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# Challenges, Opportunities and Educational Design for Interdisciplinarity in a PBL Environment

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## Abstract

In this article, we examine the challenges and opportunities perceived by university staff when planning and executing interdisciplinary activities for students in the problem-based and project-centred environment at Aalborg University. Using a qualitative approach, we interviewed 15 participants from nine pilot projects organizing interdisciplinary activities in higher education. The findings highlight various challenges to interdisciplinarities, such as building common ground to be "comfortable being uncomfortable", framing and facilitating interdisciplinarity and balancing different disciplines in student recruitment. They also present multiple opportunities, including increased awareness of one's own professional identity, a positive relationship with employability, the possibility of asking more fundamental questions about

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disciplinary practice, increased outlook when facing complex problems and the use of problem-based learning (PBL) as a frame of reference for interdisciplinarity. Based on the findings dimensions of educational design that are critical to interdisciplinary activity planning.

**Keywords:** Interdisciplinarity; integration; problem-based learning; educational design model

## Introduction

Problem-based learning (PBL) is often presented as a pathway towards interdisciplinary learning (Jensen et al., 2019), and interdisciplinarity is an inherent feature of PBL.

> "Inter-disciplinary learning relates to problem orientation and participant-directed processes, in that the solution of the problem can extend beyond traditional subject-related boundaries and methods." (Graaff and Kolmos, 2003 p. 658)

Given this definition, interdisciplinarity is evidently integrated into PBL and is closely connected to the complex and wicked nature of real-life problems. However, interdisciplinarity extends beyond PBL-focused institutions, resonating with a broader trend in higher education towards interdisciplinarity playing a more significant role in educational programmes. According to Bear and Skorton (2019), the world needs students with interdisciplinary competencies; as Telléus (2019) notes, wicked problems like climate change, overpopulation and insufficient food production do not fit neatly within the disciplinary categories of the departments and faculties of science. Therefore, the integration of interdisciplinary activities into education can help to prepare students to work on problems that call for knowledge of more than one discipline.

There are many ways to integrate interdisciplinarity into education, and special attention has been paid to the role of "distance" between disciplines. Klein (2010) distinguishes between narrow and broad interdisciplinarity; in narrow interdisciplinary, disciplines have compatible methods, paradigms and epistemologies, whereas broad interdisciplinarity "*occurs between disciplines with little or no compatibility, such as sciences and humanities*" (Klein, 2010, p. 18). An example of narrow interdisciplinarity may be found in the AAU Cubesat Project at Denmark's Aalborg University (AAU) in the field of engineering, which combines electronics and physics (space science) (Kolmos et al., 2020). Another example may be found at Chalmers University of Technology, Sweden, where students can follow a track of extra-curricular courses across

existing programmes related to a common theme of societal relevance (Enelund & Briggs, 2020). An example of broad interdisciplinarity may be found in the "Experts in Teams" course at the Norwegian University of Science and Technology (NTNU), which is offered to master's students across the STEM (science, technology, engineering and mathematics) fields as well as the social sciences and the humanities (SSH) (Wallin et al., 2017).

Other research, however, indicates that the integration of interdisciplinarity poses challenges for higher education. Based on evidence from multiple sources, Braßler and Sprenger (2021) highlight several barriers faced when integrating interdisciplinarity into curricula (e.g., conflicts stemming from interdisciplinary misunderstandings, different terminologies, diffusion of responsibility, sense of disturbance among students stemming from unfamiliarity, and additional workloads for staff). At the organizational level, Braßler and Sprenger (2021) also mention mono-disciplinary structures, competitiveness across disciplines and coordination difficulties. Notably, Richter and Paretti (2009) assert that students generally lack the ability to connect interdisciplinary subjects to their own more narrowly defined field of study.

In this study, we examine the integration of interdisciplinary learning opportunities for students within a PBL environment. This is relevant because past strategic and practical initiatives linking PBL and interdisciplinarity have faced significant challenges. For example, in a longitudinal single-case study, Braßler (2020) studied the role of interdisciplinarity when bringing PBL to traditional universities, exploring the related opportunities and challenges on the individual, team and organizational levels. More specifically, the identified barriers to PBL included diverse PBL-hindering examination regulations, varying definitions of the term "problem", varying understandings of PBL and limited willingness to stay open to other disciplines' views on PBL and education in general (Braßler, 2020). The problem is a paradox considering the inherent relationship between interdisciplinarity and PBL; PBL-focused institutions and teachers must find actionable solutions to move forward. To further the integration of interdisciplinary learning opportunities within PBL environments, this study offers a teacher's perspective, guided by the following research question:

*What challenges and opportunities do teachers experience when planning and carrying out interdisciplinary educational activities in a PBL environment?*

Based on the staff's reflections on challenges and opportunities, we further ask: *What are the implications of these challenges and opportunities for educational design? What are important dimensions to consider when designing interdisciplinary educational activities?*

The main contribution to the field of interdisciplinary research is to advance the practical understanding of the intersections between PBL, interdisciplinarity and pedagogical design. This is achieved by emphasising educational design dimensions for interdisciplinary activities based on teachers' insights gained from practising in a PBL environment. Figure 1 presents these seven design dimensions, which are important to consider when designing interdisciplinary educational activities.

