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Interdisciplinary Problem-Based Projects for First-Year Engineering Students

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Abstract

This research paper presents an interdisciplinary project setting for first-year engineering students. A theoretical frame of reference is suggested to support curriculum design for interdisciplinary competences in engineering education. Empirically, the study draws on insights from a narrow interdisciplinary curriculum project named "leadENG". Besides being significant on its own in terms of learning outcomes within faculty borders, the leadENG project is intended to act as a bridge-building project to prepare students for broader cross-faculty projects. This study follows a second semester cluster of groups from energy and materials and production, all working together on the creation of a sustainable vehicle using recycled materials. Data have been collected through three explorative qualitative interviews with 15 students and 4 observations with the entire group of 35 students. Interview data have been transcribed and thematically analyzed in NVivo. Findings indicate that students found the new narrow interdisciplinary setting highly relevant in expanding their understanding and approaches to sustainability and interdisciplinarity. Students experienced having a better and deeper understanding of their own discipline by weighing it up against another discipline and could see the meaning and dependency of contributions and collaboration with the other project groups. Although students still experienced different challenges and difficulties, this study indicates that narrow interdisciplinary projects combining different fields of engineering disciplines in a system perspective can be fruitful in the progression of students' broader interdisciplinary competences.

Keywords: Interdisciplinarity, PBL, First-year students, Engineering Education

Introduction

With the increasing technological and societal complexity, problems like the sustainable development goals (SDGs) have been emphasized as crucial aspects to address in engineering education. Engineering students need to learn how to deal with these complex problems [1][2], via a more interdisciplinary orientation and competence development in the curriculum, which prepares and enables engineering students to handle future societal problems [3][4][5].

Reference [6] defines interdisciplinarity as a range of degrees and approaches to interdisciplinary work, spanning from multidisciplinary to transdisciplinary projects. A multidisciplinary approach ensures that problems or situations are viewed from different disciplinary positions, whereas interdisciplinarity calls for a more integrated approach, letting representatives from different disciplines interact and co-construct meanings and approaches to the problem at hand. Reference [7] further introduces the terms of narrow and broad interdisciplinarity, referring to narrow interdisciplinarity as collaboration among disciplines more closely aligned in terms of paradigms and epistemology and broad interdisciplinarity as collaborative constellations with a wide understanding of ontologies, epistemologies and methodological understandings. If this

interdisciplinary mix is furthermore integrated with nonacademic knowledge, the concept of interdisciplinarity expands to the transdisciplinary field [6].

From an educational point of view, [8] introduces the SOLO taxonomy, with a distinction between multistructural knowledge (to describe, list, combine) in order to solve rather simple problems and relational knowledge (to explain, analyze, compare/contrast, apply) to solve more complicated and complex situations. However, as the complexity level increases, more dimensions have to be added to cognitive models of taxonomy. Mixes of different knowledge types are needed as a consequence of complexity, which calls for boundary work and interdisciplinary competences.

The question, though, is how to design a curriculum that will foster an adequate progression of such competences. As seen, there can be a progression by moving attention from simple to complex problems in order for students to gradually build up their capacity to address increasingly complex sociotechnical systems. In relation to the SOLO taxonomy, we will argue that the focus on complex problems adds a dimension of enactive knowledge, as the complexity of the problem is to a high degree context-dependent.

A frame of reference for discussing the progression of interdisciplinary knowledge and competences is presented in figure 1.

