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Do Students Reflect on Sustainability? Student Development of Competencies for Sustainability in Project-Based Learning

T. Bolstad[1], L. Lundheim[1], M. Orlandic[1], A. Strømberg[1], P. H. Zimmermann[2]

[1]*Department of Electronic Systems, NTNU*

[2]*Department of Computer Science, NTNU*

ABSTRACT: Higher education plays a crucial role in supporting a society based on sustainable development through the facilitation of students' acquisition of competencies for sustainable development. A suitable arena in which to integrate these competencies can be courses built on project-based learning, though knowing how to support the students' learning can be difficult and a continued challenge. In this work, we study first and second year bachelor level PBL courses and examine the effect of choosing a project theme related to sustainability. Specifically, we look at the students' own assessment of integration of sustainability aspects in their projects, and their development of the *normative competency*, *critical thinking competency*, and *self-awareness competency* from *UNESCO's key competencies for sustainability*, as a function of project theme. Through a survey, where students were asked to assess themselves and their own projects on a seven-point Likert scale, we found that while having sustainability-related project themes does have some effect, the effect is limited compared to the development of other competencies in the course. Along with how the project theme affects the development of the investigated competencies, the need for targeted support in order to facilitate the students' development of sustainability related competencies is discussed.

1 CHALLENGES OF INTEGRATING EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PROJECT-BASED LEARNING

Including sustainable development (SD) in higher education has grown significantly in importance in the last years. With a world rapidly changing, new and complex challenges arise with environmental, societal and economic aspects. Higher education must contribute to the handling of these challenges through educating citizens who are forces for positive change [1]. In 2017 UNESCO developed a set of eight *key competencies for sustainability*, providing a basis for education for sustainable development (ESD). Such an education aims to empower learners to develop the competencies necessary to take responsible actions and to become part of this positive change [2]. UNESCO's key competencies for sustainability are: 1) *systems thinking competency*, 2) *anticipatory competency*, 3) *normative competency*, 4) *strategic competency*, 5) *collaboration competency*, 6) *critical thinking competency*, 7) *self-awareness competency*, and 8) *integrated problem-solving competency*. These competencies are also embedded in the future strategy for the technology programs at the Norwegian University of Science and Technology, NTNU, in Trondheim, Norway, the host university for this study [3].

In order to include ESD without reducing other areas of the curriculum, it is often proposed to integrate SD in existing courses, thereby achieving dual use of time [3]. However, it is not necessarily clear for study program administrators and course coordinators how to effectively integrate sustainability aspects [4], and research into the development of sustainability competencies within an educational setting is limited. This appears to be especially true, from a review by Algurén [5] from 2021 on learning activities for SD from the time period 2010 – 2019, for learning activities for the development of *critical thinking competency*, *self-awareness competency*, and *normative competency*, with three, two, and one studies found, respectively.

One way to approach these problems is through already established courses oriented around project-based learning (PBL). PBL is often highlighted as a way to integrate sustainability in engineering education, with the argument being that PBL supports the development of sustainability through related learning principles such as interdisciplinarity, collaborative and contextual learning, problem

orientation, and self-directed learning, and can thereby contribute to the development of sustainability-related competencies such as critical thinking, collaboration, communication, and problem-solving skills [6]. Through interactions with real-life sustainability-related problems or problems that can be reframed as sustainability-related, the students are expected to increase their understanding of sustainability problems, develop competencies and develop a desire to take action on sustainability issues [7-10].

In a framework proposal by Lozano et al. [11], a set of 12 ESD competencies is linked to pedagogical approaches. While not directly linked to UNESCO's key competencies for sustainability, we deem the *justice, responsibility, and ethics competency*, *critical thinking and analysis competency*, *empathy and change of perspective competency*, and *personal involvement competency* from the proposed framework to overlap with critical thinking competency, self-awareness competency, and normative competency. In this framework, PBL is judged to have a high likelihood of addressing the personal involvement competency, while the other three competencies *may* be addressed by utilizing PBL as a pedagogical approach. Specifically, it has been found that normative competency can be developed within PBL settings by Birdman et al. [12]. Using a slightly simplified model of the key competencies by Wiek et al. [13], Birdman et al. [12] report how SD competencies are developed in three graduate sustainability programs finding that almost all participants self-reported a large increase in the normative competency, called "values thinking" in the work, from being involved in PBL courses.

