Exploring Social Sustainability Alignment in Software Development Projects

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Abstract: Socially sustainable software, developed with an emphasis on individual well-being, social justice, and social development, can positively impact society. In order to develop real-world software projects, a software engineering course was established to connect students and companies. This course allows students to address sustainability issues by creating solutions for problems proposed by companies, who are treated as customers. This study explores the alignment of students and customers about social sustainability. An analysis of twelve project proposals and twelve final reports from 67 students revealed that seven customers explicitly mentioned social sustainability. Surprisingly, only three student groups incorporated it into their projects. Two groups addressed the concerns raised by customers, and one proactively tackled social sustainability despite no explicit demand. This study presents a novel approach that integrates social sustainability into software engineering, evaluating alignment between customer demands and student responses. Discussions cover potential challenges and improvements in the software development process, proposing initial steps toward a foundational guideline for active engagement in social sustainability by both students and companies.

1 INTRODUCTION

Academic courses are designed to match industry and academy needs in terms of educating and preparing new professionals to work with customers by having real experience on software development projects (Andersen et al., 1994) (Paasivaara et al., 2019). Each party recognizes the benefits of this, including the opportunity for students to apply their learning and for customers to obtain a minimum viable product, proof of concept, feasibility study, and functional software.

Initial investigations about software and sustainability have happened in academic courses (Peters et al., 2023). For instance the Sustainability Awareness Framework was first assessed in the academic settings (Duboc et al., 2019). Another example is a previous study by Cico et al., focused on identifying sustainability issues in companies or customers proposals by mapping them to the Sustainable Development Goals (SDGs) (Nations, 2015). The results revealed a positive alignment between 10 out of 17 SDGs covered by the customers proposals indicating a promising implicit intention to address sustainability, especially social sustainability. However, a recognized gap is how the students incorporated sustainability in their reports with respect to what was initially proposed by the customers from a societal perspective(Cico et al., 2021). This highlights the need for further research to determine the extent of sustainability integration in software development. Therefore, while researchers are proposing methods, frameworks, practices, and guidance on addressing sustainability in software, there is still an opportunity to validate these approaches between industry and academic practitioners (Cico et al., 2021) (Oyedeji et al., 2021).

Our study aims to explore how social sustainability concerns are aligned between customers and students in software development projects of a software engineering course. The main goal of this course is to develop a working software product for a company, which we call customer, based on their project proposal. The participants of this course were 67 students and 12 customers from different sectors. Since

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we did not establish any predefined research questions or hypothesis we chose the grounded theory method (Glaser, 1978) (Strauss and Corbin, 1998) (Charmaz, 2006) to analyze customer proposals and students' reports through the lens of the social sustainability dimension (Brundtland, 1987). Moreover, since we were comparing the customers' proposals against students' reports, we analyzed the documents using a two-case model analysis in the tool called MAXQDA[1]. As part of the grounded theory method, the theoretical coding helped to reveal the relationship between social sustainability concerns, SDGs, and socially sustainable software practices.

Based on our document analysis, we have identified that the customer proposes projects that address social sustainability concerning well-being and good health, social justice, participatory society, and community development. The data suggests that both customer requirements and software requirements play a crucial role in determining which sustainability concerns the software will aim to tackle. As a result, customers who explicitly incorporated social sustainability concerns into their proposals had their solutions developed by the students with those concerns in mind. Another finding was the student's potential to reflect on social sustainability beyond what was initially stated by the customer in their proposals. Despite these promising results, 2 out of 12 customers did not mention in their proposal how the project would target sustainability issues, while the other 3 out of 12 customers addressed the environmental dimension. Further research to investigate the reasons behind these results is necessary to fully understand the challenges in addressing social sustainability concerns from both sides. Finally, our study shed light on the importance of aligning social sustainability concerns in a software development project which can be extended to real projects as well.

This paper consists of eight sections. Section 2 reviews related work on software courses and social sustainability. Section 3 outlines the course settings. The research method is detailed in section 4, while section 5 presents the findings. Discussions are provided in section 6, followed by limitations and future work in section 7. Section 8 concludes the paper.

2 RELATED WORK

Social sustainability in software development is an interdisciplinary field, which urges empirical validation of its implications in the practice (McGuire et al., 2023),(Swacha, 2022). Social sustainability refers to social equity between generations, aiming to extend all opportunities for fulfilling aspirations for a better life, health, and well-being, recognized as essential for all human beings (Brundtland, 1987). Betz et al. states "Social Sustainability debt is the hidden effect of decisions about software that negatively affect social justice, equity, and fairness, or which lead to an erosion of trust in society" (Betz et al., 2015). Software promotes direct support to social communities in various domains and includes activities or processes that indirectly contribute to the well-being of these communities (Lago et al., 2015). Social sustainability can be influenced by software, particularly when it introduces social threats, raises concerns in society, and impacts individual trust (de Souza et al., 2023). Therefore, designing socially sustainable software requires a systemic view of societal issues, threats, social aspects, and human factors.

The relation between Social Sustainability and the Sustainable Development Goals in Software Engineering is mapped in the study proposed by (Calero et al., 2022). In this study SDGs can be targeted not only during the process of developing a software but also as the product contributing to target the goal itself. Moreover (Seyff et al., 2022) proposed a pilot mapping study to demonstrate the feasibility of targeting the SDGs with the application of Sustainability Awareness Framework questions (Duboc et al., 2019) (Duboc et al., 2020). As the authors mentioned, this mapping will help the industry "partner in better understanding whether their proposed changes will support or violate specific SDGs."