Throughout the remainder of this study, we first present the methodology, including the context of the study, before moving on to the findings and discussing them in relation to other and potential future studies.

## Methodology

This study's methodology is based on a qualitative approach whereby we interviewed faculty members at Aalborg University to reveal their experiences with designing and carrying out interdisciplinary educational activities. This section details the context of the study as well as the employed data-collection and data-processing strategies.

### Context of study

The context of this study is Aalborg University, a PBL university founded in Denmark in 1974. From 2022 to 2024, various pilot projects were initiated and studied as a part of a university-wide strategic project initiated by AAU management called "SSH-STEM integration". The purpose of these pilot projects was to gain experience with interdisciplinary educational activities. This paper reports on the staff's perceptions throughout these projects with a specific focus on the challenges and opportunities that the staff experienced. It dives deep into the nuances of the projects, leading to suggestions for educational design in an interdisciplinary context.

Aalborg University has well-defined PBL principles across all faculties. These principles emphasise the use of the problem as the starting point, project organization, cooperation, exemplarity and students' responsibility for their own learning achievements (Askehave et al., 2015). However, there is diversity in the way PBL is implemented across the university's different faculties. For example, within the faculty of engineering and science, half of the ECTS points each semester are allocated to projects for which students work on real-life problems, sometimes (and preferably) in close partnership with external partners. A similar system is in place within the SSH and health faculties, though with variations in their curricular structures.

Aalborg University has a research-informed approach to educational development that entails the use of interdisciplinarity in its educational practice as well as its conceptual models to achieve a greater understanding of educational dynamics. For example, based on practical experiences, various interdisciplinary project types have been defined within a conceptual framework (Kolmos et al., 2024), different learning outcomes of interdisciplinary system projects have been presented based on student perceptions (Routhe et al., 2023) and studies of students' experiences with the so-called AAU Megaprojects have demonstrated the complexity of large-scale interdisciplinary constellations across SSH and STEM (Bertel et al., 2022). The AAU Megaprojects, launched in 2019, proved to be challenging for the university, as the interactions between groups across STEM and SSH fields leaned more towards "borrowing" knowledge from other disciplines without truly interacting rather than providing genuine interdisciplinary interaction and integration. While the intention was for students to initiate cross-group collaboration, boundary crossing proved to be a difficult task and was therefore limited (Bertel et al., 2022). Based on experimentation with different project types leading up to 2022, Aalborg University incorporated the integration of SSH and STEM competencies across AAU as a strategic goal in its 2022–2026 university strategy, dubbing the project "SSH/STEM integration". To carry out this goal, a process was initiated whereby the university developed an SSH-STEM integration model. In this model, interdisciplinarity is linked to a process in which students develop the competencies "*to collaborate with other disciplines to solve problems that require interdisciplinary collaboration*" (Aalborg University, 2022).

## Data collection

To explore the staff's understanding of interdisciplinarity and their expectations and experiences regarding the creation of learning opportunities for students to collaborate across disciplines, we conducted qualitative semi-structured interviews with teachers carrying out pilot projects. This type of interview was chosen to gain in-depth insight into teachers' perspectives (Savin-Baden & Major, 2013). The semi-structured interview guide was peer-reviewed by members of the author team.

The interviewed staff included facilitators from STEM, SSH and health fields. Some were in the planning phase of their pilot project, though most of them had already carried out their project.

The interviews were all conducted in person and participants were selected due to their engagement in the nice interdisciplinary projects at Aalborg University, which were part of the university-wide SSH-STEM integration initiative (Aalborg University, 2022). In some of the interviews, more than one participant

was present. The interviews were originally planned as one-on-one interviews, but participants were allowed to bring in more members in due to shared coordination. The interviews with more than one participant allowed for interplay between different perspectives, potentially providing richer data. Table 1 shows an overview of the pilot projects and the number of associated interview participants.

Overall, the participants were affiliated to various departments including Sports Science and Physiotherapy (Health), Energy, Techno-anthropology and Mechanical Engineering (STEM), Business, Culture and learning, and Communication (SSH). The project scopes were mainly focused on students working with cross-cutting problems related to health, sustainability, design, technology and innovation. The interviews lasted approximately 45 minutes. All interviews were conducted in Danish aside from one, which was conducted in English.

| Project | Approach to interdisciplinarity | Time frame | Interview participants |
|---|---|---|---|
| P1 | Broad | Three years | 1 |
| P2 | Narrow | Semester | 3 |
| P3 | Broad | One day | 2 |
| P4 | Broad | One day | 3 |
| P5 | Narrow | Semester | 1 |
| P6 | Broad | On-demand | 1 |
| P7 | Broad | Semester | 2 |
| P8 | Broad | Three days | 1 |
| P9 | Narrow | Semester | 1 |

*Table 1. Overview of pilot projects.*

## Data processing

The interview data were recorded and transcribed, and the transcriptions from each interview were read by two people (the interviewer and the coder) to gain an initial impression of patterns in the collected experiences. The data was then coded in NVivo using three pre-defined themes: opportunities, challenges and educational design. The choice of codes was directed by the research questions. When the coding process was carried out, the quotes from each theme were read, and quotes were selected for further analysis to express the nuances in the themes. The data revealed multiple dimensions of the educational design, leading to new subcodes during a second coding round. The interviewer validated the quote selections to ensure that the data represented their overall impression from the interview session and the transcripts.