As engineers play an important role in solving society's sustainability issues, engineers cannot be technical experts within their field alone, they must also be able to take into account their own role, consider ethical dilemmas, and assess tradeoffs. Thus, integration of ESD into engineering education is necessary in order to provide engineers with these required competencies. Work has been done to integrate ESD in engineering through PBL courses (for example [6, 8, 9, 14-16]). Servant et al. [17] find that involvement in PBL courses increased engineering students' awareness and interest in sustainability issues. However, effectively integrating ESD and targeting specific competencies in engineering PBL courses can be challenging. For example, it can be difficult to know to which degree the students need to be supported in the development of SD competencies. Some students might independently develop an understanding of SD through working on the project, while others might limit themselves to carrying out the tasks given to them without reflecting on the project's relation to SD [8]. The study by Birdman et al. [12], discusses that the degree of competency development in the graduate students might be linked to whether the students' involvement in the PBL course is voluntary or a mandatory part of the program, with the latter having the advantage of involving all students, but require more support and scaffolding from the teaching staff in order to motivate all the students in the course. This can especially be true for bachelor level courses where the academic maturity and independence of the students cannot be assumed to be developed to a high degree for all students. Therefore, targeted activities designed specifically to support the students' ESD competency development might be needed. For example, Colombo et al. [18] found that introducing SD workshops in a first semester PBL course had a positive contribution to the students' sustainability learning, compared to the same course without these workshops, though this work was not directly coupled to UNESCO's key competencies for sustainability. Additionally, we believe that the level of support should be adapted to not only the academic level of the course, but also to the character of the student body and the study program. A PBL course in an interdisciplinary sustainability program might generate reflection on SD to a larger degree through the implicit context of the course, than a PBL course in a disciplinary engineering program, as is the case in this study.

Therefore, the aims of this article are to:

- Study to which degree ESD competencies develop as a result of having real-life sustainability-related projects in a PBL course, with a focus on the normative competency, critical thinking competency, and self-awareness competency.
- Discuss the need for targeted support in the development of ESD competencies in engineering bachelor level disciplinary PBL courses.

2 LOCAL CONTEXT

In order to achieve the aforementioned goals, we look at the students' own assessments in two PBL courses of whether sustainability-related projects stimulate considerations of sustainability in the project work and development of the normative competency, critical thinking competency, and self-awareness competency. The PBL courses are given to students in the first and fourth semester at the 5-year

integrated master's program *Electronic Systems Design and Innovation* (Elsys) at NTNU. In these courses, the students collaborate in groups on a project, the specifics of which are to a large degree defined by the students themselves, within a predefined theme or setting. The theme is formulated together with an external partner and is the same in the first and fourth semester for a given class of students. During the project, the students are expected to research and understand the theme, formulate a problem, and design, prototype and test a solution to their defined problem. More information about the organization of the courses can be found in references [19, 20].

The theme given to the students changes for each new class of students and some of these have been more directly linked to sustainability than others. Through looking at the students' self-assessments as a function of project theme we can compare the effects of the different themes and consider whether having sustainability-related problems is an effective way of integrating ESD in a PBL-course. The normative competency, critical thinking competency, and self-awareness competency were chosen as they do not overlap with intended learning outcomes already included in the investigated courses or cannot be expected to be developed within the context of the course. Collaboration competency, for example, is already a focus of the PBL-activities of the course regardless of theme as the students work collaboratively in groups and are guided in these efforts. Likewise, while the ability to consider risks and consequences included in the anticipatory competency is outside of what we believe we can presuppose that the students will develop through reflection and interaction with the project. The students are to a very small degree given lectures on the project theme during the semester. At the start of the semester, the external partner gives a 30-45 minute introduction to the theme. Subsequently the students are expected, through various methods, to gain a sufficient understanding of the theme to be able to formulate a problem, and design and prototype a solution to their defined problem.