Peters et al. investigated the landscape of sustainability integration in computing education (Peters et al., 2023). The findings indicate that while there is evidence that sustainability education is valued by students, there is a need for a transformative approach in computing education that challenges existing norms and values, contributing to democratic change. The study emphasizes the importance of incorporating sustainability not as an isolated topic but as an integral part of evolving educational practices and processes. While Peters et al.'s study contributed to the broad definition of sustainability in educational settings, the conceptualization of "incremental changes" in a course to integrate sustainability aligns with the study we are presenting here. Another finding related to our research is about the relevant studies that recognizes "the value of Computer Science (CS) or (Information Technology) IT as an enabler to address many of the society-wide sustainability issues."

[1] https://www.maxqda.com/

In 2018, a study investigated the role of Information and Communication Technologies (ICT) tools in facilitating social innovation within a course (Pappas et al., 2018). The course focuses on teaching students cooperation skills through a project by practicing an experiential learning cycle where students collaborated to generate innovative ideas for SDGs. The initial phase of the social innovation process involved identifying societal issues, and students reported that the use of ICT tools assisted them in developing ideas to address these concerns.

In 2019, another study delved into the participation of female students in software engineering tasks and team dynamics (Nguyen-Duc et al., 2019). The analysis of student reports from 2015 to 2017 revealed that female students were more engaged in project management and requirement engineering. However, they remained underrepresented in specialized activities, indicating a gender gap of 66.6 percent between male and female students.

In 2021, researchers conducted a deductive thematic analysis of project proposals for software development from 45 companies spanning from 2018 to 2020 to map the SDGs (Cico et al., 2021). The proposals addressed societal issues related to the environment, social constraints, and economic dimensions, classifying them into the 10 SDGs[2]. In (Cico et al., 2021) study, the companies did not explicitly mention sustainability issues in their proposals.

The studies mentioned above are indeed related to sustainability and provide insights into how sustainability concerns have been addressed in these courses. They contribute to various sustainability aspects, such as using ICT tools for social innovation, the participation of female students in software engineering tasks, and mapping SDGs in companies' proposals. In our study, our primary focus is to identify the social sustainability concerns that customers and students have addressed in the solutions developed during the course. This study takes place in the aspects of a software engineering course that aims to expose students to unknown problems while delivering a software solution to a specific customer. The course has been adapted to deal with social innovation addressing social changes from generation to generation.

3 THE COURSE SETTINGS

The Customer-Driven Project course is a Master degree course (Cico et al., 2021). Its iteration officially started with a first meeting with all actors of the course (i.e. students, customers, teachers, and teaching assistants) in August 2022. During the meeting, the students, after they have been assigned to groups, met with their customer (each group has one customer). Proposals from 12 customers have been selected and formed into 12 student groups, intending to balance the gender, country of origin (National or International) and technical knowledge of the students. The customers' proposals were presented during the first meeting. The students also received an introduction to the report structure and what was required for the semester. A compendium with all the important topics to cover in a project was shared, as well as the previous year's students' reports. The students were free to choose their project roles based on their experiences or willingness.

The final proposals and the customers were selected in a group meeting with five teaching assistants and two professors. The selection criteria relied on the solution description, project goal, and customer profile. Sustainability was not one of the requirements for the selection of customers' proposals. However, as a first step to address sustainability in the course, the question "*How does the project target sustainability issues?*" was added to the customer proposal form. After that, we communicated accepted and rejected proposals to the respective Customers.

The students worked to develop the solutions for their customers throughout the semester, and each pair (group and company) agreed upon the final deliverable. In this case, for the validation of the solution and proposal, the group delivered a report that included the following: the background of the customer, problem, potential solution, software requirements, architectural diagrams, user cases, user story specification, tools, project management details, coding techniques, testing techniques and evidence, sprint reports, group dynamics, self-reflection about the results, course, and other items.

4 RESEARCH METHOD

For this study, we used the inductive approach of Grounded Theory (GT), which aims to propose theories from an examination of data rather than being deductively derived (Glaser, 1978). The practice of grounded theory concerns the construction of codes and analytical categories from data, avoiding pre-

[2] SDG 2: Zero Hunger, SDG 3: Good Health and Wellbeing, SDG 4: Quality Education, SDG 7: Affordable and Clean Energy, SDG 8: Decent Work and Economic Growth, SDG 11: Sustainable Cities and Communities, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action, SDG 14: Life Below Water, SDG 16: Peace, Justice, and Strong Institutions

conceived and logically deduced hypotheses (Charmaz, 2006). Therefore, according to the author's perspective, the theory emerges through constant and comparative methods applied to each collected data point (Bandeira-De-Mello and Cunha, 2003). The goal is to gradually develop a more comprehensive theory by refining and expanding the codes until reaching the central category. While the primary objective of the grounded theory method is to construct substantive theories, its application can extend beyond obtaining a substantive theory alone. According to (Strauss and Corbin, 1998), researchers can choose to employ specific elements of the grounded theory process to achieve their study goals. Thus, whether Glaserian or Straussian, it is important to explicitly state which method was used.

In our study, we chose to adhere to Glaser's method, as we aimed to approach the field without predetermined research questions. Our focus was on having a general interest in the topic and allowing the concepts and categories to emerge from the data in a more flexible manner, departing from the more prescribed approach of the Straussian method. The Glaserian method emphasizes the constant comparison of data and codes throughout the analysis process. This involves continually comparing new data with previously analyzed data to identify similarities, differences, and patterns, which helps refine the emerging theory. In this study, the new data stopped appearing when we reached out 24 documents analyzed. While grounded theory is still a flexible and recommended method for constant comparative analysis, our work relied on limited sources such as documents. Further research aiming to identify the challenges and motivators to addressing social sustainability such as interviews with students and customers could be beneficial to contribute to an in-depth definition of socially sustainable software.

