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Emergent premises in student experiences of a first-year electrical engineering course

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ABSTRACT

This study explores how project-based learning in combination with other pedagogical scaffolding approaches influences students' experiences during their transition into the university. Based on the thematic analysis of interviews with students at the end of the first semester, we show how a project-based course in electronics can create opportunities within three themes: student socialisation, curriculum integration, and peer-learning. In the light of these findings, we discuss how students build relationships with other students, as well as with faculty members and practicing engineers, and how these relationships influence their start at the university. On a more general level, this case study exemplifies how an existing electrical engineering programme can be changed by targeted interventions without the need for programme wide adjustments.

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First year students; project-based learning; engineering identity; socialisation; curriculum development; peer-learning

1. Introduction

In this study, we look at how first year students perceive different pedagogical scaffolding approaches during their transition into the university. The context for this study is a re-designed electrical engineering programme that aims at providing students with opportunities to learn engineering practices right from the start. This is achieved by a focused reorganisation of four courses, leaving the rest of the programme unchanged. Using a national student survey as an entry point, we briefly compare the programme to other electrical engineering programmes in Norway, before exploring the *how* and *why* of students' experiences in detail through in-depth interviews. Through a thematic qualitative analysis approach, we have identified three emergent themes that appear central for the students: socialisation, curriculum integration, and peer-learning.

Engineering education is constantly adapted in many different ways and on various timescales. At the heart of several reforms has been the experienced mismatch between the discipline-oriented, scientific focus of the university and the multifaceted demands of professional practice (Mills and Treagust 2003). On a more concrete level, design has been identified as a core element in engineering and resulted in a stronger emphasis on the design process in engineering education since the late '90s (Dym et al. 2005; Simon 2019). The emphasis on design can also be seen as a way to distinguish engineering education from natural science education that has moved more and more towards applications (Williams, Figueiredo, and Trevelyan 2013). In addition, and more recently, Lucas and Hanson

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(Lucas and Hanson 2014) identified six *engineering habits of mind*: 1) systems-thinking, 2) adapting, 3) problem finding, 4) creative problem solving, 5) visualising, and 6) improving. They further suggested that these habits of mind are centred around two core engineering mindsets, 'making things that work' and 'making things that work better'.

With this in mind, it is important to explore pedagogical approaches that can support students in their development of engineering habits of mind, facilitate the socialisation of students into engineering, and integrate these approaches as an important part of engineering education (Richard et al. 2017). In addition, empirical studies that examine how different pedagogical approaches can contribute to support students' development of identity, mindsets and design thinking are clearly needed. It is important to study in more detail how the process of interacting with faculty members, practicing engineers, and peers, as well as the participation in and use of engineering practices and cultural artefacts, supports students in their development of social and professional engineering identities.

One important starting point here is the use of inductive teaching strategies in engineering education that put applications and experiences before theories and concepts (Prince and Felder 2006). Inductive approaches put an emphasis on active student participation and self-regulated learning is needed to put students in a position where they can discover something that they did not know before (Lee 2004; Levy 2011; Pedaste et al. 2015).

On a concrete level, the integration of project-based learning (PBL)[1] into engineering curriculums has received growing interest in the engineering education research literature (Mills and Treagust 2003), as PBL forefronts the *application* of knowledge to create a product or artefact (Mills and Treagust 2003; van Barneveld and Strobel 2009). One particular area of interest to integrate PBL is the first year in engineering programmes (Dym et al. 2005), as that period of time establishes the cognitive, affective, and conative foundation for students and is closely linked to student retention and academic success (Simon 2019). PBL supports learning through the engagement of students in *authentic* problems or activities and in engineering education PBL is often carried out in groups over longer periods of time, which reflects the nature of how professional engineers work (Gavin 2011). This collaborative approach also emphasises peer-learning, in active and self-regulated forms (De Graaf and Kolmos 2003; Gavin 2011). Peer-learning encompasses a wide variety of educational strategies and activities (Griffiths, Houston, and Lazenbatt 1995), but at its core is 'the acquisition of knowledge and skill through active helping and supporting among status equals or matched companions'. In this way, peer-learning moves the focus from independent learning towards interdependent learning, where students develop skills to plan, organise, work, and evaluate their learning together (Boud 2001).

While there is strong support in the literature to change first year engineering courses, many engineering programmes remain focused around theory heavy courses that provide little connection to actual engineering practices in the first year. Balancing engineering science and engineering practices is challenging, and students often find it difficult to establish connections between different concepts, practices, and areas of engineering (Williams, Figueiredo, and Trevelyan 2013). In addition, large anonymous courses in e.g. math, mechanics, and electronics with hundreds of other students across different engineering disciplines make it difficult for the students to identify themselves as engineers in making and to be a part of a disciplinary socialisation process right from the first semester (Meyer and Marx 2014).