There are no activities in the course that intentionally aim at developing normative competency, critical thinking competency, or self-awareness competency. Development of these competencies must therefore happen through student-initiated reflections or discussions from interaction with the project theme.

As of the beginning of 2021, the students currently attending the study program have been involved in a total of five different innovation projects [21], one for each year from 2016 to 2020. The projects can be divided into two groups, with three projects having themes more related to sustainability than the remaining two. The projects related to sustainability were focused on water quality in local rivers, effects of windmills on the local environment, and infrastructure for walking and biking. The other two projects were related to the new offices of a local newspaper and the sport curling. This creates a basis for comparison of the effect of the theme on students' development in these courses.

3 STUDENT SURVEY DESIGN

To explore the development of sustainability related competencies, a survey was distributed through mailing lists to all active students in all five years of the Elsys study program. A survey was chosen to enable gathering of data for the entire study program and enable comparisons between different project themes. The survey was open from 20th of November 2020 through the 8th of December 2020. Two follow up reminders encouraging the students to participate were sent in that period. No data that could identify the person participating were collected, therefore is it possible that one person could complete the survey several times, though no indications of this happening has been found. The survey had 31 items that required a response and covered their views on the projects' relation to sustainability, integration of sustainability in their projects, and assessment of their development of sustainability-related competencies. Additionally, to enable comparisons, some questions were asked related to a set of competencies in the intended learning outcomes for the courses, given in Table 1. The survey was given in Norwegian and has been translated to English for this article. A translation of all questions is given in the supplementary materials.

Table 1: The key competencies for sustainability studied in this paper (first three rows) [2] and competencies related to the courses (last row). The letters and number in bold refer to the codes used in presentation of the survey results in figure 2.

Competency	Description

Normative competency	**(N1)** the ability to understand and reflect on the norms and values that underlie one's actions; (**N2)** and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.
Critical thinking competency	**(CT1)** the ability to question norms, practices, opinions and established theories; **(CT2)** to reflect on one's own values, perceptions, perspectives and actions; **(CT3)** and to take a position in the sustainability discourse.
Self-awareness competency	**(SA1)** the ability to reflect on one's own role in the local community and (global) society; **(SA2)** to continually evaluate and further motivate one's actions; **(SA3)** and to deal with one's feelings and desires.
Course intended learning outcomes	**(PBL1)** the ability to break down complex problems into simpler parts; **(PBL2)** the ability to collaborate with others; **(PBL3)** planning an extended complex project; **(PBL4)** completing an extended complex project.

Out of the 377 students at the study program, 135 participated in the survey and allowed data to be used in this project, giving a total response rate of 36%. The number of respondents for the 1st to 5th year of study were, 45 (42%), 26 (31%), 27 (37%), 21 (34%) and 15 (29%), respectively, with the response rate for each year given in the parentheses. Generally, it has been shown that when looking at a sample of this size, the obtained response rates will produce very few instances of mean errors over 0.3 standard deviations [22], though the chance of errors will be larger when looking at smaller subsets of the sample. There was one respondent who has dropped a year and participated in an earlier project. This student's responses has been disregarded when looking at individual project themes.

The email invitation to the survey revealed the theme of the survey, therefore there might be a bias of the respondents towards students with an interest in sustainability.

The survey utilizes a seven-point Likert scale, mapped onto a numerical 1-7 point scale to allow statistical analysis. Low values correspond to options such as *strongly disagree* or *to a very small degree* and vice versa for high values. In order to reveal statistically significant differences between the groups studied, Welch's t-test has been used when looking at two groups and ANOVA when looking at more than two groups. A significance level of 0.05 was used in this work. While Likert scale data is ordinal and does not strictly follow a normal distribution, it has been found that these parametric tests are as suitable for Likert scale analysis as non-parametric tests [23, 24].