Therefore, the steps from the grounded theory that was performed in this research are: a) data collection in which students' reports and customer proposals were collected; b) open coding in the documents using MAXQDA software for data qualitative analysis; c) selective coding to identify relationships between codes that might explain the in-vivo codes from the previous steps; d) theoretical coding, where the codes from selective coding explain the central category until no more new findings emerge from the documents selected. In the next subsections, we explain the method and procedure in detail.

4.1 Data Collection

Data collection was conducted in two stages:

a) Customer proposal submission: During this stage, a customer form was created, which included sustainability question. Before the course began, the customers filled out the form. Once the selection process was completed, the proposals were shared with the students as an initial description for their project.

b) Student group reports delivery: The second stage took place during the semester. Students worked on developing their solutions while considering sustainability issues. Subsequently, the students delivered their reports following the course guidelines and evaluation criteria. Later, the reports were evaluated and graded at the end of the semester.

Following the completion of the course, we initiated the analysis of the documents and uploaded them to the MAXQDA tool for further examination. We organized the documents into two different groups: Customer Proposals and Student Reports. In the following sections, we explain how the data was analyzed.

4.2 Open Coding

After uploading the documents to MAXQDA, the reading part started. The first round of open coding was conducted on the customers' proposals. In MAXQDA, the "in-vivo" functionality facilitates the open coding process, which allows the researcher to select the exact text informed by the data. In-vivo coding helps the researcher explicitly find evidence confirming or placing a code. For example, we extracted code as "decision about where to live and what to prioritize" that contributes to sustainability goal number "SDG11-Sustainable Cities and Communities". Constant comparison between codes and documents helped to identify more occurrences of the same information.

This step was carried out for all other documents. Once the open coding of the Customers' proposals was completed, we continued to perform the same process on the student reports. The challenge was explicitly to identify a mention and reflection about social sustainability in the students' reports.

4.3 Selective Coding

The idea behind selective coding is to assign meaning to the chosen open codes, group them together, and discover the connections between the findings. The process of selective coding was conducted in two rounds.

In the first round, we focused on identifying general concepts related to sustainability. For instance, we recognized the social aspect concept of "Suitable place to live", which pertains to appropriate community and city facilities for citizens, fostering social development. Therefore, this concept provided an explanation for the coded statement "decision about where to live and what to prioritize."

In the second round, we aimed to identify the SDGs explicitly mentioned in the customer proposals and student reports. Through this analysis, the categories of SDGs began to emerge from the data. This allowed us to proceed to the fourth step, theoretical coding, in which we refined the codes and relationships.

4.4 Theoretical Coding and Two-Case Model Analysis

Theoretical coding involved a continuous comparison of student reports, customer proposals and codes until we could identify the central category that encapsulated all the findings. To establish the relationships between each code, we assigned names to these relationships. We discovered eight types of relationships by using two-case model analysis in MAXQDA: *enables*, *promotes*, *targets*, *positively impacts*, *is part of*, *is directly or indirectly presented in*, *implements a*, *proposes a*.

The relationships can be explained as follows: The in-vivo code report the social sustainability concerns that will *enable* the concepts of social aspects to be targeted. For instance, these concerns are solved by identifying software requirements that promote the social aspects associated with social sustainability. These concepts of social aspects target the SDGs, which *positively impacts* the social dimension that *is part of* sustainability. The students and/or the customers *explicitly or implicitly presented* a reflection on sustainability in their report or proposal. Finally, based on two-case model analysis, we could identify that a student group *implements a* socially sustainable software product when a customer *proposes a* socially sustainable software product (refer to Figure 1. We describe in detail the findings of this analysis in the next section.

5 FINDINGS

Aiming to explore the alignment of how social sustainability concerns were addressed by both parties, we explain the findings based on the Customers' and Students' reflections on the **same issues**, **different issues**, or **did not reflect**. Moreover, we will discuss the reflections made **only by Customers**. Table 3 presents a summary of the alignments.

5.1 Customers and Students Reflecting on the Same Social Sustainability Concerns

In this section we present the findings pairing the respective customer with the student group. The two-case analysis model enabled us to consistently compare codes identified in students' and customers' documents. The concepts in Table 1 contribute to achieving the SDGs and Social Sustainability Dimension. The in-vivo statements from the documents provide further information about the social sustainability concerns, and we explain how the students implemented them in the software.

Table 1: Customers and Students reflected on the same sustainability issues.

IDs	Concepts	SDGs
C02/SG02	Suitable place to live	SDG11
C12/SG12	Good health, Well-being	SDG03

The C02 proposal was to develop a software aimed to provide information about community facilities based on user preferences, facilitating informed decisions about neighborhood and housing selection. The concept of a "Suitable place to live" was derived from the Customer's proposal and rephrased by the authors. Their report included the following statement:*"decision about where to live and what to prioritize [C02]."* The customer explicitly linked it with SDG11-Sustainable Cities and Communities, which falls under the Social dimension of sustainability. From the student's report, the user story was targeting this social sustainability issue: *"find a suitable area for me to live [SG02]."* Consequently, the students translated this sustainability issue into a software requirement for their proposed solution. Based on this analysis, we can infer that the students addressed sustainability in their project by implementing functional requirements that contribute to achieving SDG11 (see Figure 1). By translating the social sustainability concerns into software requirements and implementing the features we can infer that Socially Sustainable Software was created to assist individuals in locating a residence that aligns with their needs.