# Findings

In this section, we present the findings in relation to the three aspects laid out by the research question: challenges, opportunities and dimensions of educational design.

## Challenges

The challenges reported by staff in relation to planning and facilitating interdisciplinarity cover three themes: 1) creating common ground and being comfortable with being uncomfortable; 2) framing and facilitating interdisciplinarity; and 3) balancing disciplinary backgrounds in student recruitment.

**Creating common ground and being comfortable with being uncomfortable**
The interviewees considered allocating time for students to create common ground highly important.

> "So, they all said that they needed more time to get to know each other. This was really interesting. So, the way it was accelerated—everybody came together, and we had little bios, and we met online, but we immediately jumped into the content … If we had had one or two days of them getting to know each other first and trust each other and understand a little bit, I think we would have gone further." (P1)

This quote underlines the importance of students getting to know one another and, in turn, building up trust, confidence and a common language to navigate the interdisciplinary learning process. Other staff members suggested that students should get acquainted with the competency profiles and learning objectives in the written curricula of the other disciplines (P2).

Some of the staff members asserted that whether students had previously gone through similar interdisciplinary processes represented a relevant factor. As one staff member put it, students with such experience were "more comfortable being uncomfortable" (P1). Another staff member pointed out that being in an interdisciplinary programme made a considerable difference when dealing with collaboration across programmes (P2).

This sense of being comfortable being uncomfortable is also demonstrated by the staff's reflections on students' attitudes.

> "I think it is important, based on my experience, to work with feeling safe and motivated, and if this is not there, then you will not get them on board. If they are sitting there closed-minded because they are insecure

> or they do not think it is cool in any way, then you can present them with whatever—it will be like facing a wall." (P3)

Evidently, they consider students feeling safe and motivated to be crucial. Another staff member added to these psychological considerations, pointing to challenges stemming from students having a lack of curiosity and being unwilling to take risks, which they attributed to students' focus on grades (P4).

**Framing and facilitating interdisciplinarity**

Overall, the interviewees indicated that staff must step out of their comfort zone when facilitating interdisciplinary projects.

> "And we put teams together of people [staff] who had never worked together before because we say we must do that ourselves and model it for the students. And, you know, that was not easy, especially for professors who reach a certain point in their career and become experts in a field. So, stepping out of their comfort zone is also a challenge." (P1)

In an exemplary way, P1 staff demonstrated their ability to "walk the walk" by organising interdisciplinary activities in an interdisciplinary coordination group.

In another project (P9), students worked in relation to the intended learning outcomes outlined in their own disciplinary curriculum. Still, staff experienced that they were less in control than in a disciplinary project on account of them not knowing what the teams from the other disciplines were doing.

Another area of concern was how to frame the process. In one project, cases were used as a starting point for students' interdisciplinary process, but the interviewees considered the creation of these cases to be a challenge.

> "Actually, the hardest part when you are doing these things is to formulate a case, which, when it is so interdisciplinary, is something that all programmes can relate to." (P3)

One of the staff members observed that students had a hard time transferring their knowledge from the interdisciplinary setting to the disciplinary setting and vice versa, especially if the students were resistant to something new outside disciplinary borders.

> "While they gave great feedback on the courses, great feedback on the workshop, they had trouble relating it back to their own work and their own concerns and their own skill set, and they had trouble seeing what they could contribute." (P1)

Another staff member argued that students tend to be discipline-bound and that even if interdisciplinary activity is strongly related to a generic field (e.g.,

project management), students may consider it to be irrelevant if they cannot link it directly and immediately to their primary discipline (P5). This suggests that students want to transfer what they already know to new situations; thus, transformation through which students develop new understandings and procedures must be actively facilitated. However, the interviewees asserted that facilitating interdisciplinary activities is highly time-consuming.

> "But I think that the barrier in our system is that it [interdisciplinary activities] takes extra time compared to what we are used to … and I think that this is sometimes a reason that such activities are not initiated, as it is considered easier to do business as usual." (P2)

**Recruiting students and balancing disciplines**

The recruitment of students in the case of extracurricular activities is considered a core challenge when planning interdisciplinary activities.

> "There are always some who will join such activities, but there are also many who do not want to attend or will prioritize their time differently. So, this is actually one of the things that has been the hardest—to get them to show up." (P3)

This challenge to get students to "show up" is also the case for more flexible platforms through which students can attend whenever they want (P6).
Due to these recruitment challenges, there is a risk of facilitators struggling to balance the disciplinary (i.e., primary institution/programme) distribution of students in a way that achieves the interdisciplinarity aimed for.

> "Well, about one-quarter to half of the students from the semester will participate, and sometimes even more. Sometimes, it is three-quarters of the students. And this is, in fact, a problem, at least for us, as they end up joining a team including themselves mostly. Then they do not get to know new people or new staff. Then it is getting more of the same. Then it is just the same. This is a bit of a challenge." (P7)

Paired with the recruitment challenge, this balancing issue further complicates the educational design in the case of extracurricular activities, as staff do not know who will ultimately show up.