4 SURVEY RESULTS

The students were asked whether the project they had participated in was related to sustainability. Sustainability in general or in engineering education were not defined in the survey. None of the students in the projects in 2016 and 2019 answered that their project was related to sustainability. For the three other projects, 95%, 89%, and 98% responded a relation to sustainability for the years 2017, 2018, and 2020, respectively. This is largely in line with our earlier intuitive assumption. The slightly lower rate for 2018 might be due to the fact that the project was related to windmills, whose contribution to a sustainable society was a highly debated topic in national media at the time. However, a one-way ANOVA test does not show that these results for 2017, 2018, and 2020 are statistically different. Thus, the following results are grouped based on their theme's relation to sustainability. No statistically significant differences within these groups were found except where commented.

Sustainability is often represented as consisting of three domains or pillars: economic, environmental, and social. When asked which of these pillars they think about when hearing the terms "sustainability" and "sustainable development", 35%, 100%, and 20% (multiple choices were possible) of the respondents answered economic, environmental, and social sustainability, respectively. It is clear that the students most strongly associate sustainability with environmental issues. This question was asked towards the end of the survey to try to avoid priming the respondents' responses to the questions regarding sustainability in their projects.

The students were asked to assess the degree to which they took into account or reflected on sustainability in different phases of their project: problem formulation, design, implementation, verification and test, and end results. The wording of the questions in Table 2 and the means of the results grouped by the projects' relation to sustainability are shown in Figure 1 with the labels in Figure 1 corresponding to the bolded words in Table 2. In all cases, sustainability was taken into account or

reflected on to a larger degree in the projects related to sustainability with differences that are statistically significant. Though higher, in all cases the averages are near the neutral option, 4, with sustainability most taken into account for the problem formulation phase.

Table 2: Questions on the consideration of sustainability in different phases of the projects. The respondents were asked to take position a seven-point Likert scale. The words in bold refer to the labels used in Figure 1 and text.

Sustainability was an element that was taken into account or reflected upon in my group's:
problem formulation
design process
implementation phase
verification and test phase
end results

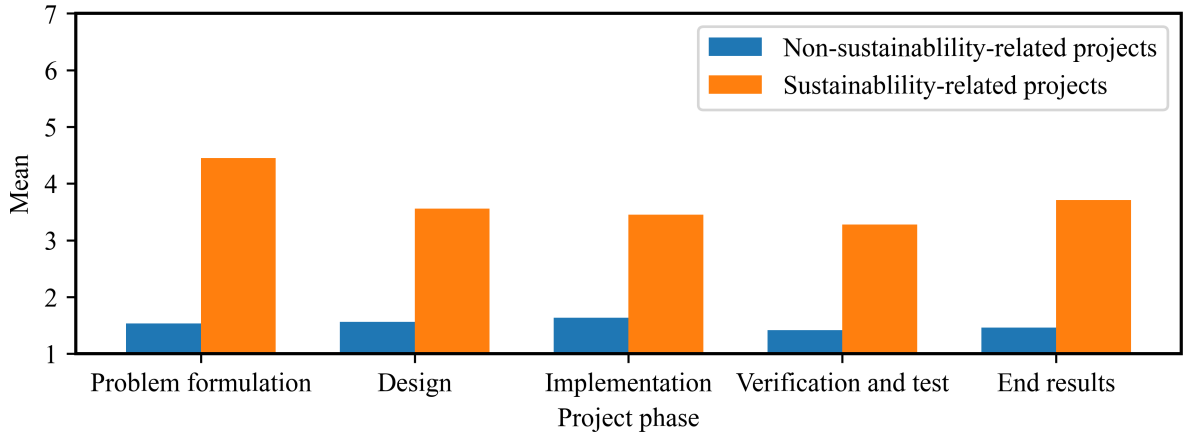

Figure 1: The mean of the degree to which the students reported that they took into account or reflected on sustainability in different phases of their project. Question wording is given in table 2. The results are grouped in two categories: sustainability related projects (years 2016 and 2019) and non-sustainability-related projects (years 2017, 2018, 2020).

