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Work-In-Progress: Examining Engineering Students' Perception of Student Agency in Solving Complex Engineering Problem

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Summary

The general source of engineering education knowledge is content driven where engineering is considered as a process of solving problems using a reductionist approach. Once each sub-system is solved, within certain assumptions and hypotheses, they are brought back together to provide an overview of the potential solution for the problem. It promotes mechanistic thinking to solve well-structured problems with known solution paths (process) and convergent answers. Little emphasis is given to solving complex engineering problems. One approach to cultivating solving complex engineering problems is through learners/ student agency. Student agency is based on the guiding principle that students have the ability and will to influence their own lives and the world around them. The aim of this is then to investigate the role of Problem-Based Learning (PBL) as an environment setting to encourage students' agency in solving complex engineering problems. The work will incorporate existing theories in relation to students' agency.

Keywords: Student agency; problem-based learning, engineering education; complex engineering problem; problem-solving

Type of contribution: Research extended abstracts.

1 Introduction

Engineering is one of the oldest professions and is responsible for the rise of civilizations. Through engineering applications and innovations, societies have experience waves of innovations, from mechanization to steam power, and from electricity to digital networks. The current question being asked is: *what will be the next wave of innovations/challenges* and *how would 21st century engineering education transform to address these challenges*? This is a common question asked by several stakeholders, from students to engineering educators and from employers to policymakers. This was highlighted and echoed heavily by the National Academy of Engineering (2004). Several stakeholders have tried to answer this call through providing resources, improving courses, and developing innovative teaching pedagogies, Graham (2018), Johri & Olds (2014). However, looking at most engineering programs, such profound innovations in engineering education, are not obvious, and many engineering programs are still within the *classical engineering education* framework (Frei & Serugendo 2011; Kolmos et al. 2016; Zilbovicius et al. 2020).

The history of engineering education can be traced back to 1702 with the establishment of school of mining and metallurgy in Freiberg, Germany (UNESCO 2010). In France, the need for engineering education helped the development of *Ecole Nationale des Ponts et Chaussees* (1747) (UNESCO 2010). However, after the French Revolution, Napoleon influenced the development of formal schooling in engineering focusing on theoretical and military fundamentals (UNESCO 2010). This influenced the formation of other engineering schools across Europe with a focus on science and mathematics. In Britain, engineering education was primarily based on an apprenticeship in the early years of the Industrial Revolution. Due to fear of lagging behind European counterparts, the British adopted *engineering science and mathematics* in its engineering education framework (UNESCO 2010). By the end of the nineteenth century, these countries in Europe had established engineering education systems based on the French and German 'Humboldtian' model (holistic combination of research and studies) (UNESCO 2010). Unfortunately, this model was one of the contributing factors to the decline in engineering interest. This led to educators' increase interest in the problem and activity-based learning. Documented details on engineering education can be traced back to 1893 when the Society for the Promotion of Engineering Education launched the Journal of Engineering Education.

Today, in most universities, classical engineering is the evolution from the Humboldtian model with an emphasis on engineering design to bridge ties between universities and industries (Froyd et al. 2012). The general source of scholarly knowledge is textbook-driven (content-driven), where engineering is considered as a process to solve problems using a reductionist approach (Frei & Serugendo 2011). In the reductionist approach, an engineering problem is broken up into its simplest forms (sub-system, components, etc.) where each one is treated separately. Once each is solved, within certain assumptions and hypotheses, they are brought back together to provide an overview of the potential solution for the problem (Frei & Serugendo 2011). It promotes mechanistic thinking to solve *well-structured problems* with known solution paths (process) and convergent answers (Sigahi & Sznelwar 2022). Little emphasis is given to solving complex engineering problems.

Real world problems solved by engineers are never simple. Examples of such problems can be found in the National Academy of Engineering Grand Challenges (NAE 2017). Real-world problems are ill-defined, unpredictable, possess conflicting goals, consists of engineering and non-engineering constraints, multidisciplinary and possess many facets to define the problem (Sigahi & Sznelwar 2022). According to ABET 2018, "*Complex engineering problems include one or more of the following characteristics: involving wide-ranging or conflicting technical issues, having no obvious solution, addressing problems not encompassed by current standards and codes, involving diverse groups of stakeholders, including many component parts or sub-problems, involving multiple disciplines, or having significant consequences in a range of contexts*". This is total contrast with classical engineering education, which often neglects broader social, environmental, and economy issues. There is an urgent need to develop our engineering students to solve complex engineering problems. We require future engineers today.

One approach to cultivating solving of complex engineering problems is through learners/ student agency. Student agency is based on the guiding principle that students have the ability and will to influence their own lives and the world around them (Jääskelä et al. 2017; OECD 2019). Universities are heavily engaged on teaching theoretical and formal knowledge (content-based knowledge construction), but do not address the need to prepare students for professional work and complex world (Jääskelä et at. 2017). In this context, student agency is important in learning situations to offer students the possibility to participate and influence solutions (Jääskelä et al. 2017; Du et al. 2022). Student agency is a complex and dynamic system that includes the sense of agency, agentic behavior, and interaction with the environment (Du et al. 2022). In addition to this, the concept of co-agency should be emphasized. Co-agency implies relations with others such as instructors, parents, peers, etc. developing an effective learning environment (OECD 2019). The aim of this ongoing work, through a complexity theory lens (Du et al. 2022), is to conceptualize student agency in solving complex engineering problems within a Problem-Based Learning (PBL) environment.