The Customer C12 proposed a software product which the goal was to encourage people to improve their health by exercising. One code identified in C12 was about *"encouraging healthier lifestyles can prevent illnesses [C12]"*. This finding was summarized with the "Good Health" concept and linked to SDG03-Good Health and Well-Being, categorized under the Social dimension of sustainability. Although company C12 does not explicitly mention

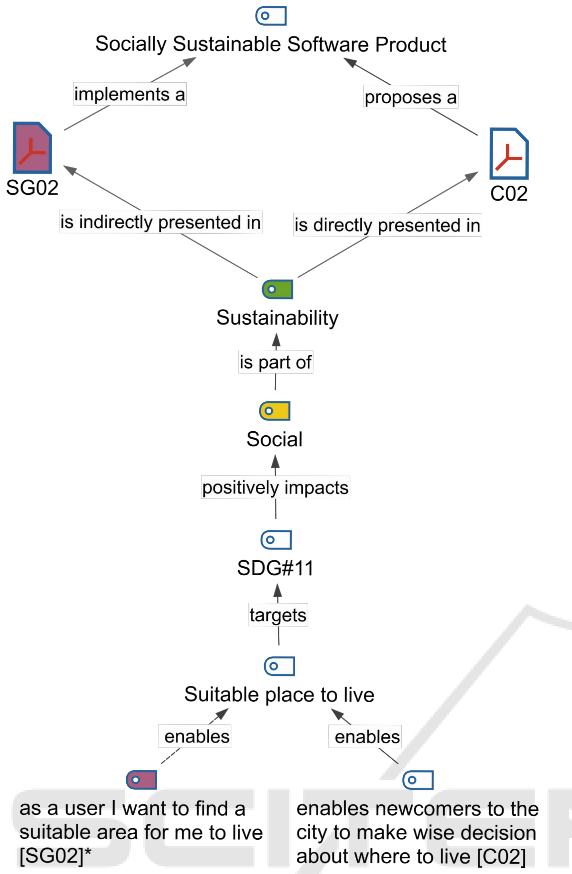
Socially Sustainable Software Product
implements a
proposes a
SG02
C02
is indirectly presented in
is directly presented in
Sustainability
is part of
Social
positively impacts
SDG#11
targets
Suitable place to live
enables
enables
as a user I want to find a suitable area for me to live [SG02]*
enables newcomers to the city to make wise decision about where to live [C02]

Figure 1: Two-Case Model Analysis Company 02 x Students Group 02.

SDG03, it provides detailed information on how the software product contributes to social healthcare. For instance, they stated "using technology and encouraging healthier lifestyles can prevent illnesses and absence from work". In contrast, the student group explicitly stated how the software product aligns with SDG03 in their report. An example of their statement is *"project focuses on improving individual quality of sleep [SG12]"* and categorized into "Well-being". Furthermore, they highlight the software product's role in making sleep healthcare more accessible. Thus, creating a Socially Sustainable Software Product involves making wellness and social healthcare accessible to society.

Highlights

A socially sustainable software addresses social concerns related to housing, community, and individual well-being, helping to target SDGs 11 and 03.

5.2 Customers and Students Reflecting on Different Social Sustainability Concerns

It is noticed from the analysis of the documents that some of the respective Customer and Student groups did not reflect on the same sustainability issues and SDGs based on this analysis. In the customer C03 proposal, the goal of the software was to make eye examinations accessible on a small device. While Customer C03 reflected on "sensitive data protection", Student Group SG03 reflected on "access to equal rights", "good health", "well-being", and a "fair workload". The students added an "Inclusion and Sustainability" section to the compendium and discussed each of the identified SDGs of the project.

Customer C09 propose a virtual reality solution which aims to experience art from anywhere by pointing to QR codes. The customer implicitly focused on SDG11-Sustainable Cities and Communities, specifically emphasizing the environmental dimension, highlighting the concept of "raising awareness about the environmental impact". In contrast, Student Group SG09 included sustainability-related statements in their report but were not explicitly linked to the SDGs. The evidence found in their report was part of functional requirements list were: "Allow cultural diversity" and "Compatible assistive technologies" aligned with the objectives of SDG10-Reduced Inequalities, while "Enable participatory processes" was implicitly associated with SDG16-Peace, Justice, and Strong Institutions. In this case, inclusion and diversity are the social concerns addressed in this software. Thus, to be able to develop a socially sustainable those concerns must be prioritize.

For SDG10-Reduced Inequalities, the in-vivo codes such as *"display different languages depending [SG09]"* and *"compatible with assistive technologies i.e., screen readers [SG09]"* were extracted from the Student Group's report. Additionally, codes like *"user should be able to rate/give feedback [SG09]"* and *"app is usable with my abilities and limitations [SG09]"* were classified under SDG16-Peace, Justice and Strong Institutions. These codes highlight the importance of institutions leading participatory processes that involve and consider individuals in software development. Customer C09 primarily concentrated on proposing environmental contributions within their solutions, while Student Group SG09 addressed concerns related to social sustainability.

Highlights

A socially sustainable software addresses social concerns related to access to healthcare, data privacy, diversity and community involvement, helping to target SDGs 03, 10 and 16.

5.3 Only Customers Reflecting on Social Sustainability Concerns

The findings presented in this section emphasize the contrast between the customers who incorporated sustainability aspects in their proposals and their corresponding student groups that did not. In Table 2, we summarize the concepts exclusively present in the customer's proposals but absent in the student group reports.