Based on our empirical findings and in connection with the literature outlined above, we will in the following illustrate students' perspectives on different pedagogical scaffolding approaches, how students perceive the transition into the university, and discuss our findings to help other educators to build upon both potential challenges and lessons learned from our case-study.

2. Research context

In this study, we focus on the five-year *Electronic System Design and Innovation* (Elsys) integrated master study programme at the Norwegian University of Science and Technology (NTNU). The

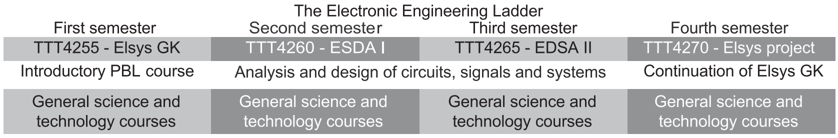

Figure 1. An overview of the Electronic Engineering Ladder. The course codes and abbreviated course names are shown inside the boxes. General science and technology courses are taken by the students in parallel with the Electronic Engineering Ladder.

programme curriculum was re-designed in 2014 by introducing the *Electronic Engineering Ladder* (Lundheim et al. 2016), an integrated sequence of four courses during the first four semesters as illustrated in Figure 1. The aim of this ladder is to, through continuous targeted modifications, improvements, and adjustments, integrate PBL and engineering practice with traditional engineering science courses, thereby transforming an existing programme without the need to change the entire curriculum. These courses are organised by a team of 4–5 faculty teachers, where everyone is involved in all four courses.

In the first semester of the Elsys programme, an introductory project-based course (Elsys GK) was added to the curriculum, where the students get the opportunity to work on an engineering group project. The second and third semester were changed by adding engineering courses on analysis and design of circuits, signals and systems. Finally, the curriculum was adjusted to include a course in the fourth semester, where students continue to work with the project from the first semester. In this article, we focus on the Elsys GK in the first semester.

The course starts with a three-week practical introduction to electronics through several short microcontroller-based problem-solving exercises. The emphasis in these sessions is to learn through the task itself and with the help from fellow students, student assistants, and faculty. To further facilitate socialisation among students, two field trips are arranged by the department: a day trip at the start of the semester to a local island and a two-day trip visiting relevant industry in a nearby town.

After the three weeklong introduction phase, all students, approximately hundred, are divided into groups of 6–7 by the teachers. The groups are formed with the goal of mixing students with varying levels of pre-knowledge. The level of pre-knowledge within electronics and programming is gathered through self-assessment on a three-point scale at the start of the semester. The students start working on a larger engineering problem in groups, called the *innovation project*. The central aim with introducing a project activity right from the first semester is to give students the opportunity to work in teams and gain insight in how engineers work. The project theme is similar for all groups and defined through a collaboration with a new external partner every year, typically a company, organisation, or public institution with an authentic engineering problem. Within this general theme, the students define and work out the details of the project themselves and solve the problem within their groups.

Throughout the course, students can get help from 4–6 student assistants, also referred to as learning assistants or teaching assistants. These are older students at the same programme who have previously taken the course. In order to prepare the student assistants, they are given pedagogical training organised by the university prior to work in Elsys GK.

The Elsys GK course is organised as one full day (8-16 o'clock) over a period of 13 weeks. Every day is structured around a general skeleton of different activities as shown in Figure 2. Starting with an introduction session called *Cross-Talk* where problems related to the current project situation and the

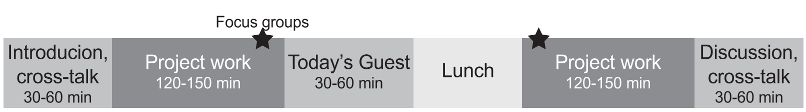

Figure 2. A typical Elsys GK day.

general study programme are discussed and relevant theory from other parallel courses is brought in. In these sessions, teachers connect the topics from all courses in the programme and explain how they may contribute to the project work and engineering in general. Following this session, the groups work individually, before the class has another plenary session around lunch. In this session, called *Today's Guest*, students meet an invited guest from industry who talks about their work and how electrical engineering is important for their company. After lunch, the group work continues, until a final plenary session at the end of the day that includes presentations from selected groups about the problems they have encountered during the day and additional cross-talk. In addition, focus groups are held throughout the day, where one or two students from each group with similar challenges or project tasks can share experiences and learn across project groups.

3. Research design

In order to get a general understanding of the effects that the redesign of the Elsys programme has on students' experiences, we used data from an independent national student survey called Studiebarometeret administered by the Norwegian National Agency for Quality in Education (NOKUT) (Studiebarometeret 2017). The survey asks students, on a 1–5 scale, about their perception of quality in study programmes at Norwegian universities and covers a wide range of topics including questions on the learning environment, professional relevance, and student involvement, amongst others. All questions are aimed at study programme level, not course or institution level. The Studiebarometeret allows the comparison of the Elsys programme to other electrical engineering programmes in Norway on a general level.