In Figure 2, the students' assessment of whether the course contributed to the development of selected competencies is shown. Questions labeled *N*, *CT*, and *SA* refer to the normative competency, critical thinking competency, and self-awareness competency, respectively. The questions labeled *PBL* are related to competencies in the intended learning outcomes of the course's explicit learning activities such as the ability to collaborate with others, break down complex problems, and plan and complete a project. The competencies can be seen in Table 1 and the wording of the questions can been seen in Table 3.

Table 3: Questions on the development of the investigated competencies. The respondents were asked to take position on a seven-point Likert scale. The letters and numbers in bold refer to the labels used in Figure 2 and text.

During the project I got better at:
Reflecting on norms and values that affect peoples' actions. **N1**
Assessing dilemmas, contradictions, and trade-offs. **N2**
Questioning norms, practices, opinions in society. **CT1**
Critically reflecting on my values, perceptions and actions. **CT2**
Taking a position in the sustainability discourse. **CT3**
Reflecting on my role in the local community and global society. **SA1**
Evaluating and motivating my own actions. **SA2**
Dealing with feelings and desires. **SA3**

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Breaking down complex problems into simpler parts. **PBL1**
Collaborating with others. **PBL2**
Planning an extended complex project. **PBL3**
Completing an extended complex project. **PBL4**

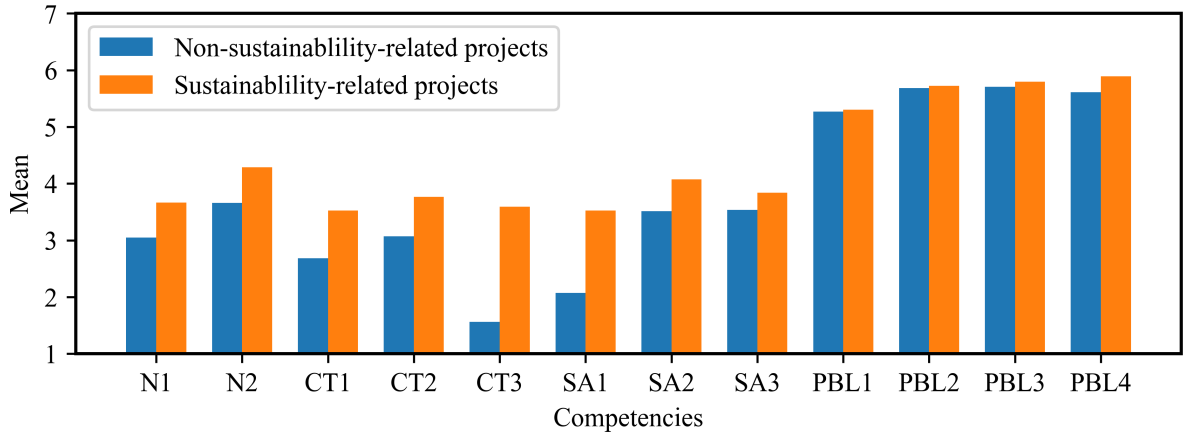

Figure 2: The mean of the students' assessment of the degree to which they developed skills within the 12 competencies. The competencies labeled *N*, *CT* and *SA* are related to *UNESCO's key competencies for sustainability*, and the competencies labeled *PBL* are related to competencies assumed to be developed by learning activities in the courses. The competencies can be seen in Table 1 and the questions in table 3. The results are grouped in two categories: sustainability related projects (years 2016 and 2019) and non-sustainability-related projects (years 2017, 2018, 2020).

The differences observed for the sustainability and non-sustainability-related projects are statistically significant except for *SA3* and *PBL1-4*. The fact that the differences for these last four competencies are not statically significant indicates that the development of these competencies is independent of project theme and enables the use of these as a benchmark for comparison.