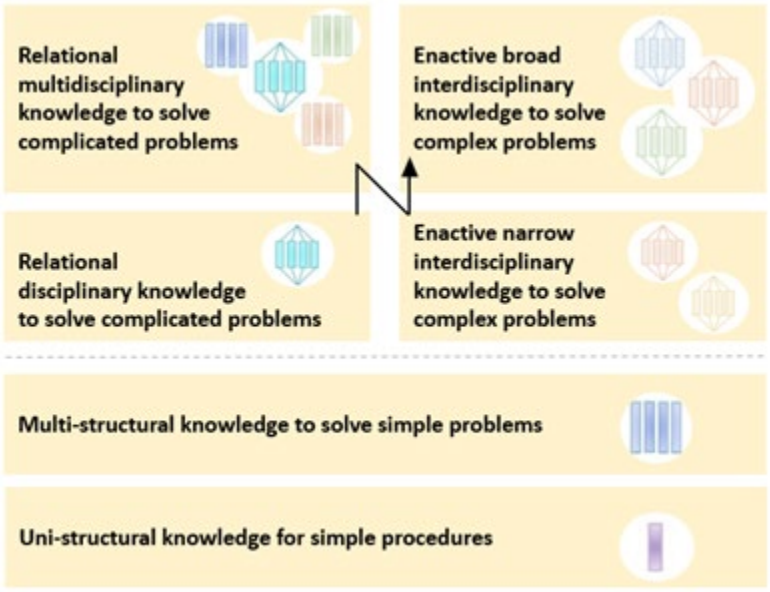

Figure 1: A frame of reference for discussing the progression of interdisciplinary knowledge and competences. The figure shows the different steps which a student must experience in their development of more complex, interdisciplinary competences. With unistructural and multistructural knowledge regarding how to solve simple procedures and problems, students are able to move to more complicated or complex project settings. To further enhance interdisciplinary competences, [7]'s taxonomy of narrow and broad interdisciplinarity helps to provide a progression, enabling students to develop competences to deal with complex, broad interdisciplinary projects.

Figure 1 is derived from the relational knowledge area of the SOLO taxonomy and outlines a potential path for progression including interdisciplinary approaches for complicated and complex problem-solving. Having a unistructural and multistructural knowledge of how to solve simple procedures and problems, students are able to move to more complicated or complex project settings. To progress further in the figure, students must experience study activities that provide them with relational disciplinary and multidisciplinary knowledge to solve complicated problems within their own discipline. Moving to the right in the figure, we now draw on Reference [7] and distinguish between narrow and broad interdisciplinary projects, and we argue from the suggested line of progression that a narrow interdisciplinary project will serve as an important bridge for students to enter broader interdisciplinary projects, as the shared paradigms and epistemological foundations of engineering will ease the boundary work between disciplines. The argument is that having a sense of how other disciplines relate to their chosen line of study will prepare students better to enter into broader interdisciplinary contexts where they, to a larger extent, have to co-construct their understandings and approaches with other disciplines.

In 2019, Aalborg University (AAU) launched *AAU Megaprojects*, allowing students to experience broad interdisciplinary projects crossing all faculties at the university. Over the course of a full semester, students have the opportunity to work on grand challenges related to the 17 SDGs [9]. A study was conducted to follow and elaborate on experiences and structures. Research shows that students have trouble in transferring approaches, methods and tools from a known disciplinary setting into a complex, broad interdisciplinary setting, both in terms of project management and teamwork [10][11].

In spring 2021, the Engineering Faculty at AAU launched a concept called *leadENG*. The aim of this initiative is to let first-year students experience and work together in a narrow interdisciplinary setting. By introducing a narrower interdisciplinary project structure, compared to the megaprojects, the intention is to offer students the opportunity to develop their collaborative, problem-oriented and project management skills and competences.

This paper will elaborate on experiences and learning outcomes from the perspective of students participating in a narrow interdisciplinary project setting, giving insight into the possibilities and points of attention in interdisciplinary teamwork and project management. In this paper, the purpose is to further investigate the assumption of progressing from disciplinary projects into narrow interdisciplinary projects, thus elaborating on the following research question:

In which ways can a narrow interdisciplinary project like leadENG within the engineering domain contribute to the progression of interdisciplinary competences of first- year engineering students?