## Opportunities

These challenges point to many opportunities that may arise from successful efforts to overcome the challenges. Moreover, this analysis reveals openings for new learning opportunities.

Overall, the interviewees stressed the importance of students having a successful experience with interdisciplinary activities.

> "With STEM-SSH collaboration, it is like it has to be a success in the way that one can leave with an experience clarifying what I can … what I need the others for, I think." (P4)

Such experiences can form a baseline for increased curiosity, openness, initiative and what one staff member called the "ability to choose and make connections" (P1). Furthermore, the empirical material exhibits indications of deeper learning, as will be elaborated in the following five themes: 1) increased awareness of professional identity; 2) link between interdisciplinarity and increased employability; 3) tendency to ask more fundamental questions about disciplinary practice; 4) increased outlook when facing complex problems; and 5) use of PBL outcomes as frames of reference.

**Increased awareness of professional identity**

The ability to explain one's own competencies was highlighted by the interviewed staff as an important step towards getting to know one's own discipline (P3). Especially in areas where the educational programme is relatively new, it is considered a strength when students are aware of how their discipline can contribute to real-life challenges in an interplay with other disciplines.

> "As a student, you should participate to explore your discipline. Consider what you can do yourself. Especially for some of the educations, where you do not know precisely what you can contribute with … It becomes extremely clear when you are sitting together with others and solving a specific problem. What is it that you contribute with that differs from the others?" (P8)

Furthermore, the interviewees related increased awareness of one's own professional identity to real-life practices by emphasising that students will experience the same kind of interactions in interdisciplinary activities when they start their careers.

> "It is the way it is; in the real world, there is a counterplay. We help each other, and we each have our role." (P3)

The ability to spot contradictions, know when to step in to help and know how one's role is combined with those of others thereby constitute important competencies.

**Linking interdisciplinarity to increased employability**

Awareness of one's own professional identity, as discussed above, was linked by staff to a higher degree of employability.

> "They come with some disciplinary competencies, which they put into play, and this provides such a—well, it strengthens them in terms of

> building on and understanding their own discipline and [they] likewise become stronger in their profiles and then, hopefully, they will get more easily employed because it will be easier for them to explain what they can do …" (P8)

Another staff member emphasized the importance of aligning education with work, asserting that interdisciplinary activities play a role in providing a "truer" picture of professional practice.

> "They learn that we are different, and we have different agendas, and this is a preparation to work with customers … What frustrates them is actually what they have to go through … it is exactly what they will experience when they come out in industry …" (P7)

This quote brings forward the idea of frustrations as a positive and inevitable part of real-life professional practice, which is essentially what students are preparing for.

#### *Asking more fundamental questions about disciplinary practice*

The assertion that interdisciplinary practices can increase one's understanding of their own discipline is elaborated by the following quote, which indicates a deeper level of knowledge, including through the asking of more fundamental questions about disciplinary practice.

> "It requires a constant revisiting of our assumptions and our priorities and what we thought we knew." (P1)

In another pilot project, staff members indicated that students were left with a clearer picture related to the question of what the whole domain—in this case, SSH—can contribute to society.

> "They [students in the humanities] experienced that they could contribute with something in the discussion that others were not aware of. It is a recurrent question: What can the humanities contribute? … So, I think that one of the experiences was that the humanities students became more aware of what they could contribute in practice." (P4)

In the same way, one could ask: What can STEM education contribute? This is dependent on the theme and, more precisely, the problem that the students address alongside students' awareness of the domain in which they work.

### Increased outlook when facing complex problems

The pilot projects were created around complex and cross-cutting study areas, such as sustainability and design. Staff considered interdisciplinary activities to be important when it comes to helping students reach a level where they can face complex problems beyond a reductionist approach.

> "They somewhat understand that there is something bigger; there are connections that are characterised differently in different disciplines. There are some technical infrastructures, some users, some actors and some institutions. It is about having a systemic understanding. I think that will give students a little or another kind of respect and acknowledgement of other disciplines in play." (P5)

This systemic understanding (or "system thinking") is thereby important for students' approach to other disciplines. Other staff members elaborated on this notion of "something bigger".

> "So, the students can approach those new evolutions—and those new developments in science, technology and society—with an understanding that they didn't have before." (P1)

Another staff member pointed to the outlook needed when working with complex energy systems to illustrate the need for cooperation between different disciplines.

> "Students have become very aware in these discussions of huge power-to-X facilities, windmill parks, solar cell parks and so on. That it is not something you can establish from a technical viewpoint only. … There are so many aspects to this. And we cannot realize something without the societal and humanistic problems that are embedded in such changes." (P4)

Overall, the increased attention paid to system comprehensiveness suggests that increased interdisciplinary work is warranted. In the case of the above quote, the staff member was very concerned with contextual factors and that which the students should know about. Although it may not be a part of the solution, they can contribute from their own disciplinary perspective; it is about knowing the limitations of their discipline as well as knowing what lies beyond it.