With regard to the normative competency, critical thinking competency, and self-awareness competency, the measured averages are in all cases higher for the sustainability-related projects. The largest differences are found for *CT3 taking a position in the sustainability discourse* and *SA1 reflect on one's own role in the local community and society.* With respect to the sustainability-related projects, the averages for these competencies are close to the neutral option 4, significantly lower than the competencies with explicit learning activities.

Similar to the results shown previously in Figure 1, having a project theme related to sustainability does, according to the students' own assessment, increase the development of these competencies compared to a project without a theme related to sustainability, except for the case of *SA3 deal with one's own feelings and desires*. However, also here the development does not happen to any large degree as can be seen both with respect to the scale and the competencies assumed to be developed through learning activities.

The students were also asked about their views on sustainability and sustainability in education with questions labeled *S* being general questions and *SE* concerning the Elsys program specifically. The questions are given in Table 4 and the results are shown in Figure 3. With regard to the differences between projects related and not related to sustainability, only question *SE2* has statistically significant differences. The students who have participated in a project with a theme related to sustainability reported to a larger degree that there is enough focus on sustainability at Elsys.

Table 4: Questions on the importance of sustainability and sustainability education with responses given on a seven-point Likert scale. The letters and number in bold refer to the codes used in Figure 3 and text.

How much do you care about sustainability and sustainable development? **S1**
It is important that sustainability is a part of education in general. **S2**

An engineer should consider the sustainability consequences of their work. **S3**
It is important that sustainability is a part of education at Elsys. **SE1**
There is a sufficient focus on sustainability at Elsys as a whole. **SE2**
What exists of sustainability focus at Elsys is done in the right way. **SE3**

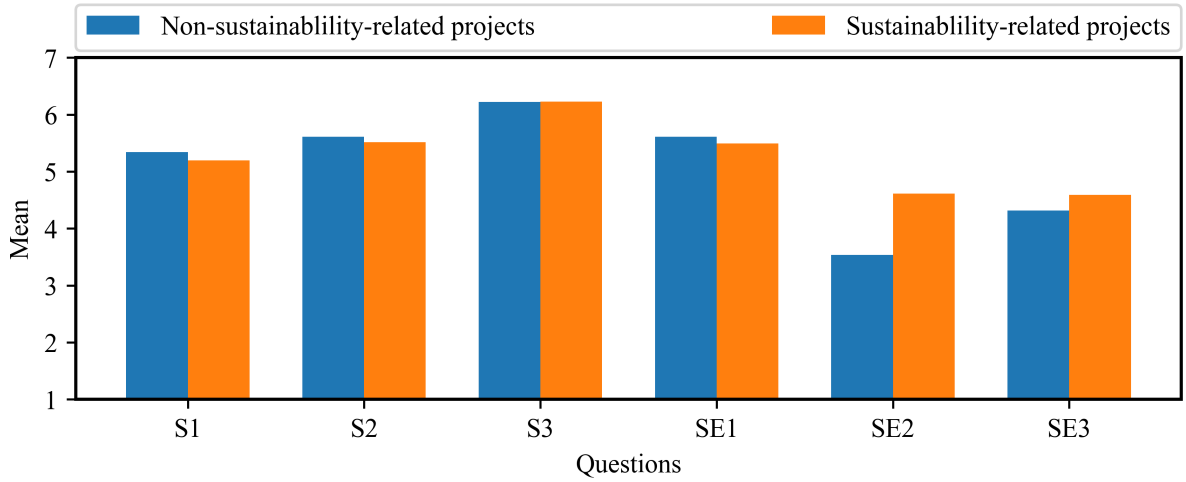

Figure 3: The mean of the students' views on the importance of sustainability in general, labeled *S*, and for Elsys specifically, labeled *SE*. The questions are shown in Table 4. The results are grouped into two categories: sustainability related projects (years 2016 and 2019) and non-sustainability-related projects (years 2017, 2018, 2020).