Using this quantitative evaluation as a starting point, we used a qualitative case study approach to explore students' experiences in the first semester of the Elsys programme further (Merriam and Tisdell 2015). Students were selected to cover different project groups and all levels of pre-knowledge in electronics, which was assessed using self-reported answers on a questionnaire at the beginning of the semester. Based in these criteria, six students were selected and contacted. All six students agreed to participate in semi-structured in-depth interviews at the end of the Elsys GK course and gave their informed consent to be part of the study. This strategy of student involvement was chosen to secure a sufficient variation in pre-knowledge and project group experience, two important parameters that we anticipated to influence students' learning experiences. The aim was to have deep and rich accounts to access how students perceive and interpret situations, and dig deeper into why the students 'act, think and feel as they do' (Krefting 1991).

In order to minimise students bias and desire to please active teachers of theirs, the interviews were conducted by author two. Author two has a basic understanding of electronics but is not part of the teaching team, nor has he any connections to the programme or department that host the course. The interviews lasted between 20–45 min each and covered topics about students' pre-knowledge, their perception of the learning environment, and experiences coupled to their first semester curriculum. All interviews were audio-recorded and transcribed.

For the analysis, the interviews were pooled together and a thematic analysis approach was used to identify, analyse and describe patterns and themes within the data (Braun and Clarke 2006). The material was read and re-read to explore what factors in the course the students described as central for their experiences. Through this iterative process, we identified different themes that emerged from the interviews. These themes were further explored by considering relevant literature, which was used as an additional perspective to develop and deepen the thematic analysis. In this study, we will focus on three themes from the analysis: socialisation, curriculum integration and teamwork.

4. Results

The Elsys programme differs from more traditional electrical engineering programmes in Norway, as briefly described above. Overall the teaching approaches used in the programme seem to be well

Table 1. Comparison of Elsys with other electrical engineering programmes in Norway (Studiebarometeret 2017).

	Elsys – 5-year programme at NTNU			Average of all 5-year study programmes in Electronics		
NOKUT Studiebarometer (1=dissatisfied/disagree; 5=satisfied/agree)	2017	2016	2015	2017	2016	2015
The academic environment among the students in the study programme	4.5	4.5	4.2	4.2	4.3	4.2
The environment between the students and the academic staff in the study programme	4.5	4.5	4.4	3.7	3.8	3.8
The study programme contributes to your motivation for studying	4.1	4.1	4.2	3.8	3.9	3.8
The study programme has good collaborations with industry	4.5	4.5	-	4.0	4.0	-

received by the students. Table 1 shows a comparison of the Elsys programme with an average of other electrical engineering programmes in Norway for 2015–2017 for four selected areas. Regarding the learning environment, the Elsys programme scores slightly higher with respect to the academic environment among students, and considerably higher on student satisfaction with the environment between students and academic staff. Furthermore, students in the Elsys programme feel that the programme contributes more to their motivation and say to a larger degree that their programme has a good collaboration with industry. For a more detailed analysis of this data please see Lundheim et al. (2018).

Building upon this general programme evaluation, we will, in the following, focus on three themes that emerged from the qualitative analysis of the interviews: socialisation, curriculum integration and teamwork.

4.1. Socialisation

The first theme that emerged from the interviews with the students is how the Elsys GK course contributes to the students' socialisation process at the university. One important aspect that the students highlight is getting to know each other and the feeling that they belong to the study programme. From the students' perspective building a community is a core element in the Elsys GK course. They perceive that the disciplinary learning is not at the centre of the course, but that the overall goal is to have a good start at the university and get some basic ideas about group work and different working approaches:

> I do not think the main point in the course is to learn so much about electronics, just to use it a bit, try it a bit, play with it. But the point is to learn a little more about group work and different working approaches and having a good start to the Elsys programme … (Student 2)

The students value this approach and the focus on building a community within Elsys, as they feel that it helps them beyond the Elsys GK course. By emphasising getting to know each other and establishing a community, the students feel that they belong to something:

> For me Elsys made it much easier to get to know people. You start to recognise faces and then when you see someone later at the university you feel - It feels friendly and familiar. You feel that you are part of a community even though we are so many students. (Student 5)

This feeling of belonging is an important aspect in students' life as more than one fourth of Norwegian students report that they often or very often feel some sense of loneliness (Knapstad, Heradstveit, and Sivertsen 2018). By creating an arena for low stakes social interactions, the Elsys GK creates an important opportunity for students to connect with each other. Many of the social interactions arranged within the course are partly organised by the faculty, i.e. the students do not decide who to be in groups with or share rooms with on field trips and therefore not everyone who they interact with. The students experience this as good approach:

> You get forced to get to know each other and I think that is a good thing. […] You get forced to sit together and talk with each other and I think that's good. […] Group work makes it easier, because then you get friends you can study with. And then the daily life becomes easier. So being placed in groups, and that there is someone deciding the groups, that I support. I think it is really good. (Student 4)

Even though the students talk about the situation as 'forced', the notion is positive, and it appears that some students are relieved that there is 'someone deciding the groups'.

