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WIP: An Exploration of the Development of Engineering Students' Engineering Identity in PBL Team Setting

Introduction

Engineering identity is believed as a significant indicator for engineering students' professional persistence and competence development [1][2]. Engineering identity could be understood as the awareness of the needed qualities of engineers [3], the sense of belonging in engineering groups [4], and self-identification as future engineers [5]. Recent researches have explored components and measurement of engineering identity, as well as diverse perspectives related to engineering identity, such as gender and ethnicity, from the perspective of individuals or individual learning processes [6][7][8]. However, according to Wenger's [11] communities of practice theory, identity is built and developed constantly in the processes of negotiating the meaning of experience and interacting with others in social communities. In engineering education, engineering identity is not just an individual concept but also the formation for groups of professionals, especially among engineers who share values as parts of collaboration in developing the technologies [9][10]. Although teamwork and collaborative learning may be employed as part of the course delivery methods in some studies, prior studies mainly focused on students' engineering identity development from the individual perspective [5][6][12]. The role of teamwork on students' engineering identity development has not been sufficiently evidenced.

For better understanding of how students' engineering identity could be constructed through teamwork, problem and project-based learning (PBL) was chosen as a learning environment. As one of the core active learning methods, PBL has been widely adopted in engineering education to develop students' comprehensive skills and professional competences [13]. By exposing students to complex, real-world and ill-structured problems in collaborative learning environment, PBL enables students not only to learn professional knowledge and engineering skills, but also to gain the membership in an engineering community and develop their sense of belongings as future engineers [2][13][14]. With positive peer perspectives on the values of professional competences provided by team members, students could reach higher levels of engineering identity and better learning outcomes in PBL environment [15]. Compared with traditional learning methods, PBL significantly increased engineering students' self-efficacy and enable students to create engineering identity via working in engineering project teams [16]. However, although prior research pointed out that PBL has positive influence on students' engineering identity development, it is still unclear that in which way the teamwork in PBL enables the formation of engineering identity. Therefore, this study aims to explore how teamwork contributes to the formation of engineering identity. The research question formulated in this study is: In which way teamwork may enable the development of engineering identity in PBL context, seeing from students' perspectives?

This study adopts Godwin's [17] model of engineering identity as the theoretical framework, with three dimensions of performance, recognition and interests. Performance refers to students' belief and ability to achieve learning goals and understand engineering content. Recognition means that students could get recognition from peer, parents or teachers as being good engineering students. The last components, interest means students' desire and curiosity to explore professional fields, which motivate students to learn knowledge and skills. Godwin's model mainly focused on the individual learning processes. For expanding the model to a collaborative level and catching catch the missing link between engineering identity and teamwork, we use this model to have a structed understanding and identification of the dimensions of engineering identity. Instead of focusing on individual learning processes, we concentrate on how engineering students develop their interest, improve performance, and gain recognition through interaction and negotiation the meanings with their team members, with the angle of the communities of practice theory. Findings could inspire the

improvement of students' teamwork and learning experience, optimizing PBL curriculum design and incorporating effective learning activities for students' engineering identity development.

Method

This is a pilot study to optimize the methodology and research design for a continuous exploration of students' engineering development through teamwork in PBL. Methodologically, a qualitative method is used in this study. Teamwork observation was conducted for an initial understanding of students' teamwork experiences. Main source of qualitative data in this study was collected through semi-structured interviews. With the guidance of Godwin's model of engineering identity, an interview protocol with those three dimensions was designed, tested and revised with three rounds. Part of the final interview questions is shown below (Table 1). Data were collected through semi-structured focus group and individual interviews since students from one group would like to have interview together. In this pilot study, using both focus group and individual interviews enables researchers to compare the effectiveness of two data-collecting methods, and optimize the research design in the next step. Focus group interviews allow us to explore how students construct the meaning of engineering identity together, inspire each other, and share the benefits of working in groups and learning together, while more sensitive questions such as conflicts and difficulties in students' teamwork experiences are asked in individual interviews.

Table 1 Sample questions of the interview protocol

Descriptive questions
Could you describe briefly how you collaborate with your team members to finish the projects?
Questions in the dimension of performance
What do you learn from this PBL and teamwork experience? How do you assess your team's performance in completing the project?
Questions in the dimension of recognition
In which ways you consider yourself as a future engineer? In which ways your current study has helped you develop such as sense of feeling as an engineer? Have you got any comments from people around you (family, friends, teachers) as an engineering students or future engineer? If so, could you elaborate it?
Questions in the dimension of interests
What makes engineering interesting for you? In which ways do you find teamwork may make the engineering interesting for you?