Experimental Methods/Materials/Project Approach

Research Context

The study has been conducted during the second semester at the Faculty of Engineering and Science at Aalborg University in Denmark, a university where Problem-based Learning (PBL) has been the primary pedagogical approach since its foundation in 1974. The PBL principles at

Aalborg University takes problems as the point of departure, letting students work together in groups elaborating on problem identification, problem analysis and project organization in a student-centered way. Each project group has a facilitator. Each semester consists of a 15 European Credit Transfer System (ECTS) project and 15 ECTS courses – typically three courses for each 5 ECTS. Prior to the studied second semester, all involved students had worked on a disciplinary project during their first semester. In spring 2021, this study followed the first round of leadENG projects, focusing on the subproject "Small Electrical Vehicle". This project focused on the construction and production of a sustainable vehicle. leadENG projects are projects at the Faculty of Engineering and Science designed to let study groups across engineering disciplines collaborate to develop sustainable solutions. The study groups work within their semester's themes, and the facilitators work together as a team to support the process [12].

The project was initiated with a kickoff meeting for the students, where the facilitators presented a system design for the small electrical vehicle showing the vehicle's different components. These components were later recognized as the foundation of the student groups. Moreover, the facilitators presented a plan for the entire project containing five phases: project kickoff, concept review, decision on individual conceptual solutions, completed component design and EV integration and finally prototype building and testing. After kickoff, interested groups could apply to participate. The groups were not automatically enrolled; it was up to the facilitators to decide which groups could attend. To share information and project progress, the facilitators arranged biweekly status meetings with the involved project groups during the whole project period. In the middle of the semester, a status seminar was arranged where the students gathered to present their status and progress. Due to COVID-19, the groups had a common Teams channel with subchannels named with the group ID, through which they could communicate with each other.

Developing interdisciplinary competences is a challenging process and demands that students develop and progress their PBL competences through experiencing a variety of problem types and project settings. With the leadENG initiative, students already in their first study year are provided with the opportunity to experience and work across disciplinary boundaries on a common problem. By introducing a narrow interdisciplinary project setting, students experience and learn how to manage and maneuver in and across disciplines, sharing knowledge, communicating and planning a project process with fellow students from other disciplines, though still with less complexity regarding differences in ontological and epistemological differences.

Data were collected in the period from March–June 2021 from approximately 35 students and 5 supervisors participating in this project. Students' disciplinary backgrounds were energy and materials and production, both in the Faculty of Engineering and Science. Six groups were formed, focusing on forward wheel suspension and steering, rear wheel suspension system and drive shaft, brake system, safety and comfort, battery and propulsion design. Students were put together in disciplinary subgroups working together in an overall team focused on building the sustainable vehicle. Data and information were gathered via observations and interviews both during and after the project period.

Observations

During the project, a number of official and unofficial meetings were organized in the team. Every fourteenth day a status meeting was arranged, facilitated by the supervisors. The aim of these meetings was to share information and guide the process related to the vehicle. Data were collected from four meetings, three status meetings and one status seminar. Through the participatory observations, it was possible to collect information about how the subgroups interacted among each other but also about the degree to which support from their supervisors was needed. Due to COVID-19, the majority of the meetings were facilitated online. Having access to the MS Teams channel provided the study with information about workflow, updates and alignments created and maintained throughout the project. All observations were collected through observation sheets with a special focus on project management, communication and knowledge sharing, and were afterwards compared with the explorative, semi-structured interviews.

Interviews

After the submission of the project at the beginning of June 2021, three explorative semi-structured interviews were conducted with 15 students. With the qualitative approach to data, it has been possible to explore experiences and learning outcomes from being part of an interdisciplinary project setting. Three disciplinary student groups volunteered to answer more detailed questions regarding their participation in the project, and each of the interviews lasted approximately 30–45 minutes. The interviews were conducted as focus group interviews with each of the disciplinary groups, taking in questions presented in table 1 as the point of departure. The interviews were conducted in Danish to minimize language barriers, and quotes were translated afterwards. Data were collected from two subgroups from materials and production focusing on rear wheel suspension system and drive shaft and brake system and a subgroup from energy focusing on the propulsion design. The semi-structured interviews provided the study with retrospective data about experiences and points of attention with regard to interdisciplinary projects. In this article, focus has been on students' perspective on participation in interdisciplinary projects focusing on how they experience and develop their understandings and competences within complex project management and collaboration.