While the project work and general design of the Elsys GK course play an important role in the socialisation process and community building, the students explicitly highlight a kick-off trip at the beginning of the first semester. This trip plays a significant role, as it changes the learning environment and boundary conditions for student-teacher interactions. By moving out of classical learning environments at the university, expectations and associations change and students experience that they can interact with their teachers in a more informal way. The students value the possibility to talk to the teachers in a safe and relaxed environment and point out that this make their start at the university feel easier and less dangerous:

> In the beginning, we had a trip to Munkholmen and all the professors, all the lecturers and engineers from the programme joined. […] We sat in groups on the grass and talked together. This made it a little bit less dangerous to start at university. Also, when we sat to eat, there was a professor at each table, so we could talk a little. (Student 2)

In the interviews, the students described that it is this type of disciplinary socialisation into a community of current and becoming professionals is an important factor for them, rather than participating in more general social activities. The students pointed out that not all of them feel comfortable or want to participate in social activities organised outside the disciplinary context of their study programme. Some students expressed that the community they found within Elsys was enough for them:

> It has been very nice to get this community in the Elsys programme. I'm not very active in the student association and do not enjoy social happenings very much, so I have not gotten to know a lot of other students, but the Elsys community is enough for me. (Student 2)

The disciplinary socialisation process is further strengthened, as the students start to see people within the community as role models. The students emphasise the importance of teachers connecting concepts to authentic engineering tasks and how the multifaceted interactions with the teachers help them to identify themselves with the community:

> Because [the teachers] have engineering degrees and they know what engineering actually is. They always draw parallels and make comments to what it is in the engineering world. I think this helps very much. And to feel that there is a community and something to identify yourself with. That we are going to be engineers and that [the teachers] are with us. (Student 1)

While many students do not reflect upon that their teachers are academics and not necessarily practicing engineers, some students do point out the important role that guest lectures from industry play in the socialisation process. They highly value the possibility to listen to and interact with practicing engineers and to learn more about how engineering work looks outside of academia:

> Today's guest, I think it's been what I've been looking forward to most on Wednesdays because you can see how things are at different workplaces. [At the university] you can see professors and so on. But many of us want to go to work outside academia and here we can see what professional engineers are doing. (Student 5)

Overall, the students emphasise how the first semester in the Elsys programme contributes to their socialisation process into a community and that this is something that they feel is important and valuable for them.

4.2. Curriculum integration

The second theme that emerged from the interviews as important for the students is how the Elsys GK course contributes to integrate different aspects of the curriculum during the first semester of the

Elsys study programme. One central activity in the Elsys GK course are *Cross-Talk* sessions. In these sessions, teachers connect topics in the Elsys GK to the other courses that students take in parallel. The interviewed students report that this really helps them to see how different ideas, theories, and concepts can be used and the practical implications associated with them:

> The teachers are very good at the Cross-Talk sessions. They help you to see that "OK you have had that in the circuit theory and this in math. Then we can use these two things to do this". Even if there is nothing we can do immediately, it shows at least what we have learned will be needed later … It becomes more meaningful. So, I think the Elsys GK course is very good to connect the entire programme together as a whole. Because everyone has math and a couple of programmes have circuit theory. But in Elsys [the teachers] show exactly what you can use it for. I think that is very good. (Student 2)

In this way, the Elsys GK course can help students to situate theory and connect it to practice by showing concrete examples that they more easily can relate to. As the students point out, this also helps them to differentiate their own study programme from other programmes and contributes to the socialisation presented before.

By connecting theory and practice and integrating aspects of the entire study programme, the students also experience that the course helps them to gain a better understanding of how the different courses contribute to the Elsys study programme, as well as see more clearly the relevance of what they are learning:

> At the beginning of each Wednesday [the teachers] tend to go through what we are doing in the other courses and show how it is related to the Elsys GK course. So, it helps me to gain an insight into why we need all the other courses and see that it is useful to what we will learn in the future. (Student 3)

The students also talk about how seeing the relevance and usefulness of the different ideas, concepts, and theories help them with their motivation. On a more general level, the Elsys GK course connects many different elements together and the students feel that this helps them in their motivation towards becoming engineers:

> What I might feel is that this course really helps me to be motivated to become an engineer. […] You see that the theory you learn is very useful in practice. And the course is in a way a link between all the other subjects. There is a circuit technology course, a programming course, and then you have the Elsys GK course that just ties everything together. And that's awesome. (Student 1)

In addition, some students mentioned how the positive experiences and the satisfaction from working with the project helps them with their motivation not only for the Elsys GK course, but also have cross-motivational effects for their other courses:

> I think it has been fun working on the project and really the whole course I think was awesome. And it has helped a lot with my motivation to work in this course and the other courses actually. (Student 3)