As observed from questions *S1* and *S2*, the students care about sustainability and think that it is important for sustainability to be a part of education in general, respectively. They also believe that it is important for sustainability to be a part of the Elsys program specifically as observed from question *SE1*. In addition, the students report that they think that an engineer should evaluate the sustainability ramifications of their work as shown from question *S3*. For this question 51% of the respondents chose 7, strongly agree. In the questions labeled *S1-3* there was a statistically significant difference between the projects.

With regard to the current integration of sustainability at the Elsys study program, the students agree to a lesser degree that there is enough focus on sustainability, *SE2*, and that the existing focus on sustainability is done correctly, *SE3*. Two potential issues with these questions is that there is limited focus on sustainability in most similar study programs at the university and that the students might have a limited understanding of SD in general as revealed in the question on the three pillars of sustainability. Therefore, the students might have a limited perspective on what sustainability in engineering education looks like or what it could look like.

5 LIMITATIONS OF THE STUDENT SURVEY

Although the results show a clear trend regarding the posed research questions, there are also clear limitations, which can be the subject of future inquiries. All data presented is based on self-assessment. There might be a discrepancy between the competencies that the students have developed and the competencies they believe they have developed, for example students can be poor at assessing their own learning when comparing different methods of instruction [25]. Additionally, the students' limited understanding of the three pillars of sustainability will affect their answers, especially with regards to the questions in Figure 3, where sustainability is explicitly mentioned. Lastly, some of the respondents who participated ended their participation in the courses more than two years before they completed the survey, which might affect their memory.

6 THE STUDENTS' DEVELOPMENT OF SD COMEPTENCIES

The results show that the environmental pillar of sustainability is mainly what the students associate with sustainability. That environmental issues is to a large degree linked to sustainability compared to the other pillars is also found in other works [15]. This implies that if an inductive approach to ESD in

PBL is to be applied as investigated in this work, then students need to be explicitly made aware of the project's relation to SD if the project is mainly related to the societal or economic pillars of sustainability. This also indicates that the three sustainability-related projects were seen as such due to their link to environmental issues.

The results found here indicate that having a theme related to sustainability does generate some considerations of sustainability in the students' projects and some development of sustainability competencies compared to other themes as seen from Figures 1 and 2, however limited compared to other competencies developed in the courses. While PBL courses can be an arena for the development of contextual self-directed learning [26] and be well suited for integration of sustainability competencies, we observe that in this case it is not something that happens to a large degree just through interactions with a certain project theme. Even though the students are interested in sustainability and think sustainability is important for an engineer to consider, this is not, even in a sustainability-related project, sufficient to generate learning regarding the normative competency, critical thinking competency, and self-awareness competency to a large degree, at least not observed with the methods used here.

As sustainability is important to the students and has been an important topic in Norwegian society in the last decades, the students have likely to some degree been involved in reflecting on aspects of these competencies for example through informal discussions on norms or through high school learning activities. However, in the context of the electrical engineering, these students have not been explicitly asked to reflect on these issues before. The transfer of skills and knowledge between different domains and contexts is known to be challenging [27], and we observe that this is a challenge here. It is clear that in a disciplinary bachelor level context like the one presented here, we cannot assume that all students will apply competencies developed in previous learning experiences or in personal life to new projects in PBL courses.

During the period the survey was open, one of the respondents got in touch with us to express their qualms with answering the survey. They said (here paraphrased with their permission) that they believed they learned and reflected significantly on sustainability due to an already present interest and engagement in sustainability, and had answered as such in the survey. However, they also believed that the average student without their interest in the topic would not achieve the same learning, due to a lack of facilitating structures in the course. This natural variation in interest and ability to connect previous experiences to the course activities can explain the slightly higher survey results for the sustainability-related projects, as the interested students are given opportunity through the project theme to develop sustainability competencies for example through reflection upon their own norms and values in relation to their projects, while other students do not engage with the theme in the same way and therefore loses the opportunity to develop these competencies.