Table 2 The basic information of participants

Name	Gender	Semester	Subjects	Interview Types
Dora	Female	7th semester	Energy engineering	Group interview
Karo	Male	7th semester	Energy engineering	Group interview
Diego	Male	7th semester	Energy engineering	Group interview
Ray	Male	5th semester	Electronic engineering	Individual interview
Jesper	Male	5th semester	Civil engineering	Individual interview
Mike	Male	5th semester	Electronic engineering	Individual interview
Ida	Female	7th semester	Energy engineering	Individual interview
Regina	Female	7th semester	Energy engineering	Individual interview
Soren	Male	7th semester	Computer engineering	Individual interview

In this pilot study, purposeful sampling was employed in recruiting undergraduate engineering students in their fifth- or seventh- semester of PBL study as interviewees, since junior and senior students were reported having higher level of engineering identity because of more work-related and PBL experiences to work as real engineers [14]. We sent invitations via emails in three PBL courses each with 20-30 students from different engineering subjects to finish interdisciplinary projects in a Danish university. Among all invitations, nine students responded with their preferred interview methods, three of which were from one project team and selected the focus group interview. All

interviews were conducted at the end of the semester, so students enabled to reflect on their full range of projects. We conducted one focus group interview with three students from one team in energy engineering and six individual interviews with students from energy engineering, civil engineering, and computer engineering (Table 2). Since this is a work-in-progress, we reported our primary findings based on the group interview and six individual interviews. In our next step, for triangulation and enrich data with different aspects of students' learning experiences in PBL, we planned to conduct focus group interviews firstly, and then invite same students from focus group interviews to participant in individual interviews.

In the data analysis process, all interviews involved in this study were transcribed and reviewed carefully. For the sake of privacy protection, pseudonyms are used in the transcripts for all interviewees. The codebook was built upon the analysis of three information-rich transcripts, which constitutes a relatively stable frame for coding [18]. Aimed to build a structure codebook, the three initial categories proposed in Godwin's model were defined as prior codes in the first step. Then open-coding and thematic analysis methods were used to identify both theory-driven and bottom-up codes, which enables us to come up with new characteristics of identity development in a team setting. In qualitative research, researchers are regarded as "the primary instrument for data collection and data analysis" and should be "responsive and adaptive" [19, p.5]. In this study, the researcher with prior PBL experience and basic pedagogical knowledge was involvedly in daily journaling and self-monitoring in conducting the data collection and analyses to be aware of any potential bias and influences from prior experiences. During these processes, research group discussion with two experienced exports in engineering education and PBL research were conducted frequently as auditing procedures. In order to enhance the inter-coder reliability, a graduate student with rich qualitative research experience, majoring in higher education, was invited as the external coder to code one part of the transcripts and discuss with the leader coder, resulting in agreement of 86.3%. Codes were modified and refined for two rounds through those auditing processes, and then a revised codebook was formed and used for data analysis.

Findings

In this section, we report how teamwork in PBL contributes students' engineering identity development in the dimensions of performance, recognition and interests. Parts of our preliminary findings are presented as follows.

Performance

Learn and apply knowledge in a better way

Among all nine students, seven students mentioned that teamwork in PBL enabled them easier to learn knowledge because of help and support from each other. Learning is not a lonely process, and in PBL, students had more opportunities to explore knowledge together and conduct self-directed learning, which could enhance their ownership of knowledge. When encountering with issues together, students could get more insights or different angels on a problem from team members and makes them realize the importance of this working mode for engineers. As what Soren said, teamwork is important for engineers because it can provide them a bigger picture of the entire project and help them move forwards faster and further.

> *"Teamwork is the necessity because **you don't get very far on your own**. If I had to do this entire project on my own, it would take a long time. So, teamwork makes everything more interesting because you can do a lot more and see you can move up to a group soon to see a grander scale for the project. So, you **get a bigger picture of everything**, and then you also have your knowledge because you **get knowledge from what other people** are doing. You can also see what other people have done. So, you're not one-person learning, you are team learning. **Everyone shares the knowledge,** so you can **move faster and further**. It's **important for engineers**."* —— Soren

Develop transferable skills as future engineers

In this study, students reported their improvement of transferable skills through teamwork in PBL, including the communication skill, presentation skill, time management skill, and problem-solving skill etc. On one hand, PBL provided them a simulation to work as real engineers, which made them realize why transferable skills are important for engineers. On the other hand, through those processes of identifying the core problems, learning by themselves, dealing with conflicts and disagreements, and presenting their team products, students' transferable skills were trained and developed.