Customer C01 explicitly engaged with the Sustainable Development Goals ”3-Good Health and Well-being”. They elaborated on how their software product could contribute to this goal. For instance, the in-vivo code *“good for mental health by reducing depression [C01]”* underscored the software's objective of recognizing various knitting patterns, which are known to have positive effects on mental well-being.

The SDG17-Partnerships for the Goals is explicitly mentioned in Customer C02's proposal, reflecting the possibility of sharing the resulting solution with other municipalities by stating *“spread the technology to other municipalities [C02]”*. This would enable technology sharing by allowing other parties to use the software developed by the students. By addressing this issue in the software, the students have created socially sustainable software that enables partners to reuse the same technology and provide similar public services in their own contexts.

Table 2: Only Customers reflected on sustainability issues.

IDs	Concepts	SDGs
C01	Good Health	SDG03
C02	Technology sharing	SDG17
C08 C11	Enable participatory processes	SDG16

More implicitly, Customer C08 addressed SDG16-Peace, Justice, and Strong Institutions by enabling participatory processes through real user testing. The corresponding in-vivo code extracted was *“tested with real users [C08]*.”* Utilizing user-centric approaches in software development has been recognized as both economically and socially beneficial for involved stakeholders (Kopec et al., 2018). This finding emphasizes that Socially Sustainable Software Products engage and involve affected individuals in their development.

Another implicit code emerged in C11, concerning *“ensure that we build a functioning technology for people [C11]*”* related to social sustainability and the goal SDG16-Peace, Justice, and Strong Institutions, which emphasizes “Enable participatory processes.” From this customer's viewpoint, a Socially Sustainable Software Product promotes local economic growth, enabling locals to explore city activities and develop software that facilitates people's lives.

In summary, while certain customers actively integrated sustainability considerations into their proposals, their corresponding student groups surprisingly did not reflect the same level of attention to sustainability. None of the student's reports SG01, SG08, SG11 appeared to mention sustainability issues raised by the respective customers. With the exception of SG02, that addressed SDG11 and not SDG17.

Highlights

A socially sustainable software addresses social concerns related to community involvement, partnerships, and mental health, helping to target SDGs 03, 16 and 17.

5.4 Customers and Students not Reflecting on Social Sustainability Concerns

In this section, we explain the remaining customers who did not address social sustainability concerns in their projects. After reviewing Customer C04's proposal, it was confirmed that social sustainability concerns were not addressed. The question related to sustainability remained unanswered in the document. However, upon examining the report of Student Group SG04, a dedicated section on sustainability was discovered. Their focus was directed towards economic and environmental sustainability dimensions. Furthermore, the report did not mention SDGs.

Customers C05 and C06 reflected on environmental sustainability, but not specifically mention the SDGs. Even though SG05 added a section about sustainability in their report, it reflected on the same concerns related to sustainability as Customer C05. However, SG06 did not mention sustainability in their report. The reasons why this might have happened are argued in the discussion.

Regarding C07's proposal, the question about how sustainability issues were addressed was left unanswered. In contrast, Student Group SG07 reflected on four SDGs related to environmental goals: numbers 11, 12, 14, and 15. Most of them are related to preserving marine life, which is a goal of the solution.

Our analysis of Customer C10 and Student Group SG10 revealed that neither the company nor the students deliberated on sustainability within their respective documents. Despite the project's health-related domain, the customer explicitly expressed that sustainability considerations were not a focal point of the project. Within SG10's report, the students mentioned a requirement for sustainable architecture; however, they did not establish a clear and explicit connection to sustainability.

6 DISCUSSION

Our study showed documentary evidence that aligning software development endeavors with social sustainability demonstrate a potential and tangible contribution to the society. The data highlights a symbiotic relationship between customer-driven sustainability priorities and the subsequent development of software solutions tailored to address social sustainability concerns. It means that, when customers prioritize sustainability, it influences the development of software solutions that align with and address social sustainability concerns. In this section, we will discuss the integration of social sustainability into software engineering. We also discuss the potential challenges and improvements in the software development process, and provide a steps on how to perform this integration within the course.

6.1 Integrating Sustainability in Software Engineering Course

Integrating the sustainability topic into a software engineering course has been the primary goal of universities striving for a sustainable world. In the review of (Peters et al., 2023), the efforts made by researchers to teach software engineering students systems thinking, a sustainable mindset, and awareness of the sustainability impacts of their software are more evident. Our study investigated how both customers and students were addressing social sustainability during the process of software product development.. The question ("How does the project target sustainability issues?") introduced in the customer proposal presented an initial step towards the university goal of teaching and forming students with a sustainability mindset.

As Peter et al. argue, introducing sustainability as a topic may not be enough to cover the broader facets of sustainability in software. However, since 2018, this course has been exploring the following sustainability topics in an incremental approach, such as: a) developing software targeting one of the SDGs (Pappas et al., 2018), b) analyzing the gender representation in software engineering tasks, in alignment with the SDG5-Gender Equality (Nguyen-Duc et al., 2019), and c) identifying the relation between customer proposals and SDGs (Cico et al., 2021). Therefore, in this course, incremental changes to approach sustainability have been made, including the introduction of that question. This study opened up the opportunity to further explore what improvements regarding sustainability integration are required in the course. Based on the results of our analysis, we identified a recommended list of steps to integrate sustainability into a software engineering course with project-based learning involving companies:

- Organize a software sustainability workshop for customers before submitting proposals - this will help them to reflect on this aspect even if they have not thought about it and integrate sustainability criteria linked to the Sustainable Development Goals.
- Update the course compendium to cover software sustainability topics before the start of the course.
- Give lectures on software sustainability to students during the course.
- Evaluate sustainability criteria related to the SDGs by receiving reports from students.
- Collect feedback from students and customers on how sustainability was addressed after completing the course.