Another activity that the students highlight as motivating is today's guest, who couples the study programme to relevant industries and exemplifies a selection of possible career paths. While some students are motivated from a wish to work in a certain field, other students do not have ready formed career goals when starting at university, as some students report, today's guest can help them in the formation process:

> I want to work with medical equipment. That was something I didn't know before I came here, it was something I realised due to today's guest. Because the first day there was a lady who works here […] She had a PhD in bruises and had designed a machine that could register arthritis. […] That's the things I find interesting, when you see something else than the tiny thing we are learning about here. (Student 5)

Through the Elsys GK course and the other courses in the engineering ladder the students are allowed to get to know their study programme. The study trips, today's guests, cross-talk sessions and innovation project also help to situate the programme beyond the academic context and build strong connections to potential work places. This helps students to create an idea about themselves as electrical engineers and how the study programme and courses are relevant to their future career:

> I like that you've got this engineering ladder that lets you have introduction courses for the study programme you have chosen. Because then you figure out: "Is this where I want to be? Is this that I want to work with?" (Student 4)

However, some students also realise that their chosen study programme does not lead to the possibilities they envisioned for themselves, thereby motivating them to switch study programmes.

One student explained that due to today's guest, he could see what future potential job options might be and found none of these particularly interesting, but he was grateful for the opportunity to discover this early on:

> Then I saw that almost everyone that has finished [Elsys] works with programming or makes computer chips. And I don't want to do that. I saw where they ended up and that didn't exactly catch my interest. And that made me realise what I wanted to do and that was very good. […] It is very good that you see what you are doing, what you will become. That you don't get surprised when you are finished. (Student 4)

Overall, the students experiencing that the Elsys GK course, especially through the Cross Talk sessions, strongly couples together the entire Elsys curriculum and greatly helps them to see the relevance and usefulness of different concepts and theories. For the students, it is critical that the teachers help them to see the connection between different parts and support them in their personal development of a more holistic view on the field, which the students describe as important for their motivation.

4.3. Peer-learning

The third theme that emerged from the interviews was how students experience to work together in groups in a project-based course. While somewhat experienced with group work from high school, the innovation project offers freedoms and responsibilities that few students have experienced before. The students are curious about the group work in the Elsys GK and hope that it will help them to develop important teamwork skills and competencies:

> Yes, it is exciting, because I thought I had never been good at group work. Just because I like to work quickly, I like to work a lot, and I like to work my own way. So, it was interesting for me to see, I saw that there was emphasis put on working in groups and teams. So, there was expectations both on me and on the course. I hoped for a large personal development there. (Student 2)

As many students have limited experience with this form of project work, they report that they gain valuable experience in group and project work. They state that they have realised the importance of making plans, organising a project, and having meeting points where groups can share experience and knowledge, as well as the importance of making decisions that are supported by all group members, and utilising everyone's strengths in a group with different pre-knowledge:

> I will take with me how you make plans when working as a group […] setting the group to cooperate and taking decisions that everyone can get behind. And trying to make use of all the resources in the group. […] The challenges we have had with differences in skill levels, and trying to achieve [something], that I will take with me. (Student 4)

The differences in skill levels and pre-knowledge between students appear to be significant to students' experiences and central in how they perceive each other. In the Elsys study programme, students are required to have taken courses in mathematics and physics in high school, but do not need to have knowledge within computer programming or electronic circuits, which means that they will come with very different entry points with respect to these fields.

A goal of organising the students in groups where students with and without technical pre-knowledge and experience need to work together is to enable peer learning. For some groups this works well, and students enjoy working within the groups and feel that they can learn a lot from each other:

> It is fun to work with others. Creates better work ethics. It's more fun when you sit and work on something you want to work on, than sitting and working all by yourself. So, there is a lot to learn from others. They might have a might have a smarter solution to something you have been trying to figure out. (Student 3)

> Yes, it is important that those who know it best or those who have worked with it before get the others up [to a higher level]. And that is how it was, so that was very good. (Student 4)

The freedom in the innovation project enables the groups to exploit their perceived differences, which is apparent through the way the groups chose to organise the project. A possible consequence of the perceived differences in technical pre-knowledge is that each group member chose to take on tasks that they feel match their level of relative experience, where the less experienced students take less technical aspects related to the innovation project such as exterior design and documentation:

> I noticed that the others in the group that didn't have that much experience, two girls. They took, they would like to do the design. Things like the design of the robot, and planning things like that. The report and such things. I did the poster, I think design is very fun. And then, there was three guys in my group that had a significant amount of experience with programming from before. They took care of the motors and how the robot should drive. […] But I think everyone got something they wanted to work on. (Student 5)

This, in turn, might result in an allocation of tasks where the person who has experience in a field relevant to the project takes responsibility of that subproject and leaves the other tasks to the other project members which can limit the degree of peer learning within the group:

> Often, the one who knows robots does that, and then the others do the other tasks that must be done. They take responsibility for the other tasks because they don't know as much. […] But that makes it a bit more difficult to get into that with the robot and try to learn programming and Arduino and things like that. (Student 4)

As stated by the students and observed by the faculty, skills within programming is the largest differentiator between the students. As a result of the projects being microcontroller based, programming is central to the functionality of the resulting prototypes. This means that students with previous programming knowledge can achieve results quicker than students with less pre-knowledge.