**Using PBL outcomes as frames of reference**

The university context behind the initiatives provides both PBL principles and the integration of intended PBL outcomes in the curricula. One staff member noted that this integration can serve as a stepping stone to argue for interdisciplinarity as part of assessment criteria.

> "There are these intended PBL outcomes in the curricula already, which maybe can be used. In the exam, for example, you can have a dialogue considering how this kind of collaboration has turned out, what they have gained from it and what their approach has been. So, this is, in any

> case, one thing that opens for making it [interdisciplinarity] explicit." (P2)

Another area related to intended PBL outcomes in curricula is the ability to reflect on one's own learning processes. This kind of reflexivity was pointed out by a staff member.

> "Maybe such a day could be rounded off by focusing on the process—that they simply write down what they have wondered about that day … One should take seriously that this is about interdisciplinarity and a way to get acquainted." (P4)

However, another staff member asserted that a "one-disciplinary-group" PBL practice is not enough to move students beyond their initial boundaries.

> "The awesome thing with this boundary-crossing work is when you get out on the other side and experience that it doesn't bite. Then, you have crossed boundaries, and you learn an awful lot of this not being what they are used to. You do not just sit in your own group …" (P3)

This quote serves as a reminder that, although intended PBL outcomes are integrated into the curriculum, it is important to stress interdisciplinary processes in a way that does not reduce PBL to disciplinarity from within. It is a matter of moving not just the content but also the people across boundaries when designing PBL for interdisciplinarity.

## Pedagogical dimensions when designing for interdisciplinarity

During the interviews, different reflections and considerations regarding the educational designs under discussion were raised by the interviewees, and we subsequently coded these reflections into seven overarching dimensions (see Figure 1). Balancing the different presented dimensions can create a basis for pedagogical considerations when designing interdisciplinary educational activities. We argue that these dimensions in the design of interdisciplinary activities are highly interdependent. Thus, an overview of these dimensions as a tentative framework—or, more modestly, a tool—can likely aid the design of interdisciplinary activities in higher education. This is not to say that we cover every possible dimension of educational design, but we do touch on at least some of those prompted by our empirical data.

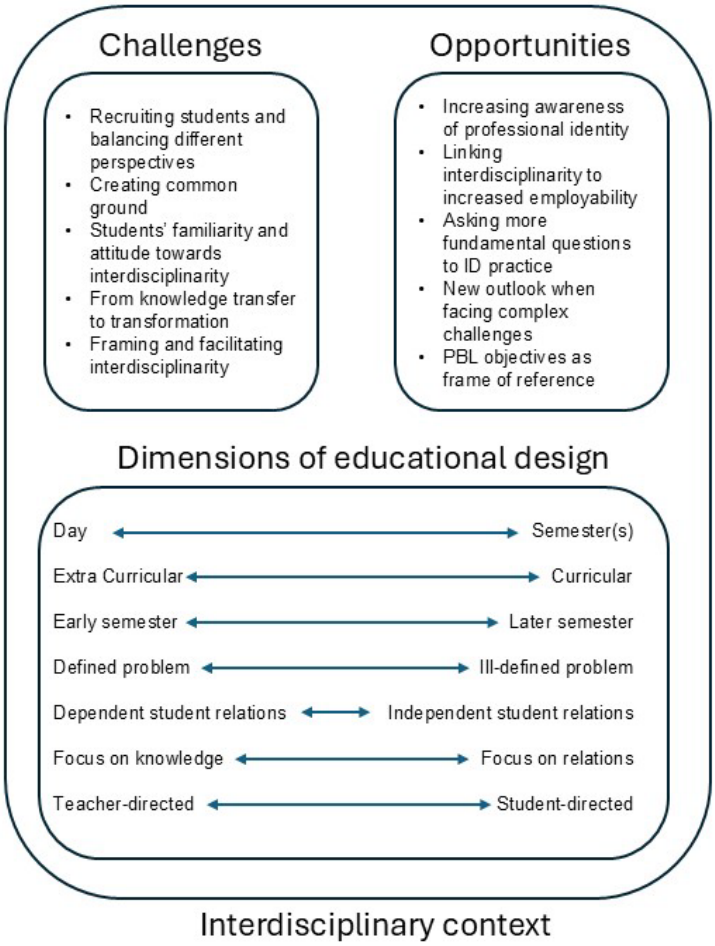


*Figure 1. Pedagogical dimensions when designing for interdisciplinarity.*

**One-day vs. full-semester activities**

The pilot projects differed in length, ranging from half a day without preparation to a semester-long project (around 15 ECTS). In this study, the interviewees expressed that short-term activities bring about some frustration.

> "A day is just nothing, to be completely honest. We can sit here and have all kinds of ambitions, but it can only be a beginning. It can only be that you can look at something and that you can sow some seeds. If you want dialogue, discussion, curiosity—it is more like creating an approach to things … The highest level we can reach is to contribute to a problem identification and get to know other disciplines." (P4)

However, this frustration is relative to the ambition of the broader SSH-STEM initiative. One could also argue that working on problem identification or getting to know other disciplines in half a day is a relatively efficient use of time; this is especially true if the framework conditions do not allow sufficient time for long-term activities.