> *"Unless you're a theoretical scientist, you will **need to cooperate with someone else**… I think that this's very **important for an engineer and for many working people**. **As an engineer, having to apply the knowledge onto the real world and onto something physical, that's always more aspects to communication**, because it's impossible to know everything yourself." —— Mike*

> *"(What I learn is) more about organizing, **organizing our time and the tasks**. So, I guess it was also **very important for engineers**. In the beginning we sort of listed down all of the tasks that we need to do, in order to make the project successful. And we need to try to determine how much time we need for each task. Then, we tried following the schedule. But it's **important to be very patient**, because every time you try to do something, it's one hundred percent that it's not working at the first try. It's a rule, not even the second or the third, maybe the sixth and seventh. So, you have to be very patient. So, I think that was **a good experience to work in this way, the way how engineers work**." —— Ida*

As what Mike said, this teamwork experience enhanced his awareness of the importance of communication skills for engineers. In order to apply theoretical knowledge into practice, engineers need communicate skills to understand the market's need, collaborate with specialists in other specific fields, and promote their products for clients. In Ida's case, PBL enabled her to experience a real-world project and trained her abilities of project management, including task division, time control, considering possible failure and so on, which can help her better prepare for future engineering jobs.

Recognition

Develop self-recognition via recognition from others

Through interaction with team members and supervisors in the projects, students could get feedback and recognitions from people around them, which inspired students' self-recognition and helped them know more about themselves, just as Ray's quote below. In his case, he identified PBL as a pathway to build confidence and get the sense of achievement because what he did in the project was recognized and praised by his supervisors. Recognition from others enthused his interests in engineering projects.

> *"My parents and teachers have high expectation on me, to be a successful engineer in the future, which pushes me to move forward. **PBL is a good way to build confidence and gain recognitions** because you're really creating something. When you finish a project, no matter how hard the process is, you will have **a great sense of achievement**. And we also **got very positive feedback from our supervisors, so I felt encouraged and can't wait to the next project**." —— Ray*

Better understand the responsibilities of engineers

Based on qualitative data, four students pointed out that they had a deeper understanding of the responsibilities of engineers. In their opinions, engineer is the one who solves real-life problems and create new things, which needs interdisciplinary knowledge and skills in the fields of engineering, social science, business and management. At the same time, engineers need to have the sense of duty for the society, and consider the aspects of cost, clients' needs, engineering ethics and influence on the environment when they find a solution or design a product in their project. As Dora said, the project experience made her realize the responsibilities of engineers are not limited in engineering,

but also involve science, social science and humanity fields. It's necessary for engineers to prepare themselves with interdisciplinary skills and learn to look at things from various perspectives.

> *"Through the project, I realized* ***that being an engineer means being good at math, good at physics, chemistry, electricity, any part of the human life****. I think you cannot ignore these and say: I'm a mechanical engineer, and I don't care about the environment. You always have to take, for example, that part in your projects and everything, also the economical and humanity part. So,* ***if you want to be a great engineer, you really need to consider a lot****." —— Dora*

Interests

Share new interests with team members

As reported by five interviewees, they chose engineering subjects because they were interested in or good at mathematics and science, but they preferred to link theories to reality instead of totally focusing on theoretical work. PBL provided them the chance to apply theoretical knowledge into practice via solving real-life, open-ended, and interdisciplinary problems, which was also a chance for them to develop new interests. Among all nine students, six students expressed that they enjoyed solving problems and explore un-known things with team members. In PBL processes, discussing project directions and sharing interests with others might open students' horizon and help them keep curious and enthusiasm of exploring. In Karo's case, at the beginning, the topics might be interesting for other group members but not for him, however, with more group discussion and communication, his curiosity was inspired, and he found the joy of exploring the unknown problem.

> *"One benefit of teamwork is the chance to* ***develop new interest****. At first, I had no idea with this problem, but when other members discussed it and asked teachers, I realized I don't know the answer either. The problem is worthy to explore. It's* ***good and interesting to try and learn new things****." —— Karo*

Identify future career directions or job types

As mentioned before, PBL provides a simulation of real engineers' work, which could influence students' decisions of future career directions. As reported by Ida, she got work-related experience and developed interests in working as a project team through PBL. She found her future career direction and she was on the right way to become an engineer by equipping herself with professional competences through PBL and professional training.

> *"I think I somehow get* ***more relevant experience****, working in a group than I would get if I was working and learning alone. I'm pretty sure that in the future, at a future job, I won't be working completely alone and will work in teams, just like we are now. So,* ***that's a good imitation of that, and enhances my interests in this kind of jobs****. Working with others in this university is more* ***like working as a real engineer****. It did give us that feeling because we're working on a project where solving a problem by ourselves, and in the end, we're going to do something that has a specific function. That's a good feeling. I'm* ***on my way to become an engineer****, and I feel like I'm* ***acquiring some skills that are necessary to be a successful engineer****." —— Ida*

However, not all students enjoyed the teamwork experience. For some students, these teamwork experiences made them prefer jobs with less chance of teamwork. Among all participants, one female student reported her inadaptation in teamwork. In Regina's case, although experiencing PBL and teamwork was valuable for her, she still tended to choose those theoretical jobs and work alone. In teamwork, members should be sensitive of others' feeling and need good communication skills for effective group discussion, which she was not good at. For higher level of productivity, she would like to consider future jobs with less teamwork.