In the utmost consequence, the group organises itself in such a way where the students with the programming skills do the majority of the work, thereby gaining the most from the project work and creating a larger divide between the students:

> Those who know a lot from before does everything and those who don't know much get left behind. (Student 1)

Problematising this type of group organisation and potential to learn from each other during the interviews revealed that the students experience the framing of the innovation project to create limitations for peer learning. The students, regardless of their own level of pre-knowledge, explained that in an environment where the focus is on realising a prototype before the end of the semester, educating the weaker students is not a priority:

> It's not going to work when you have eight weeks to make a product. So, then you can't, you don't have time to simultaneously teach those who don't know [programming], right. You just have to get it done. (Student 1)

The students' focus seems to be on fulfilling the task and completing the project, rather than learning from each other. Overall, students report issues with regards to differences in the level of previous knowledge as highly relevant to their experience of the course and the degree of learning gained.

There is a risk of reduced peer-learning within the groups due to a strong project focus and desire to build a functioning prototype. At the same time, students also state that there is valuable experience to be gained from what initially can appear as a disadvantageous situation, though the benefits gained is dependent on the specific group.

5. Discussion

In this article, we have focused on how a first semester project-based course influences some important aspects of students' university experiences. Our findings highlight some benefits and challenges associated with PBL and illustrate possibilities for change within existing study programmes. More specifically, we have, through the interviews with the students, explored the socialisation of students as participants at the university and future professionals, a possible approach for curriculum integration, and students' experiences of working together in teams. Central to all three is how the Elsys GK supports students to build relationships with other students, as well as with faculty members and practicing engineers.

5.1. Student-student relations

From the interviews, it appears that the Elsys GK creates multiple opportunities for low stake social interactions, and in particular shows how a first-year team project can enable socialisation amongst students. It is through the framework of the project that interactions are stimulated and organised. Furthermore, the introduction of group laboratories and fieldtrips provide additional arenas for students to interact with each other. In order to give students, the chance to get to know a number of different peers during their first semester, group compositions are changed between the different activities. In general, these faculty-initiated interactions between students are experienced as something positive and helpful to overcome initial reservations and anxieties, when entering the new context of the university.

Opportunities to get to know fellow students are crucial for first year students, as the need to belong and the ability to create social bonds are central for humans (Baumeister and Leary 1995), and it has been found that quality relationships are important for motivation, wellbeing, and educational performance (Bergin and Bergin 2009). Though most studies of wellbeing and educational performance have focused on secondary education, it has been shown that wellbeing also correlates positively with performance at the university level (Yu, Shek, and Zhu 2018). In addition, socialisation is also linked to attrition (Terenzini and Pascarella 1977), and other studies have shown that personal contact amongst students and between students and faculty can lead to lower attrition rate (Daempfle 2003).

By providing first year students with multiple possibilities to interact with each other and build new relationships, the Elsys GK tries to actively contribute to the socialisation process at the university. The aim is that each student can acquire a significant number of acquaintances, lowering the degree of social separation within the course, and thus create a stronger community within the study programme (Furlong and Cartmel 2009). As highlighted by the students, this community fills an important function in large courses at a mass university, as it means that students will see familiar faces and are more likely to feel that they belong (Tinto and Goodsell 1994). We argue that the disciplinary socialisation process is an important element in first year engineering programmes and a part of the responsibility of the faculty. From the interviews with the students, it is clear that they want activities that blend engineering and socialisation, rather than social activities that are disconnected from the programme.

Beyond getting to know each other, the project also supports students to experience and reflect upon working in teams. The students' responses indicate that the non-technical challenges associated with completing a project can stimulate reflection on project organisation, leadership, and group dynamics. In this way, the project provides an important opportunity for students to experiment with one of the central working modes – collaboration – in the programme and engineering in general (De Graaf and Kolmos 2003; Crawley et al. 2007). The ability to collaborate is one of the most sought-after skills in the workplace (Dym et al. 2005), commonly reported as an outcome of PBL (Kumar and Hsiao 2007), (Musa et al. 2012), and is a central intended learning outcome at the programme level of the Elsys study programme. The students value the opportunity to be exposed to teamwork directly from the start and perceive learning about teamwork and group dynamics as a central goal of the Elsys GK. This approach also sets the tone for the entire programme and emphasises the importance of collaboration and peer-learning, either in organised forms like during the first semester or in more self-defined forms in later semesters.