There might be a disconnect between the theme of the project and the students' work on the project itself. This disconnect would clarify the results in Figure 1, where it can be observed that sustainability is accounted for to a larger degree in the problem formulation than in the other phases. When moving from the problem formulation to the other phases, the students may move mentally from the sustainability-related theme to focus on the electronics-related problem of realizing a working prototype, and in the process do not continue to reflect on sustainability.

7 THE NEED FOR SUPPORTING ACTIVITIES

It is clear that the students do not (at least not all of them) develop the normative competency, critical thinking competency, and self-awareness competency to a degree in line with the other investigated learning outcomes. While some students reflect on the theme of the project and therefore inductively develop sustainability competencies, in general the effect of this approach will be highly dependent on the students' previous experiences, interest, maturity, and the culture of the student group. For a first and second year bachelor level course this can be difficult to predict and control, however it might be possible for smaller student groups in higher level courses.

Thus, in order to address the low development of the studied competencies in the investigated courses, we see two possible routes: raising the students' academic maturity within SD with a dedicated SD introduction course or module before starting the PBL-courses so that the students will spontaneously and continuously consider and reflect upon the sustainability aspects of the project or creating targeted

activities in the PBL-courses aimed at developing these SD competencies. This reflects the vertical and horizontal approach to ESD, respectively [28].

The students' answers to the question on the pillars of sustainable development indicate that there might be limited understanding of sustainability in the students. Therefore, a course giving an introduction to SD in engineering and in general could give the necessary basis for the students to further develop SD competencies throughout the projects. However, while the students' understanding of SD might be insufficient, using this approach alone poses some challenges. The transfer of knowledge between different contexts is difficult as discussed earlier and the motivation for the students to engage with the sustainability aspects of the project might be limited, both aspects also discussed by Birdman et al. [12] looking at three sustainability graduate programs.

To activate the students' knowledge of SD, either from a previous course or earlier education, or to incentivize the students' to, by themselves, further their knowledge of SD, and thus be in position to reflect upon, consider and engage with the sustainability aspects of the project and develop the relevant SD competencies, targeted learning activities addressing sustainability in all phases of the project are needed. By targeted activities we mean educator-initiated activities that scaffold or facilitate the processes that lead to development of a specific set of competencies. To ensure the early start of the development of sustainability competencies early in all students, activities that facilitate reflection and consideration of sustainability in the project are needed, to allow all students to integrate these aspects in their thinking and habits of mind. These habits of mind can then be reinforced in later PBL courses, thus supporting spontaneous considerations of sustainability when entering working life.

These activities could be based on the operationalization of some of the SD competencies by Wiek et al. [13] combined with the promising results from *problem-based* courses aiming to develop SD competencies (for example [29-31]). It has been suggested by Brundiers and Wiek [32] that a hybrid project-problem-based approach can be beneficial as it can add the element of problem inquiry to the project-based course, thereby allowing the students to properly frame and analyze the problem and give opportunity for the students to reflect on sustainability aspects.

Along with learning activities, clear learning objectives and methods for assessment are needed to constructively align the course [33]. Expressing SD competencies as learning outcomes has earlier been shown to be a challenge in PBL courses, similarly with assessment [32], though efforts have later been made to develop general learning objectives [13] and assessment [34] for SD competencies.

Targeted learning activities can limit the need for projects that have a clear link to sustainability. As all future engineering endeavors need to take sustainability into account, all projects in PBL courses should also have the prospect of including aspects of ESD. With well-designed activities (which involve all phases of the project) and assessment, it is possible to create motivation and opportunity to develop sustainability competencies in PBL courses regardless of theme.

Possibly, both general introductions to SD and targeted learning activities are needed to generate the desired degree of competency development, as working on a sustainability-related project alone is not sufficient as shown here. This combined approach has been favored by for example Ceulemans et al. [35] as the most promising for ESD. Specifically, what support the students need, and how to tailor activities and supporting assessment that facilitates the development of SD competencies in a setting as described here, should be a target of future studies, supported by investigations into the students' understanding of sustainability in education.

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