Table 1. Guide for semi-structured interviews.

Preliminary questions
Try to tell us about your participation in the leadENG project? What did you work with?
Why did you choose to participate in the leadENG project?
What did you expect of the process before you started?
Experiences related to participating in a narrow interdisciplinary project
How were your experiences participating in the leadENG project? (What functioned well/what did not?)
How was the project structured? (What functioned well/what did not?)
How did you experience the interdisciplinary collaboration between the groups? (Degree of collaboration)
How did you manage the collaboration between the groups? (How many meetings/timing)
What type of knowledge have you shared among the groups? (Difficulties in understanding each other)

Can you try to tell us how (and if) the process has been different from your ordinary semester projects?
Retrospective reflections
Could you have done this project within the other groups? (Your contribution/contributions from the other groups)
Have you gained a better understanding of your own disciplinary contributions?
What have you learned being part of leadENG?
Did it make sense being part of leadENG already in second semester? (Pros and cons)
What do you think should be done to improve leadENG further?

Data were transcribed and coded using the software NVivo. The coding was data-driven, letting data highlight points of attention and structures concerning the narrow interdisciplinary teamwork experienced by the students. The coding was gathered afterwards according to themes guided by the focus in the coding. The following themes helped form the content of the results: *motivation for joining the project, meeting frequency, good experiences from participation, project initiation, critical parameters and different units, project management and planning, experiences with collaboration, communication and knowledge sharing, compromises and dependencies, facilitation and support from supervisors and learning progression and outcomes.* Results were guided and structured in relation to these themes.

Results and Discussion

As students move from disciplinary, delimited semester projects to more complex system-driven projects their understanding and approach to project structures and collaboration needs to change accordingly. The leadENG initiative helps students bridge their disciplinary PBL competences with a broader interdisciplinary context, providing them with an opportunity to enhance and develop their competences in relation to collaboration and management in more complex environments, though still within a shared ontological and epistemological frame. Results highlight interview sequences and observations, emphasizing the process and development of managing and handling more complex problems for students during their second semester.

Progress in the project was guided by the problem in focus, creating a dynamic team structure where the different subgroups contacted and collaborated with one another depending on the questions and knowledge that was important to share. This process was not clear to the students from the beginning though, and it was facilitated and guided by the supervisors to a great extent at the start of the project. Focus has been on creating common ground among the participating groups and results show a development in how students discover and expands their interdisciplinary project management and teamwork skills throughout this process.

The results is presented and discussed by addressing four themes: i) importance of facilitation, ii) compromises and dependencies to establish common ground iii) interdisciplinary project management and teamwork and iv) gains of participating in a narrow interdisciplinary project setting like leadENG.

The Importance of Facilitation and Support from Supervisors

As students experienced the project process as chaotic and at times frustrating, they needed guidance and facilitation. Supervisors facilitated the creation of common ground and mutual adjustments at the beginning of the project through biweekly meetings. The meetings were focused on each subgroup's progress and offered an opportunity to get to know what each of the groups were working on. There were different opinions about the relevance and frequency of the biweekly status meetings by the students. In the first month, most of the students found the status meeting valuable:

"It worked mega well to begin with. The first two meetings [....] the first month, we felt that we got a lot out of it, because then we also know a little where.... so what do the other groups do, so what exactly are they working on. But the further we came towards the end, and the closer we got to a solution, we think it was much more worthwhile that we just took the initiative to talk to the other groups."

In the beginning, it was mainly the facilitator who enabled the contact between the groups and took the lead in the project. All groups highlighted the support and facilitation by the supervisors as important for the outcome of the project. Having the supervisors as facilitators and mediators at the beginning of the process created less complex and chaotic situations. Supervisors helped to highlight interfaces and points of attention that were important for the groups to have in mind. One group stated that the supervisors at different times acted as the link between the two disciplines, clarifying questions and asking relevant questions for the students to understand how to relate and connect to one another:

"Sometimes he [the supervisor] acted as the link between MP [Materials and Production] and us. He explained why we were looking at different elements… So, sometimes it seems as if he was the link between our two groups."