> *"It's interesting to try it (teamwork). I'm happy I can learn how to work in a team. But the thing is I* ***like working alone as well****. I'm not really the best in play. I know it's not good, but that's true…*

*I'm **not good at teamwork**, and I **don't really like to speak to someone such as supervisors**… We spent too much time and **wasted time on group discussion**, and you also **need to be sensitive to others' feeling**, which made me tired. Sometimes **I would feel more productive if I work alone**. So, I will consider more theoretical jobs or working in a lab, with less teamwork." —— Regina*

Discussion

With the guidance of Godwin's [17] model of engineering identity, this work-in-progress explored how teamwork in PBL contributes students' engineering identity development, from students' perspective. In accordance with prior studies, PBL as one kind of work-related experiences could improve the development of students' engineering identity by enhancing students' interests in engineering, knowing more about engineers' work, and understanding engineers' responsibilities [14][20]. More findings about students' engineering identity development in this study are discussed in the following dimensions.

In the dimension of performance, students identified PBL as an effective pathway to apply theoretical knowledge into practice. The experiences of working as real engineers in PBL programs could shorten the gap between universities and industries by helping students better prepare for their professional careers [14]. Through teamwork, students could realize the importance and necessity of engineering competences, such as communication skill, teamwork skill, problem-solving skill, project management skill etc. Consistent with patterns identified by previous studies, in PBL context, students' transferable skills were improved via identifying core problems, constructing knowledge together, dealing with conflicts and disagreement, and presenting their work for audience [13][21].

In the dimension of recognition, students could better know themselves via recognition from others and teamwork experience in PBL. Effective teamwork could enable engineering students to create the self-categorization and the in-group membership, thereby promoting their engineering identity formation and enhancing their persistence, which was in accordance with Wenger's [11] communities of practice theory [22][23]. Positive feedback from supervisors and peers could enhance students' confidence to become engineers in the future. In addition, students were reported to have deeper understanding of the responsibilities of engineers in this study. In order to solve real-life problem, they have realized that only having engineering mindset is not enough for successful engineers, and they need to develop their interdisciplinary knowledge and skills to take more responsibilities for the society, which is accordance with the UNESCO sustainable development goals [24].

In terms of interests, teamwork was found to inspire students' new interests and help them identify future career directions. According to Lewin's [25] group dynamics theory, a team as a whole would exert pressures on individual members, influence their thoughts, identity and actions. In the processes of constructing knowledge and exploring unknown things together, with influence of team members, students could develop interests in new engineering directions they were not concerned before. However, as pointed out by prior researches, students might experience anxiety and stress, and some of them failed to integrate into their peers and to gain the membership of engineering groups in teamwork processes, which influenced their learning outcomes and persistence in engineering negatively [26][27]. In this study, one student also reported that she preferred to work alone to avoid wasting time on ineffective communication, though she was aware of benefits of teamwork. Thus, more attentions are needed to explore the reason behind those situations and to provide possible strategies for both students and engineering staff to optimize current PBL design and improve students' learning experience and outcomes.

In this pilot study, we adopted both focus group and individual interviews to collect qualitive data. Though limited data we had, we still see the difference between these two data-collecting methods based on researchers' self-reflection and data analysis. In the case of the focus group interview, students in one group could inspire each other when answering the interview questions. For example,

when they were asked more abstract questions like "in which ways you consider yourself as a future engineer?", they began to discuss their own understanding of engineering students and construct the meaning of engineers together. When it came to the topics of their task division, team roles or contributions for the team, students could add more information for others and give their recognitions or comments for peers, but none of them gave negative feedback for each other. In individual interviews, more critical answers were collected, such as conflicts between team members, issues of emotion management, dissatisfaction with team members, ineffective communication and depressed teamwork experience. Based on the differences between two interview methods, we will continue to utilize focus group and individual interviews. For triangulation, students from focus group interview will also be invited to join the individual interviews.

The study promises an overall understanding about students' engineering identity formation and development in the dimensions of recognition, performance, and interest with the perspective of teamwork. Through identifying components of engineering identity in PBL context, this study could enrich current engineering identity theories from the perspective of teamwork. Future work will optimize current research design and continue to explore the components and possible impact factors of teamwork on students' engineering identity in the dimensions of performance, recognition and interests. For the development of students' engineering identity, suggestions will be proposed for engineering staff to optimize the design of PBL curriculum and incorporate effective learning activities to improve students' teamwork experience.

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