One central challenge regarding peer-learning and group dynamics that emerges from the empirical material is associated with differences in pre-knowledge about programming. While differences in experience and pre-knowledge are recognised by nearly all groups as influencing their teamwork and shaping the group dynamics, approaches to handle the associated challenges differ significantly between groups. Some groups use collaborative strategies to make an effort to reduce the knowledge gap, whereas other groups view differences as a strength that helps them to find better solutions through discussions of various perspectives. By acknowledging differences as a strength, these groups move beyond the assumption that everyone needs to be able to do the same work and rather adopt a collaborative strategy where group members have different tasks to fulfil the project goal. However, there is a fine line between acknowledging differences and working together through discussions and assigning tasks based on perceived technical skill, where the students with less pre-knowledge are either given simpler tasks or no tasks. In the second case, the group does not work collaboratively on the project any longer and there is a clear divide within the group. This is a challenging situation for students and Mabley (Mabley, Ventura-Medina, and Anderson 2020) showed in their empirical study on group problem solving strategies that students have a tendency to adopt relatively rigid structures and find it often difficult to move beyond what is familiar to them. With this in mind, facilitation of group dynamics is a key element in PBL and it is important that faculty and student assistants can help students to become aware, reflect upon, and work with the underlying processes (Kolmos et al. 2008).

While we argue that pedagogical training for student assistants and team teaching creates a good foundation to facilitate group processes, we see less peer-learning than aimed for and it remains an important area for future development to better understand underlying motivations that lead students to adopt different strategies, as well as improve scaffolding strategies that stimulate peer-learning as an important part of teamwork.

One element that the students do point out as strongly influential for their teamwork is the project task itself. The pressure to complete the project and have a working prototype at the end moves the focus away from peer-learning and supporting each other towards finishing the project. The interviews point also towards a structural problem with the projects. Until now, all projects were based on microcontrollers and the programming of the controller emerged as a central critical element, which has limited the ability for students to learn truly interdependent from each other in the groups.

Furthermore, the word 'design' appears to be used mainly with regards to aesthetic and other exterior aspects of the prototype by the students. Such a limited view of the concept of design, where the strategic, practical, and cognitive processes of the development of technical solutions is omitted, reveals a belief that the challenge behind innovations is mainly technological. This view of design artificially narrows the scope of an engineer's job and limits the cognitive room available when the students encouraged to think as engineers in a project like this. To overcome this limitation, Dym (Dym et al. 2005) suggested to introduce a more encompassing view of design based work. By including simple methodologies for understanding user needs and design processes, it would be possible to utilise a wider array of the students' pre-knowledge and thereby bringing the focus away from programming skills.

5.2. Student–faculty and student-engineer relations

From the interviews with the students, student-student relations emerged as central in the Elsys GK and were emphasised throughout. In addition, the students also point out how their interactions with faculty members and practicing engineers have influenced their learning experience and socialisation process. The way relationships between students and faculty, as well as students and practicing engineers are formed is little researched in the engineering education field (Hagenauer and Volet 2014). The students' responses presented in this study show how interactions in a relaxed non-academic environment can strengthen what Hagenauer and Volet (Hagenauer and Volet 2014) term the affective dimension of the student teacher relationship, the bond between students and teachers that forms the basis of positive relationships.

In connection with this, learning environments play an important role, as they create possibilities for interactions in different ways, as well as shape expectations and associations (Choi and Hannafin 1995). It is through variations in learning environments that traditional hierarchies and relations can be opened up and opportunities for new interactions can be explored (Wallin and Aarsand 2019). The students express that the field trips are important for them, as they experience that the teachers are more approachable and it is easier to engage in discussions. During the project work, the students are in an open space dedicated for group work, without the hierarchical structure of the auditorium, with the goal of facilitating more interaction between students, student assistants, and faculty.

One important teaching approach that teachers use in the Elsys GK is modelling of engineering thinking (Collins, Brown, and Holum 1991; Wedelin and Adawi 2014). While this is used throughout, it is particular apparent in the Cross-Talk sessions that the students experience as both important and motivational. From the interviews, it appears as Cross-Talk sessions position the Elsys GK as the defining course of the study programme, as opposed to courses such as mathematics that are common to several programmes.

Through this activity, the students are given the possibility to see how the courses they are enrolled in are important to their chosen field of study. Therefore, by implementing Cross-Talk, the faculty teaching the Elsys GK can motivate students for other courses, where they normally have very limited influence. This is an important aspect, as it helps to mediate a common problem in many first-year engineering curriculums: the lack of alignment and interaction on the programme level (Heitmann 2005). While it would be desirable to work from a holistic perspective and ensure alignment between courses on the programme level, it is often challenging and changes require larger shared initiatives, as many general engineering science introductory courses are part of several programmes and given by different departments. Cross-talk sessions offer an alternative by focusing on what can be done within the department that is responsible for the programme and within the central course of the first semester. From the empirical material, it appears that this approach can alleviate some of the lack of alignment for the students, who report that it helps them to get a better overview of the programme and experience how courses are connected to each other.