Observing both the status meetings and the status seminar showed that the supervisors at several times asked the subgroups questions linked to one or more of the other groups. The supervisors also often discussed elements related to the project, providing students with insights into how the subgroups were interlinked and dependent on each other. They managed to break down questions to a level at which it was understandable for the second semesters groups:

"… There have been some big questions. He [the supervisor] has taken it down to a level where all of us could understand it in relation to the connections between different elements."

During later stages of the project process, what the student got out of the biweekly meetings fluctuated. Some still found them relevant, whereas others said they were more reporting and sometimes too technical:

"I think they are important. So, I think they were good..."

"So, we had to have a meeting every other week, and it was not always something new we had with us. We just said the same thing every other week. Maybe it should not be so frequent."

At this stage, the supervisors started to challenge the subgroups, pointing out interfaces that were important to align and adjust between the groups in the team. The supervisors went from being the link between the groups to helping the students create common grounds for communication and knowledge sharing among each other. The students experienced the contact with the other groups as difficult in the beginning, but it became easier as the project progressed, and the groups got to know more about the project and their roles in the team:

"In the beginning, we were a bit bad at taking the initiative and figuring out by ourselves how to work with the others. It was often our supervisor who said that we should talk with the others, and then we did afterwards."

One group said that their supervisor was different from what they have experienced earlier when comparing their supervisor with their first semester supervisor:

"We had a supervisor in the first semester who guided us through everything, which was good in the first semester because we did not know what to do. But here, it has been nearly opposite. We have had to take big decisions ourselves, which has also been fine…. But we could maybe have used a bit more guidance at some points."

Students said that the support from the supervisors was a balance between helping to guide them through the process and to push them to manage the process themselves. Through the observations, this balance between supporting and letting the students maneuver in the complex project setting themselves became clear as the students at later meetings managed the meeting discussions themselves, discussing budgets and components of the car in plenum. Here, the supervisors stood in the background, supporting the students if necessary:

"We have had a trial by fire if you can say that. We have been thrown in with our heads first. I think we have come out of it well. We have learned so much. So, I think that he (the supervisor) has done it in the right way in relation to this leadENG because we could also find support in the other groups. So that's where we have gone for help in relation to data or help in relation to things we have found challenging, and then we have gone to X (supervisor) if they could not help us either."

As seen in the above, students have, with the help of their supervisors, discovered the importance of cross-group communication, developing their competences within the interdisciplinary field. Important to note is that this process, to a large extent, has been supported and facilitated by the supervisors. Students found the interdisciplinary processes challenging, even in a narrower interdisciplinary setting which created common ground and mutual alignments among the groups.

Compromises and Dependencies – The Discovery of Common Ground

Overall, students found collaborating with other student groups on developing, planning and prototyping a sustainable vehicle exciting and motivating. Students articulated that the collaboration was both challenging but that it was also interesting to be part of a bigger team working towards the same common goal:

"Of course there have been challenges in terms of the use of different terms and understandings of elements they had and vice versa…"

Communication among the participating subgroups became easier as the project progressed. One group viewed interdisciplinary communication as a learning process, where they had to learn how to collaborate and share information:

"We have experienced a development in the communication throughout this project. In the beginning, we had to learn how to communicate with one another. People used different platforms, and we had to agree on how to communicate in the easiest way…"

A number of groups experienced difficulties with communication at the beginning of the project. One group emphasized this as being due to a lack of mutual alignment and knowledge of each other. The subgroups had to get to know one another to build trust and mutual respect. One student described this process as the realization they had to "break out of their shell":

"… it was like we had to "break out of our shell", so to speak. We just needed time to get started. We don't know that many from the other groups, so we had to figure out how to approach and communicate with them. And when we did that, it became much better. Also, when we came back to campus, we could just drop into the other groups' rooms and ask about how they were planning to do things."