Our analysis reveals the maturity of students in targeting topics not covered in the software engineering curriculum, demonstrating their ability to integrate sustainability considerations into their software products. This ability is particularly evident in their identification and translation of social sustainability concerns into explicit requirements, emphasizing their alignment with customer demands.

Unlike previous studies, exemplified by (Cico et al., 2021), which focused on identifying SDGs within customer proposals, our study took a different approach. We investigated how social sustainability concerns were addressed in the solutions delivered by students, aligning them with the customer proposals. Surprisingly, our findings revealed that certain students groups unintentionally incorporated SDGs into their reports, even when these goals were not explicitly outlined in the initial customer proposals.

Table 3: Summary of SDGs Alignment.

Customer Sector	Business Domain	Students Group Members	SGDs	Social Sustainability C vs SG	Alignment Status	Comments	Customer Quotes	Students Quotes
C01 Private	Knitting industry	SG01 - 6	SDG03	✓ ×	Not Aligned	Students did not address SDG03 in their report.	”Knitting is good for mental health by reducing depression and anxiety which targets Goal 03”	None
C02 Public	Cities	SG02 - 6	SDG11, SDG17	✓ ✓	Aligned	C02 proposed SDG17 explicitly but the students reflected on SDG11 only.	”Goal 11 sustainable cities and communities as it enables newcomers to the city to make a well-informed decision about where to live and what to prioritize” and ”Goal 17 Partnerships for the goals as it will spread the technology to other municipalities”	13 user stories are addressing SDG11. For instance, ”As a user, I want to personalize the search to find an area that suits my wishes and needs.”
C03 Private	Health	SG03 - 5	SDG03, SDG10, SDG16	× ✓	Not Aligned	Students reflected on SDG 03 and SDG10 explicitly in their report. Customer implicitly reflected on SDG16	”Sensitive patient data requires compliance with national privacy regulations”	”Goal 3 Good Health and Well-being... distribute workload over health care workers, causing less work and stress” and ”Goal 10 Reduced Inequalities allowing the patients to get their eyes scanned closer to their residence”
C08 Private	Content Management	SG08 - 5	SDG16	✓ ×	Not Aligned	Students did not address SDG16 in their report.	”When it is ready for integration it will be published to our test servers and be tested with real users”	None
C09 Private	Entertainment	SG09 - 5	SDG10, SDG16	× ✓	Not Aligned	Students reflected implicitly on SDG16 and SDG10 while the customer was reflecting on SDG11 related to the environment.	”The experience also clearly may present the object’s environmental impact”	Four Functional Requirements related to SDG10. For instance: ”Compatible with assistive technologies like screen readers and keyboards”
C11 Private	Eco-tourism	SG11 - 6	SDG16	✓ ×	Not Aligned	Students did not address SDG16 in their report.	”A user-centric and participatory process, to ensure that we build a functioning technology that people need”	None
C12 Private	Health	SG12 - 5	SDG03	✓ ✓	Aligned	Student group explicitly stated how the software product aligns with SDG03.	”Thus, using technology and encouraging healthier lifestyles can prevent illnesses and absence from work and thereby facilitates sustainability of the health care system”	”Improving individual quality of sleep, which is a personal health issue and fits goal 3: Good Health and Well Being”

Our findings echo the study by Oyedeji et al. (2021) (Oyedeji et al., 2021), which sought to understand academic and industry perceptions of software sustainability. Their research emphasizes the need for common standards in software engineering curricula to include software sustainability and highlights the importance of cross-disciplinary collaboration between academia and industry in addressing sustainability dimensions. This collaboration is evident in our study through the customer proposals and the potential for software products to address sustainability goals developed by the students, who are future software engineers mindful of sustainability concerns.

6.2 Potential Challenges

Heldal et al. conducted interviews with 28 organizations in nine different countries to explore their perspectives on sustainability (Heldal et al., 2023). The results revealed a significant demand from companies for skills and knowledge in sustainability. To address this gap, many companies have implemented internal sustainability training programs. The discussion includes insights into current practices within companies aimed at mitigating the sustainability skill gap. While our study focused on document analysis, it highlights the same challenges as (Heldal et al., 2023) related to the sustainability knowledge domain among customers and students. The potential challenges in the alignment of social sustainability in software development identified during this study are revealed:

Deficiency in Formal Sustainability Knowledge. The study identified a significant challenge in the form of a lack of formal knowledge and skills in sustainability among both customers and students. This deficiency hampers their ability to specify detailed requirements that address sustainability concerns in software development projects.

Insufficient Intuitive Understanding of Sustainability. The study also revealed a lack of basic awareness or intuitive understanding of sustainability principles. This gap in knowledge impedes the ability of customers and students to incorporate sustainability considerations into their projects effectively.

Neglect of Sustainability Reflection. The study found that some students failed to reflect on sustainability issues, even when these were explicitly mentioned in the project proposals provided by customers. This finding suggests a disconnect between project requirements and the awareness or priorities of students.

Discrepancy Between Customer and Developer Priorities. The study observed instances where there was a mismatch between the sustainability concerns of customers and those of the students. This discrepancy can result in projects that fail to adequately address sustainability concerns.

Inconsistency in Sustainability Focus. The study noted that different pairs of customers and student groups targeted different sustainability issues and Sustainable Development Goals. This finding indicates a lack of consistency or alignment in sustainability goals across different projects.

