SDG 7: Affordable and clean energy
	Children's education platforms	SDG 4: Quality education
2019	Health stakeholder's interaction	SDG 3: Good health and well-being
	Population growth and protein demands	SDG 2: Zero hunger
	Underwater products and boxing materials (e.g., fish boxing with polystyrene and fish farming)	SDG 12: Responsible consumption and production
	Social work and job seeking	SDG 8: Decent work and economic growth
	eHealth solutions	SDG 3: Good health and well-being
2020	Smart devices and IoT for the environment	SDG 11: Sustainable cities and communities
	Social work and job seeking	SDG 8: Decent work and economic growth
	Environmental, social, and governance data	SDG 11: Sustainable cities and communities SDG 16: Peace, justice, and strong institutions
	Sport activities for students	SDG 3: Good health and well-being
	Health data sharing	SDG 3: Good health and well-being
	Air quality	SDG 13: Climate action SDG 3: Good health and well-being

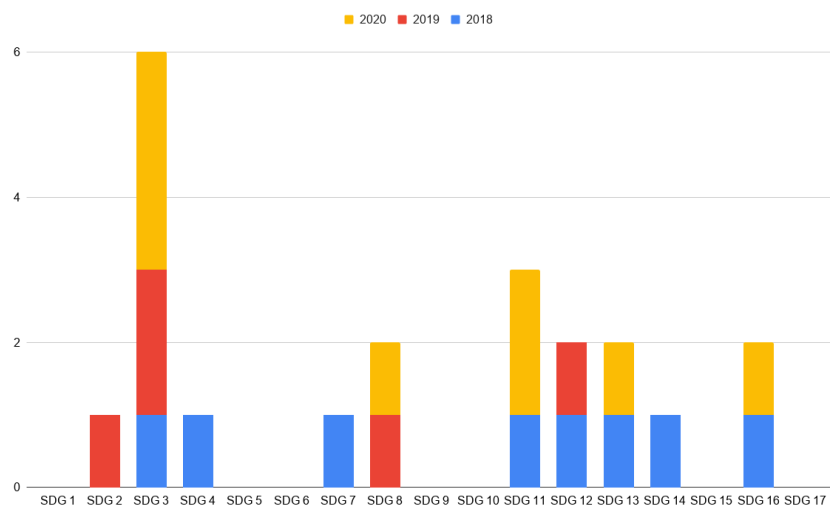


Figure 5. SDG distribution in relation to societal topics over three academic years.

Answering RQ4: Which categories of individuals do project descriptions target?

We read through the project descriptions to identify the different categories of individuals that the projects target. We mainly identified target groups based on age and working status. We observed that less than 20% of the projects target children, young, and elderly individuals. The remaining projects target a broader age group. Most of the projects target job seekers (50%), whereas employees and students are targeted at a lower rate of 20%. To a meager extent (around 10%), some projects also target employers. We observed that projects do not target any marginalized, culturally diverse, ethnic, or gender groups.

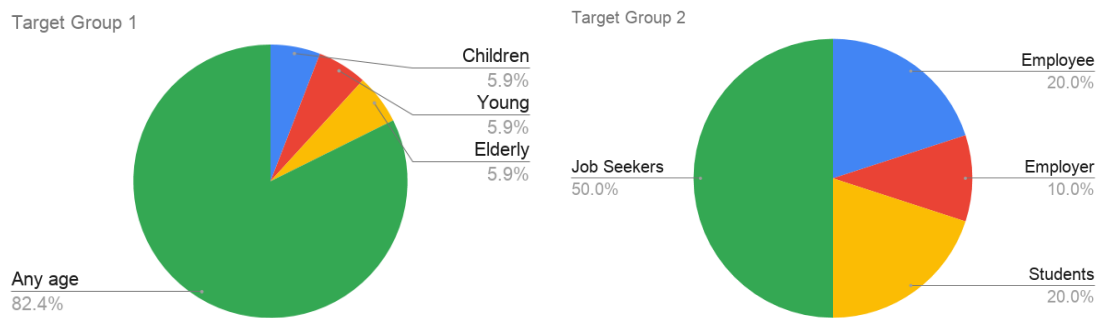


Figure 6. Two target groups addressed from the project descriptions

Key Findings

1. Projects addressing societal topics are at a low percentage in comparison to the total number of projects.
2. The coverage of the SDGs remains at moderate levels with little more than half of the total number of SDGs addressed from the projects in the last three years.
3. Projects successfully address different groups based on age and work status; however, marginalized, culturally diverse, ethnic, and gender groups are not present in the project descriptions.

VI. Discussions

The customer projects showed low interest in societal topics with most projects focusing on technical solutions only. The reasons for not addressing societal issues vary. We argue that the first step toward introducing projects more relevant to society is to specify this as an explicit course requirement. It is imperative, when having a large set of customers coming from a broad range of industries from all over Norway, to ask them to present the societal aspect of their project in the description. The customers should also put effort into describing the SDGs they are targeting within their projects. We discover that the connection between the project topic and the SDGs in many project cases is straight forward. In the last two years we observe that projects address more than one SDG, which is a sign of increased interest in the societal aspects of the customer projects. This might also indicate that the project descriptions are shifting from a pure technical to a more societal nature.

However, we cannot attribute the lack of social topics only to the customers. The course teachers and coordinators need to actively work with them to increase presence of social topics in the project descriptions. At present, the communication seems to be unidirectional (customers submit the proposals and the course teachers/coordinators accept or reject them). It would be a good initiative from the course teachers/coordinators to ask for revisions of the projects with an iterative, ever-improving approach.

We also recommend that after projects are accepted, the customers should make a presentation with the aim of further discussing and gaining feedback from the course teachers/coordinators. Such activity would help improve the quality of the overall project proposals and address expectations beforehand.

Overall, the teachers and the course coordinators, in the coming years, should encourage the trend of customer projects introducing more societal topics covering several SDGs.

Some customers over the past three years have been repeat customers. Thus, to some extent, we have not observed any major improvements within the project descriptions, indicating that an improved effort in the project's quality check is necessary.

The course coordinators should also emphasize the necessity of projects addressing a variety of target groups, such as marginal, culturally diverse, ethnic, and gender groups. We observe a direct connection between the customer and the groups being targeted. To this end, the course coordinators should not allow a customer to participate into the course for more than two consecutive years. This would lead to a broader range of customers participating in the course, which in turn might encourage the targeting of different groups and societal actors.

VII. Conclusions and Future Work

We designed our X course to allow students to interact with external customers through realistic projects, and we sought to evaluate whether customers were addressing enough societal topics within their project descriptions. To answer our research questions, we conducted a thematic analysis of the project descriptions from the past three years. After a meticulous investigation, we conclude that we need to increase the societal topics present in customer projects through the active collaboration of teachers, course coordinators and customers. The course requirements should also better emphasize the expectations so that customers can explicitly identify the SDGs they address as part of their project. Finally, although projects target age and employability to a large extent, customers need to put in more effort to include marginalized, culturally diverse, ethnic, and gender groups. To the same extent, the course coordinators should avoid selecting repeated customers for long period of times.

In the future, we intend to address the issues found in this investigation in improving the quality of the customers' project descriptions within the course. Based on the present findings, we intend to continuously run an analysis of the proposed projects in the timespan of three to five years, considering that the course in Norway has been very successful in the past five decades. We encourage other educators and researchers to analyze the presence of societal topics in their customer-driven project courses. In the future, we also plan to run semi-structured interviews to evaluate the student perceptions about societal topics in their customer-driven project courses.

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