The meeting frequency changed during the project. This also showed in the Teams channel, where more communication and meetings occurred as the project progressed. One of the groups had their meeting frequency increase to four times a week or even several times a day because of dependencies in the integration phase between the groups concerning drawings, space and weight. The form of the meetings was often informal, like connecting on the Teams channel or going to the group room, or if it was a simple question just using the chat function in Teams:

"Well, there have been, for instance, some groups we might have worked a little closer with than others because of a closer relation to what we and they have been doing. There have been some groups we have communicated more with in relation to getting things to work together. They have some things that must occur for the drive shaft to work, and we have some requirements as to how to get the engine running. It has been a bit back and forth, and we have talked a lot with them, and so if they change something in theirs, then it may have an impact on what we do, and if we change something in ours, it may affect how to change something in theirs. So, like that, there has been a bit of back and forth…"

One of the elements emphasized by all interviewed groups was the discovery of the influence of mutual compromises and dependencies during the project period. More of the groups started off by making assumptions about how the system should be controlled and managed but quickly

experienced that different calculations, units of measure and alignment of the components were necessary for the vehicle to come together as a functioning system in the end:

"*I think it's cool to see the difference between two lines [disciplines]. I was working with the drive system group, where they used rad per sec. and we used revolutions per min…So to start with where I looked at their calculations, it did not agree with mine, and I thought that they probably used another unit, which they might use in their part…, So, then you might just have to have the same units."*

Also, learning objectives and outcomes were important elements for the groups to align as a way to secure common ground and mutual alignment in relation to the final product. More of the groups highlighted the collaboration between the participating groups as essential for producing the vehicle in the end, and the groups found it motivating to experience mutual dependencies with the other groups:

"It has been motivating to know that more groups have been part of this project together, and it has also made the group work more interesting…"

As the project progressed, the groups became better at aligning and adjusting to one another. Each subgroup experienced that they could not just make a decision about how to move forward as decisions related to one component would influence one or more of the other groups. More of the groups stated that this process was chaotic and frustrating but, on the other hand, also more closely related to the real world. One element influenced by this was the time scheduling. Sometimes the students needed to wait for input from other groups. In addition, the groups were not at the same phase or part of the process:

"So, I feel that sometimes we have been a little ahead with some things in our project, and then we have waited a little for some things. It has been the most challenging compared to our other groups."

In the retrospective interviews, more groups emphasized that this acknowledgement of mutual dependency and the importance of knowledge sharing first became clear later on in the project:

"I just think in the beginning we did not have much interaction with the others. It was quite late when we really came into this. It came when we saw that we were missing something. We could have benefitted from looking ahead saying, "okay now we need to look at this. Which points are important to address here?" We, maybe, approached it a bit wrong. Instead of looking forward, we looked backwards".

Discovering the interdependencies between the participating groups seemed an essential part of creating common ground. The students had to acknowledge the importance and relevance of the other groups, not just for sharing information but as partners in the creation of the sustainable

vehicle. Lacking this realization, students lack the reason for collaboration, thus being more likely to just do things themselves. Interdisciplinary teamwork and management rely on mutual dependency, which gives a much more complex interdisciplinary space with compromises, adjustments and alignments.

Interdisciplinary Project Management and Teamwork
During the project process there was no, or limited, project management between the groups. In response to questions about their collaboration and management across the groups, the response was the following:

"No, we actually did not. But I think it's because we've been a little uncertain. It has been a bit difficult to evaluate when we should connect things together like this, for example, and how things should be connected, so it is different in which part of a project that is going to happen. That way, it's hard to predict and also hard to plan how to deal with it like that. It has only been a little spontaneous."

In the observations, it was clear that the project management and collaboration between the groups progressed as the project developed. There was no interaction and barely any questions aligning the groups at the beginning. Each group worked with their own project planning:

"... In relation to this alignment, I just think of us as a group. We just wanted to achieve as much as we possibly could. We thought that if we reached as far as possible at all, then other groups would have to correct in relation to us, which should say that we should just take control of our work and the interfaces afterwards around it. Because then we thought that if we had made something, then maybe we could not do much with it because now we had already made a solution for it, which was probably also the wrong way to look at it because it was. You should probably have just made a small-time map of when you possibly had some big deadlines with this drive system .... so that you just had a few deadlines, so you knew you could get the details you needed. It would probably have been a little smarter."