Ineffectiveness of Sustainability Integration. The study identified a lack of a common goal for integrating sustainability. The primary focus is on delivering a functional product, followed by customer satisfaction, with sustainability often being a tertiary concern. The absence of a shared goal poses a risk of failing to measure and achieve sustainability objectives.

6.3 Improvements in the Software Development Process

In general, each of the mentioned challenges presents an opportunity for improvement in the alignment of social sustainability in software development. By addressing these issues, we can enhance the integration of sustainability principles into software development practices. More specifically we discuss some of these potential improvements here.

Defining a software sustainability goal might improve the software development process while addressing sustainability (Heldal et al., 2023)(Noman et al., 2024). In this study, particularly in two student groups, we noticed that when the customer clearly defined a software sustainability goal, the students were able to translate sustainability issues into user stories or functional requirements that targeted at SDG03-Good Health and Well-being and SDG11-Sustainable Cities and Communities, thereby contributing to the social dimension of sustainability.

As a well-know topics in software requirement, the customer expectation, communication alignment and satisfaction towards the final product is highly discussed in this research field (Huijgens et al., 2017). It is in the software requirement phase of software development process that sustainability concerns emerged (Bambazek et al., 2023) (Condori-Fernandez and Lago, 2018) (Duboc et al., 2019). From this perspective, we realize that to create a socially sustainable software product within the course, it is essential to have proposals that address sustainability concerns. Customers should consider time and effort on putting the details on how their solution targets sustainability when they are proposing projects for students' development.

Bambazek et al. (2022) conducted a systematic mapping and identified seven of 55 published papers that proposed tools to integrate sustainability during the software requirements. The authors also emphasize the need for the availability of software tools that practitioners can use to accelerate the adoption of proposed approaches in practice (Bambazek et al., 2023). On one hand, students must design solutions that effectively address these issues. On the other hand, the design of sustainability-oriented solutions still requires supporting tools, approaches and practices to guide students in developing socially sustainable software products. A list of existing recommended tools to address social sustainability is reported in this study (de Souza et al., 2023).

Even though our study is identifying some actions and connections that could explain a socially sustainable software product, there is still a need to further investigate the effectiveness of those actions. Therefore, incorporating indicators and metrics to evaluate the social aspects of software can be a driver for improving software development process in the adoption of social sustainability actions (Venters et al., 2018) (Al Hinai and Chitchyan, 2014).

7 LIMITATIONS AND FUTURE WORK

The absence of a preliminary assessment of prior knowledge about software sustainability and the long-term impact of implementing any of these sustainability goals are recognized vulnerability in the validity of this study. This gap hampers the ability to deduce the correlation between sustainability concerns and sustainable development goal, as the degree of understanding remains unclear. This recognition highlights the study's self-awareness of its potential limitations.

Adopting selective and theoretical coding analysis is one strategy to mitigate qualitative analysis biases. The involvement of two researchers in collaborative discussions to establish shared interpretations of grounded theory data highlights the effort to minimize bias and increase the reliability of results. This highlights the study's dedication to methodological rigor and reliability.

Including sustainability in student projects can prepare them for future careers and serve as a motivational factor to contribute to social well-being, although this aspect is not the focus of this study. Future research opportunities lie in empirical investigation into motivational factors and the empirical validation of sustainability integration in academic and industrial settings.

8 CONCLUSION

As part of an engaged society that strives to achieve the Sustainable Development Goals by 2030, developing socially sustainable software can contribute to addressing these goals and positively impacting our society. Traditionally, software engineering courses have predominantly focused on technical aspects. However, history has taught us that human values, principles, and behaviors are interconnected with the technical aspects of software development and its utilization. Therefore, it is essential to recognize that sustainability, as another interdisciplinary field, deserves attention.

In this context, social sustainability concepts become practical tools for designing and developing software to tackle social issues and threats. Our study has revealed that introducing sustainability-related questions can raise awareness, prompt discussions about sustainability issues, and facilitate the creation of socially sustainable software products.

Furthermore, we explored how aligning with social sustainability is a fundamental step to integrate concerns into a project-based learning course. We discussed the practical implications in terms of improvements in the software development process to address social sustainability concerns within software products. Students with a background in software engineering can reflect on these issues and relate them to sustainable development goals, thus making sustainability more tangible within the realm of software development.

In light of this agenda, there are still ample opportunities for enhancing and transforming our software engineering curriculum to better prepare future generations by integrating sustainability topics.

REFERENCES

Al Hinai, M. and Chitchyan, R. (2014). Social sustainability indicators for software: Initial. *Science*, 79(68):29.

Andersen, R., Conradi, R., Krogstie, J., Sindre, G., and Sølvberg, A. (1994). Project courses at the NTH: 20 years of experience. In *Conference on Software Engineering Education*, pages 177–188. Springer.

Bambazek, P., Groher, I., and Seyff, N. (2023). Requirements engineering for sustainable software systems: a systematic mapping study. *Requirements Engineering*, pages 1–25.

Bandeira-De-Mello, R. and Cunha, C. (2003). Operacionalizando o método da grounded theory nas pesquisas em estratégia: técnicas e procedimentos de análise com apoio do software atlas/ti. *Encontro de Estudos em Estratégia*, 1:2003.

Betz, S., Becker, C., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., Seyff, N., and Venters, C. C. (2015). Sustainability debt: A metaphor to support sustainability design decisions. In *International Requirements Engineering Conference (RE 2015), Ottawa, Canada*, volume 1416 of *CEUR Workshop Proceedings*, pages 55–53.