**Curricular vs. extracurricular**

Even though one programme has incorporated the notion that students should become acquainted with different project types (including interdisciplinary projects) into the curriculum and other interdisciplinary activities have been obligatory for some students, the majority of the nine pilot projects were established as extracurricular activities. The interviewees did, however, bring up the possibility of linking the interdisciplinary activities to the curriculum, indicating that such a link would be a positive enabler.

> "And this is where I am thinking that, if it is curricular, … it is not extra-curricular, the more they feel it as a part of their disciplinary development, the safer, the more understood, the more sense it makes for them to be a part of it even though it becomes complicated—it is a part of their study." (P4)

While extracurricular activities do give way to certain recruitment barriers, as discussed earlier, they are also far more open, enabling considerably different disciplines to tap into the process.

**Early vs. later semesters**

Staff expressed a diverse range of opinions on whether students should be given the opportunity to work interdisciplinarily at the beginning or in the later part of the educational programme. These differences seem to have been at least partially driven by the structure of the programme. In the following case, staff argue for an early integration of interdisciplinary activities.

> "It all has to come together, and here it is a challenge that the later semesters, at least in our study programme, the more locked the projects are and the more fixed the framework is—there has to be closure. It is maybe broader in the earlier semesters; there might be more freedom. And it is there [the integration of interdisciplinarity] is, because the curriculum is getting more and more specified during the study." (P9)

In contrast, in another programme, staff argued for the integration of interdisciplinary activities in the later semesters, once the students have become more solution-oriented (P5). In this manner, one can argue for different timings for the integration of interdisciplinarity from an alignment-based perspective.

**Defined vs ill-defined starting point**

Compared to collaboration in intra-disciplinary settings, defining the thematic framework for interdisciplinary student collaboration across programme boundaries proved to be more challenging. To what extent should the starting point—the problem—be defined from the outset of the activity? To open an activity to students from a broad spectrum of disciplines, the interviewed staff

members expressed a preference for broad, ill-defined issues over well-defined problems.

> "I think that you start, when you are looking at what is the problem, to solve the problem … they are in the phase of a project before you start problem-solving, and what characterizes this phase is that you learn to handle uncertainty. So, you can say that this day, it is not a problem-solving day; it is what it takes to make a good problem identification." (P4)

Such problems may still lead to positive experiences for the students, especially if they are aware that the experience involves a certain level of unpredictability. The ability to work on uncertain ground is arguably an integral part of learning to work in an interdisciplinary setting:

> "We couldn't tell them exactly at the beginning what they were going to learn so … they had to trust us, but, you know, … I think students who were not interested in that didn't apply." (P1)

The fact that organizers often provide relatively broad and open frameworks for interdisciplinary activities points to a potential dilemma between inclusiveness and student expectations. On the one hand, the attractiveness of the activity relates to the opportunity to engage in a concrete issue, often with the ambition of "making a difference". On the other hand, broad, ill-defined issues require extensive discussion before the problem can be properly defined—let alone solved.

One potential solution to this dilemma entails limiting the number of disciplines involved and letting the object of collaboration be a concrete (material) product. The following quote illustrates a project involving narrow interdisciplinarity (collaboration among students from different engineering disciplines).

> "I think the biggest challenge is if it is not defined. Then, I can imagine that it gets—that it might cause problems or frustrations, in any case, considering the storyline. Because what is this about, why are we doing this … I have not experienced that it went badly. But again, I think that one of the explanations is that exactly that project with the car—it has been so well defined. Everyone could understand what it was all about and what their one role in it was." (P9)

**Dependent vs. independent student relations**

In one of the pilot projects, the balance between dependent and independent student relations was described as an important aspect of educational design for interdisciplinarity.

> "It [dependency] is a delicate balance. There must be a dependency, or else there is no collaboration, but it must not be too strong because if one group does not deliver … then it should not affect other groups in a way where they cannot finalize their project. But, on the other hand, if the dependency becomes too loose (and maybe is non-existent), there is no collaboration—because what should you collaborate about." (P9)

In another pilot project, the lack of dependency between students' learning was not considered a problem, as the idea was to create a knowledge base for further collaboration by offering micro-credits to individual students.

> You get to follow your own interests, specialize or get some outlook and more perspectives on one's own projects. We believe that it will strengthen the students, their programmes, and their hand-ins so that they get more perspectives. The idea is that the students get so much flexibility that they can specialize. (P6)

The idea here is that the students gain an outlook that they, in various ways, can relate to their disciplinary work. Therefore, students are not merely collaborating interdisciplinarily; rather, they are shifting their perspectives and expanding their disciplinary outlook.

**Knowledge vs. relations as the primary outcome**

As noted earlier, some projects take a system or a product (e.g., a car, an energy system) as their starting point, which can also serve as the focus of a more traditional disciplinary semester project. However, there is added value in interdisciplinary activity that may not be immediately obvious to those who fail to consider learning outcomes.

> "So, I think… Well, it is not because they learn something different that they could not learn in a normal student project—I could have defined other [projects]. So, it is more all that additional—this is about interacting with others, to be able to work with other teams towards a common goal." (P9)

In another pilot project, one staff member presented the focus on knowledge and that on relations as equally important, highlighting both collaboration and learning processes.