A student also reflected upon the meaning of start-up meetings and alignment as important for this type of project:

"Definitely, that with project management and collaboration with disciplines, it's definitely something to think about. They do not know exactly the same as you. They know something you do not know, and you know something they do not know. There you just have to be a little more aware of how. Maybe you should have a start-up meeting where you just agree on what things and how to calculate them, and what competences they have, and what they really want here. Before you just get started, there will also be a collaboration over time."

Even though the students experienced the interdisciplinary project management as challenging, more of the students said that communication was fundamental to a good interdisciplinary project process:

"Good opportunities for knowledge sharing are essential here. No matter if it is technical or more overall in relation to the project, it is very important to share information with everyone."

Regarding knowledge sharing, students emphasized the importance of knowing what to share with the other groups in the team. Efficient communication and knowledge sharing were expressed by one group as a balance between sharing the right amount of knowledge bringing insight into processes and decisions and providing too much information, which is confusing or of no interest to the other groups:

"… But also in terms of more technical stuff, then it is important to know what kind of knowledge to share. When we work on the electrical components, then we could talk about all the elements that we are looking at and working with, and that is also very interesting, but maybe not that important for the other groups. There are some specific things that we do, some key numbers or values, or key problems important to handle with the other groups, and then there are some problems not important to handle and share with the other groups. So, sometimes too much information is also bad. It might confuse the other groups in regard to what is important and what is not in relation to the collaboration you are doing with them."

Another group expressed that it was challenging if things became too detailed. At the status meetings, the group experienced some information as too technical in relation to either energy components or production components, with the common understanding and language among the subgroups somehow being lost:

"It becomes very technical in regard to energy, which Materials and production do not understand, and vice versa…"

A student expressed the importance of patience in this process:

"You need to have patience when communicating with the other groups. It was a bit frustrating to see the other groups have other calculations than me, but it was also good."

The groups experienced the interdisciplinary communication as something different from what they had experienced internally in their group. Other things needed to be aligned and negotiated in order to create common ground among the groups. One group felt this process was insightful with respect to how to collaborate and communicate across disciplines. Especially, an understanding of how each of the disciplines became important and necessary in the process were emphasized as important learning outcomes from being part of an interdisciplinary team:

"Also, how much more knowledge they have, for instance, about the engine, because I just looked at the technical drawing, found the numbers and calculated on that from the beginning, but then one of the other groups told me that they were able to draw more out of the system by using [something else]. So, what I take from this is that there are huge differences between the two lines

[disciplines], but this is also good because then other competences come into play, and it is possible to gather something more and better."

In the retrospective interviews, it was clear that the students had gained a lot from participating in the leadENG initiative. Maybe not directly during the process but afterwards when we asked them to elaborate on their process, more of the students were able to articulate and reflect upon missing elements and points of attention for future interdisciplinary projects. Students not only developed their interdisciplinary competences in this process, but they also had a clearer understanding of their own disciplines when viewed in relation to other disciplines.

What to Gain from Being in a Narrow Interdisciplinary Project Setting
In the retrospective interviews, questions focused on experiences and discoveries made by the students. In addition, questions invited students to elaborate further on learning outcomes and development from being part of a narrow interdisciplinary project.

The interdisciplinary collaboration and project management was evaluated by more of the groups as great and fruitful, with the opportunity to get an insight into one's own and others' disciplines:

"It is about how much we can gain from a project by using each other in this way. You can do so much more. You can quickly get an overview of the system… We have used one another and gained a lot of knowledge from each other."

"The interdisciplinary way of working has been great. Experiencing talking to other groups, who do not do the same as you, gives you a picture of what happens in the real world, which I find extremely cool."