Brundtland, G. H. (1987). Report of the world commission on environment and development: Our common future.

Calero, C., Ángeles Moraga, M., and García, F. (2022). Software, sustainability, and un sustainable development goals. *IT Professional*, pages 41–48.

Charmaz, K. (2006). Constructing grounded theory: a practical guide through qualitative analysis.

Cico, O., Jaccheri, L., and Duc, A. N. (2021). Software sustainability in customer-driven courses. In *2021 IEEE/ACM International Workshop on Body of Knowledge for Software Sustainability (BoKSS)*, pages 15–22. IEEE.

Condori-Fernandez, N. and Lago, P. (2018). Characterizing the contribution of quality requirements to software sustainability. *Journal of Systems and Software*, 137:289–305.

de Souza, A. C. M., Cruzes, D. S., Jaccheri, L., and Krogstie, J. (2023). Social sustainability approaches for software development: A systematic literature review. In *Proc. of the 24th International Conference Product-Focused Software Process Improvement PROFES, Dornbirn, Austria*, volume 14483, pages 478–494. Springer.

Duboc, L., Betz, S., Penzenstadler, B., Koçak, S. A., Chitchyan, R., Leifler, O., Porras, J., Seyff, N., and Venters, C. C. (2019). Do we really know what we are building? raising awareness of potential sustainability effects of software systems in requirements engineering. In *27th IEEE Requirements Engineering Conference, RE*, pages 6–16. IEEE.

Duboc, L., Penzenstadler, B., Porras, J., Akinli Kocak, S., Betz, S., Chitchyan, R., Leifler, O., Seyff, N., and Venters, C. C. (2020). Requirements engineering for sustainability: An awareness framework for designing software systems for a better tomorrow. *Requirements Engineering*, 25(4):469–492.

Glaser, B. (1978). Sensitivity: Advances in the methodology of grounded theory.

Heldal, R., Nguyen, N., Moreira, A., Lago, P., Duboc, L., Betz, S., Coroama, V. C., Penzenstadler, B., Porras, J., Capilla, R., Brooks, I., Oyedeji, S., and Venters, C. C. (2023). Sustainability competencies and skills in software engineering: An industry perspective. *CoRR*, abs/2305.00436.

Huijgens, H., Van Deursen, A., and Van Solingen, R. (2017). The effects of perceived value and stakeholder satisfaction on software project impact. *Information and Software Technology*, 89:19–36.

Kopec, W., Nielek, R., and Wierzbicki, A. (2018). Guidelines towards better participation of older adults in software development processes using a new spiral method and participatory approach. In *Proc. of the 11th Inter. Workshop on Cooperative and Human Aspects of Software Engineering*, page 49–56.

Lago, P., Koçak, S. A., Crnkovic, I., and Penzenstadler, B. (2015). Framing sustainability as a property of software quality. *Commun. ACM*, 58(10):70–78.

McGuire, S., Shultz, E., Ayoola, B., and Ralph, P. (2023). Sustainability is stratified: Toward a better theory of sustainable software engineering. *arXiv preprint arXiv:2301.11129*.

Nations, U. (2015). Measuring progress towards the sustainable development goals.

Nguyen-Duc, A., Jaccheri, L., and Abrahamsson, P. (2019). An empirical study on female participation in software project courses. In *2019 IEEE/ACM 41st International Conference on Software Engineering: Companion Proceedings (ICSE-Companion)*, pages 240–241. IEEE.

Noman, H., Mahoto, N., Bhatti, S., Rajab, A., and Shaikh, A. (2024). Towards sustainable software systems: A software sustainability analysis framework. *Information and Software Technology*, 169:107411.

Oyedeji, S., Shamshiri, H., Porras, J., and Lammert, D. (2021). Software sustainability: Academic understanding and industry perceptions. In *Software Business*, pages 18–34, Cham. Springer International Publishing.

Paasivaara, M., Vanhanen, J., and Lassenius, C. (2019). Collaborating with industrial customers in a capstone project course: The customers' perspective. In *Proc. of the 41st International Conference on Software Engineering: Software Engineering Education and Training*, page 12–22. IEEE.

Pappas, I. O., Mora, S., Jaccheri, L., and Mikalef, P. (2018). Empowering social innovators through collaborative and experiential learning. In *2018 IEEE Global Engineering Education Conference (EDUCON)*, pages 1080–1088.

Peters, A., Capilla, R., Coroama, V. C., Heldal, R., Lago, P., Leifler, O., Moreira, A., Fernandes, J. P., Penzenstadler, B., Porras, J., and Venters, C. C. (2023). Sustainability in computing education: A systematic literature review. *CoRR*, abs/2305.10369.

Seyff, N., Betz, S., Lammert, D., Porras, J., Duboc, L., Brooks, I., Chitchyan, R., Venters, C., and Penzenstadler, B. (2022). Transforming our world through software: Mapping the sustainability awareness framework to the un sustainable development goals. In *Proc. of the 17th International Conference on Evaluation of Novel Approaches to Software Engineering-ENASE, Bristol, UK*, pages 417–425.

Strauss, A. and Corbin, J. (1998). *Basics of qualitative research techniques*. SAGE.

Swacha, J. (2022). Models of sustainable software: A scoping review. *Sustainability*, 14(1).

Venters, C. C., Capilla, R., Betz, S., Penzenstadler, B., Crick, T., Crouch, S., Nakagawa, E. Y., Becker, C., and Carrillo, C. (2018). Software sustainability: Research and practice from a software architecture viewpoint. *Journal of Systems and Software*, 138:174–188.