> "Not all of them worked together because I think so much of that learning happens when working through the hard parts, and getting to the other side is working with other people. And that was as much… This was as much a project about collaboration as it was about sustainability and creativity and trans-disciplinarity. It really was about learning and grappling with collaboration." (P1)

In other cases, the primary outcome is related to generic competencies, which are open to all disciplines rather than any single specific discipline. One example of this is a focus on innovation and entrepreneurship, which is more concerned with getting students from different disciplines together to relate their knowledge to the process of value creation.

> "The contribution we come with relates to innovation, and, as we are used to saying, it does not have to be domain-specific—we help to support them. We experience that the students have considered the workshops to be exciting no matter the discipline. It is this kind of scaffolding; there is a pedagogical process for this—how you work together … Then, it is not a matter of who knows the most or who can do the most but instead how we can use this in an innovation process." (P4)

In another case, staff expressed that using such process framings—in this case, project management—can result in students perceiving the interdisciplinary activity as irrelevant, as it is not domain-specific (P5).

Finally, one staff member touched more fundamentally upon the learning experience as a process of social formation.

> "There is somehow a social interplay which is played out and which really does not have anything to do with what we are handling … it is some kind of social formation process." (P8)

This focus on social formation, or maybe more precisely "Bildung", links interdisciplinary activities to comprehensive life skills.

**Teacher-directed vs. student-directed**

In every interview, the staff characterized themselves as facilitators who need to support or scaffold students in their learning process, embodying the self-directed characteristics of a PBL process. In the following example, one of the staff members described the mutual collaboration between them as facilitators and the students.

> "But, you know, there is in any case an initiating meeting where the two facilitators meet with the two groups. Then, you set the tone considering the further direction." (P2)

The level of teacher control also depends on various factors, such as the length and goals of the learning process. If the activity is, as was the case in several of these projects, only a single day, then there is a greater need for scripted activities than if the students work on a project over the course of the whole semester.

The discussion about teacher-/student-directed learning is also heavily related to the problem-design process; the learning processes differ in how much direction staff want to set out for their students.

> "Well, in some way, it is the idea of having project catalogues versus no project catalogues at the university. Should you make a project catalogue that the students tap into, then they might get further in the process and maybe they can make an article on the other side of the project? Yes, a project catalogue, it gives … you know, this thing about getting a problem field together and such things—they miss out on that." (P8)

The mentioned project catalogue presents a list of project proposals made by the facilitators for the students to choose from. While it is merely a starting point on which students can elaborate, they might "miss out" on the learning related to the problem design itself. This learning objective may be taken care of through other learning activities, but it is nonetheless important to consider in the design of interdisciplinary activities alongside alignment with the rest of the curriculum. It is a question of how much uncertainty the students can cope with and, at the same time, how much freedom they must have to take ownership of the process.

## Discussion and conclusion

Figure 1 provides an overview of the challenges and opportunities associated with interdisciplinary student activities, as revealed in this study. Furthermore, it highlights the identified dimensions for educational design, where the interviewed staff were able to point to both challenges and opportunities depending on the interdisciplinary context.

### Challenges

As a potential challenge, this study highlights the ability to create common ground as one of the basic requirements for interdisciplinarity. Repko (2007, p. 15) phrases this challenge as follows:

> "Creating common ground is like building a bridge in order to span a deep chasm. The near side is the place of identifying the sources of conflicts between insights; the opposite side is the place of combining as many insights as possible. Unless the interdisciplinarian builds the bridge of common ground to connect the two sides, the process of integration and producing an interdisciplinary understanding cannot proceed."

Evidently, the process of creating common ground is a pre-condition for disciplinary integration. However, an even more mundane challenge lies before that: attracting students to sign up (at least for extracurricular activities) and bringing an open attitude towards other disciplines. Only once these tasks are accomplished can we begin to discuss other obstacles, such as ensuring transfer and even the transformation of learning to and from the event. However, overcoming barriers to the transfer and transformation of knowledge is important for interdisciplinary activities to be successful—and this study indicates that doing so is far from easy to facilitate. For students to be able to transfer their experiences to a new context, they must be able to analyse the problem at hand as well as the new situation (Habbal et al., 2024, p. 152). This ties the transformation process in interdisciplinary settings to PBL processes, and the time needed to move through such processes.

Another area in this study is the staff's ability to walk the walk in co-constructing the pedagogical basis of the event across different disciplines. In one of the pilot projects, the staff cited co-teaching as an important element. A similar positive relationship between co-teaching and interdisciplinary courses is highlighted by Rooks et al. (2022), among others.

Furthermore, staff noticed that students sometimes consider that which is "not domain specific" irrelevant. This may be counteracted by the notion of levelling (Beddoes, 2020), a strategy aimed at preventing the disciplinary capture of other disciplines to ensure that each discipline's goals, needs and wants are equally valued and addressed. This attention on levelling relates to the challenges of defining a suitable case but also to the balance in the number of students from each discipline. One discipline being overly dominant could lead to the disciplinary capture of the other discipline as well as a lack of motivation among the minority. As noted by Macleod and Veen (2020), the problem design (or, as dubbed by staff in this study, the process of making an inclusive case design) is important for equality in interdisciplinary teams.