One student articulated the interdisciplinary process as:

"When we have different competences across the two lines [disciplines], I think it becomes clear that we really have something to contribute and that we can teach others something. And when we pass on knowledge to others, we understand the elements better ourselves as well."

Students experienced the leadENG project as a learning process, where they not only learned more about their own discipline but also about the impact of sharing knowledge with others. Another student described interdisciplinary knowledge sharing as the process of acknowledging that knowledge sharing is not about knowing the other discipline in depth but instead getting the right amount of knowledge out of the collaboration:

"We have learned to collaborate with someone that might not have the same disciplinary background as us. We have learned to collaborate with someone we may not understand 100% because we don't understand materials and production 100%, and they don't understand 100% what we are doing in energy…. And then interdisciplinary communication, we could articulate and share knowledge in a simpler way easier to understand."

All participating groups would like to try out these types of interdisciplinary projects again, as they expressed that this project had created a foundation for how to collaborate with others in relation to communication, knowledge sharing, dependencies and compromises:

"It has provided us with a better understanding of how to collaborate in larger group work, and now that we have tried it, I would very much like to try it again because I think we could gain a lot more from it. Now we know more about how to establish the general communication and how to be more effective."

One student felt that the progression of his learning was motivating with respect to joining projects like leadENG in the future, as this process had developed his competences and provided him with a better starting point for how to cope with this type of problem and project in the future:

"I am more willing to do this now than I was before, even though we also were very keen on doing it before. I am very positive. Now I know how to handle this another time."

Another student also articulated that the leadENG project was a steppingstone for future projects:

"Well, I guess even if we did it in a later semester, it would get better too. This is the first time we're doing this."

More of the students mentioned that this project was very reminiscent of real-life workplace situations and that they had experienced how their discipline fits into this:

"Yes, that is, that you have gained great insight into what it is like to have communication between several groups that you collaborate with and how it really is our study, what it is we really have to deal with when we come out in the labor market."

"*... After all, when you get out of here, it's not just an energy engineer. Then there are more people who need to work together, and that is also what we have experienced here, where we have had to brief each other in these ongoing meetings and where you are a little updated on what the others are doing. It gives great insight into the whole system, and not just what you yourself are just dealing with.*"

Regarding asking the students about the relevance of these types of projects in an early semester, such as the second, a student responded:

"It makes good sense in the second semester because here we have the time to get a hold of the communication parts…. Those who have not been part of leadENG... In the last semester, doing an interdisciplinary project, then they have to learn about communication while they need to implement more things than we do in the second semester. That could be busy. Now we have some experience in doing this, and then in the future we can focus more on the technical things."

Final Remarks

Overall, students find it both relevant and interesting having narrow interdisciplinary projects at the second semester. To answer the question about how a narrow interdisciplinary project can contribute to the progression of interdisciplinary competences of first-year students the following is observed.

During the first semester, getting to know both how to collaborate in disciplinary and interdisciplinary teams would have been too complicated, while during the second semester, they can progress with their experiences from disciplinary teamwork and project management. Introducing students to narrow interdisciplinary projects at an early stage in their education provides students with a variety of problems and project types, to which students can relate and reflect upon. On the other hand, students need to have some experience in problem analysis, project management and teamwork before entering more complex project settings like leadENG, as they need fundamental disciplinary PBL competences for managing this type of project setting.

The fact that students got to work in a bigger, more systemic environment was emphasized as motivating and rewarding by several students. The six participating student groups finalized their semester projects in June 2021 but continued working on the vehicle over the summer holidays and were able to present a driving vehicle at the beginning of October 2021.

LeadENG 2021 was the first narrow interdisciplinary project in this setup. Based on the experience from leadENG and the earlier megaprojects the development of different project types continue. The changes made in the next iterations of leadENG is researched to further elaborate on the design criteria for setting up such projects. During the next years, it is possible to observe more long term learning outcomes of leadENG to identify whether participation in a narrow inter-disciplinary project like leadENG can scaffold progression of interdisciplinary competences.

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