It is through these small adjustments and a change in mindset from faculty members and student assistants that the Elsys GK emphasises participation and student-centred learning beyond transmission of factual knowledge (Delaney et al. 2010). This shift has implications that go well beyond the first semester and can help to frame relations that allow students to continue to engage with faculty, ask questions, and participate in disciplinary discussions throughout the study programme.

Looking even further, the disciplinary socialisation process in the Elsys GK also builds a strong connection with industry and practicing engineers. While teachers can model engineering thinking, scaffold students' learning of engineering, and sometimes might be seen as engineering role models by the students, it is important to recognise that the majority of faculty members have mainly research experience and oftentimes lack first-hand engineering experience within industry settings. This is a general limitation in many engineering programmes and in contrast to for example medical education, where many teachers are also practitioners in the field (Dym et al. 2005). To overcome this limitation, professional socialisation in engineering needs to be a collaboration between the education institution, graduates, and industry (Keltikangas and Martinsuo 2009).

The Elsys GK actively establish links between the university, industry and other stakeholders through the projects and today's guest. Today's guest gives the opportunity to provide the students a more nuanced and wider view of their prospective futures. From the students' point of view, the industry representatives in today's guest appear more authentic and provide additional perspectives on what engineering can be. Providing multiple perspectives on what engineering might be is important for the students, in order to find their own understanding, contemplate their future as professional engineers, and connect the different elements of the curriculum towards an integrated view of engineering (Edward and Middleton 2001). A challenge for first year courses, due to the advanced nature of modern engineering, is that students can only be given a limited insight into what they can do with the competence they will have gained at graduation.

From the interviews, we see that today's guest can help to stimulate long-term motivation in the Elsys study programme. A study programme that traditionally has been dominated by a focus on fundamental engineering science knowledge and that has struggled with a low number of first-year students understanding and seeing the relevance of the different concepts and theories (Larsen and Lundheim 2014). On a more general level, the study barometer also indicates how the programme has been improved over time and in comparison to other programmes in Norway.

Interestingly, the emerging understanding of what engineering might be and how engineers work can also create the motivation to switch study programmes early. This is not necessarily desirable from a programme perspective, some of the initiatives described here have reduction of attrition as objectives, as both socialisation between students and personal contact between students and faculty have been linked to lower attrition rates (Terenzini and Pascarella 1977; Daempfle 2003). However, it is important for the individual students that choose to switch direction. We argue that it is better that students are put into a position to make an informed decision and discover early on that electrical engineering might not be for them, than for them to discover it much later into the programme. It allows students to switch to other programmes at a time where there are no or only minor personal and financial penalties (Gomme and Gilbert 1984). Still, the most beneficial strategy for both the study programme and the student would be to more accurately inform these students of the prospects of an engineer within this field before they apply.

6. Summary and outlook

In this article, we have presented a way of integrating PBL in combination with other pedagogical approaches into the first semester of an electrical engineering programme without the need to change existing structures of the programme. From the interviews with the students, three themes emerged as central for the students' experiences during the first semester: socialisation, curriculum integration, and peer-learning. We argue, based on the data, our own experiences, and in the light of the literature, that the course contributes to the development of a disciplinary community, both with respect to the community of students participating in the programme and the community of engineers that they are joining through their education.

Through interactions with faculty, today's guest, and project-based learning, the students report that they are introduced into a community of engineers, enabling them to develop an identity as future experts in their field. The students can through these activities develop a sense of belonging to a community within the university, but also to a disciplinary community. We argue that these measures can create long-term motivation and show how the different courses of the programme are integrated without the need to change courses outside of the practitioner's control. The students report that their entry into university is made easier through these faculty organised activities and that they create an arena for learning important engineering and social skills. However, this study also shows that there are large variations in the degree of peer learning between the groups. Based on the ideas presented here, and supported by the empirical findings, we provide a case example of how targeted modifications can have programme wide effects, which we hope can serve as a starting point for other educators.

In the future, we wish to explore the relationship between peer learning, pre-knowledge and group dynamics in the context of PBL in more depth, both from a research and practice perspective. Two important direction for future research that we envision are, 1) multi-case studies and 2) longitudinal studies. Using the findings from this research as a starting point, it will be interesting to compare different first year courses, either across cases from various engineering programmes at one university or from electrical engineering programmes at different universities and cultural contexts. In addition, a focus on longitudinal studies that follow students through entire programmes will be important to explore engineering identity development in more detail and from a holistic programme perspective.

Note

1. The acronym PBL is used both for project-based and problem-based learning. Problem-based learning emphasises the activity the students engage in (solving problems), whereas the name project-based learning more highlights the scope and format of the learning activity (students work on projects) (van Barneveld and Strobel 2009).

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