## Opportunities

This study's analysis of the pilot projects points to new possibilities. One argument to come from this analysis is that interdisciplinarity is linked to higher employability, which has been recognized by previous studies (e.g., Friedrichsen et al., 2024). There are, however, more possibilities linked specifically to potential learning outcomes. The pilot projects have contributed a new outlook on complex challenges created with regard to cross-cutting areas of study. This approach resembles those covered in other studies of interdisciplinarity across STEM and SSH fields, most prominently those related to sustainability (e.g., Braßler & Sprenger, 2021; Horn et al., 2022) and design (e.g., Graff, 2022; Han et al., 2021; Kiernan et al., 2019). The interviewed staff

further highlighted that they believe interdisciplinary activities increase students' awareness of their home discipline. This supports findings from Taylor (2018) on final learning outcomes that enabled students to assess viewpoints, methods and outputs from other disciplines as well as their home discipline.

Furthermore, the opportunity to ask more fundamental questions about disciplinary practices is highlighted in this analysis to counteract the stereotyping of SSH/STEM fields. In a comprehensive study of SSH integration into civil engineering education, Josa and Aguado (2021) highlight barriers to incorporating SSH in civil engineering curricula, including misconceptions about what SSH involves in relation to civil engineering. Olmos-Peñuela et al. (2014) argue that such misconceptions of the "others" may arise from disciplinary stereotyping of the social value of the different disciplines. Others emphasise the synergy between STEM and SSH fields (e.g., Sharma et al., 2023, p. 68), arguing that "*While STEM education is often seen as the key driving technology progress, it is the humanities and social sciences that help to shape the ethical and social considerations of that process*". While it may be argued that this statement emphasizes what SSH can bring to STEM rather than the other way around, it is an example of a more fundamental position that may help organizers as well as students to understand how the synergy between SSH and STEM is viewed in certain contexts.

In terms of characterizing enablers for the integration of different disciplines, STEM and SSH might entail different perspectives. Borrego and Newswander (2010, p. 80) conclude that while the humanities literature operationalizes integration through critical awareness and emphasizes intellectual skills, engineering and science proposals operationalize integration as teamwork and emphasize interpersonal skills. This represents a deeper layer of analysis than that presented in this study, and the staff members did not address these differences between SSH and STEM by themselves but instead centred more on the problem/challenge that the students are tasked with facing together. Nevertheless, such considerations of different academic cultures and epistemologies could be interesting to explore further.

On another level of abstraction, staff interrelated the intended learning outcomes of interdisciplinary learning activities with the intended learning outcomes of PBL; this perceived interrelationship, due to constructive alignment, influences the design of the interdisciplinary activities. Scholkmann et al. (2023, p. 116) conclude that it is important to provide a very clear picture of the problem or concern that one is addressing by integrating different disciplines. However, the question is whether students are prepared for the design of interdisciplinary problems, effectively granting students the freedom

to define what they want to work with. As effectively put by Ming et al. (2023, p. 12): "*Developing interdisciplinary education inevitably involves balancing between two valued principles: granting students freedom in shaping their identities while crossing disciplinary boundaries versus ensuring students gain genuine and meaningful interdisciplinary experiences*."

## Design dimensions

Looking at the design dimensions for interdisciplinary activities revealed in this study (see Figure 1), there are also indications of the PBL context of these pilot projects, e.g., the dimensions of defined vs ill-defined problems, or teacher-directed vs student-directed. As such, the dimensions are not that different from those used in designing other PBL activities. However, the interdisciplinary context adds a new perspective on these dimensions, and new questions for pedagogical reflections can be put forward. Can interdisciplinarity be the cornerstone of a full semester? Is interdisciplinary nice to have (extracurricular) or need to have (curricular) according to staff? In which semester are the students properly acquainted with their own discipline so that they can introduce it to others? Can the students cope with ill-defined problems in a student-centred and interdisciplinary environment simultaneously? How much interdependency between students is needed to motivate students to build a common ground and integrate their disciplinary knowledge? Do the students need to solve a problem to stay motivated, or is it enough to 'just' analyse one? Is it naive to think that students can reach interdisciplinary learning objectives as an added value to the disciplinary outcomes, or are there trade-offs that need to be considered? The purpose of the dimensions offered for educational design in an interdisciplinary context is precisely to inspire such inquiries.

## Final remarks

Finally, this study supports the assertion that interdisciplinarity is a complex matter. Thus, we will conclude with a quote from an interviewed staff member that encapsulates the challenges associated with planning and carrying out interdisciplinary activities.

> "We dreamed, like, what if we made a programme that was for people like us? The programme we wished had existed when we were doing our education. Because this interdisciplinary and transdisciplinary work especially—it is not easy. It is hard to do. Because there are so many assumptions about, kind of, priorities, criteria, foundational knowledge. That we do not speak the same language … Like even when everybody is willing to do it and excited about it, it's still hard because it requires—because that step into the unknown and dealing with the others and

dealing with the other kinds of points of view and holding these things in balance. It's—it's always dynamic, and it's always shifting. And that's very—that's very hard to do." (P1)

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