2 Research Design

The research has two parts to it. The initial part was an exploratory research, conducted in Spring 2022 based on questionnaires developed in-house, whereas the second part will be conducted in Spring 2023 as an extension to the first part. The initial part of the study had the aim of understanding which ways students perceive their learner agency in a PBL setting. The focus is on two basic dimensions of student agency namely active participation (Lipponen & Kumpulainen 2011) and team dynamics (Edwards 2005). The questions developed for each dimension are listed in Table 1. The questionnaire used a Likert-Scale from 1 – 5, 1 being *Never* and 5 being *Always*. During this time, the delivery mode was online due to Covid-19. The course was at the sophomore level in the mechanical engineering program with the title *Introduction to Design*. This course is offered once every academic year in Spring. The course instructor had implemented PBL in this course for previous offerings. In this PBL teamwork-setting environment, an ill-structured project (complex problem) given at the beginning of the semester where students were required to use the project to organize the learning process. Each team comprised between 4-5 students. Most students in this course will have no prior PBL experience. This course typically sees around 50 students on each offering. In running the project, the Sun Model of co-agency will be adopted (OECD 2019). This model depicts eight levels of different degrees of co-agency. *Level 0* (lowest) is where the students and the instructors believe that students cannot contribute, and all initiatives and decisions will be taken by the instructor. *Level 8* (highest) is where the students initiate a project, and the decision-making is shared between the student and instructor. Since the class is at a sophomore level and due to internal academic policies, for this class a *Level 6* is adopted. The *Level 6* is where students are part of the decision-making process of a project, however the project definition and initiation is by the course instructor.

Table 1: Initial Dimensions in student agency.

Dimensions	Questions
Active Participation	• I actively participate in the assignment of roles for the team members • I clearly express my ideas • I don't feel intimidated to make mistakes working on the team
Team dynamics	• I can ask members of my team for help with my task • I am are open to discuss ideas • I feel comfortable discussing difficult issues in the team • I support other team members with the accomplishment of their tasks

After the initial study done in Spring 2022, more literature on student agency was researched to better define student agency. The literature on student agency is very discipline specific (Jääskelä et al. 2017). After much research, based on the work of (Jääskelä et al. 2017), the following domains of agency was identified for the second part of the study: (1) Individual, (2) Relation and (3) Contextual. In the *Individual* resource domain, the underlining concepts are meaning-oriented studying, self-efficacy, competence, belief and participation activity. For the *Relation* resource domain, the key concepts are equality among students, reciprocal relation between instructor and learner, peers as resource for learning and emotional atmosphere. Finally, for the *Contextual* domain, the underlining concepts are participatory pedagogy, opportunity to influence and opportunity to make choices. Here student agency deals with subjective thinking, goal oriented, autonomous and characteristics such as beliefs, feelings, thoughts and learning behavior. The second part of this study will be conducted in Spring 2023 for the same course setting. The research question being investigated here is the students' experiences and sense of agency for engaging in knowledge construction through the complex problem scenario within a PBL environment. In terms of assessing student agency in a more detail manner, validated questions (Jääskelä et al.2017), will be given to students. These questions are centered on the three resource domains described earlier (Individual resources – 19 items, Relational resource – 18 items and Contextual resource – 17 items). The questions were developed by using a 5-point Likert scale. Ten factors emerged from the study reported in (Jääskelä et al. 2017). These factors are: (a) interest and motivation, (b) self-efficacy, (c) competence belief, (d) participation activity, (e) equal treatment, (f) teacher support, (g) peer support, (h) trust, (i) opportunities to influence and (j) opportunities to make choices. Besides this, students will be interviewed randomly to allow for a mixed research approach. The interviews will help to gain better understanding of the quantitative data obtained from the questionnaire. This study will be administered in class to the students during the last week of the Spring 2023 semester. There are around 50 students registered for this course. The students have 30 minutes to fill the survey, where a pen and paper format will be adopted for the administration of this questionnaire. Students will fill the questionnaire anonymously. This will be followed by selecting randomly 20% of the students for the interview session, where each interview session will not take more than 15 minutes per student. We will use established statistical analysis such as exploratory factor (EPA), reliability test and descriptive statistics to analyze the data and to draw conclusions.

3 Preliminary Results

The initial phase of this study in Spring 2022 showed that students had some elements of student agency when working in together in solving complex design problem. The students felt confident in active participation and using peers as support. However, not much could be said about knowledge creation from this survey. It goes to show that PBL team-settings supports student agency to a certain extent, but further domains of student agency need to be explored. Table 2 shows the average response for each on this question (qualitatively). The second part of this study will commence in Spring 2023.

Table 2: Results from the exploratory research conducted in Spring 2022.

Dimension	Questions	Average Response
1	I can ask members of my team for help with my task	Frequently
2	I actively participate in the assignment of roles for the team members	Always
3	I clearly express my ideas	Frequently
4	I am open to discuss ideas	Always
5	I feel comfortable discussing difficult issues in the team	Always
6	I support other team members with the accomplishment of their tasks	Always
7	I don't feel intimidated to make mistakes working on the team	Frequently

4 Conclusion

This study is a work in progress in nature. The study is to be completed by end of Spring 2023 through a more comprehensive mixed research approach. The overall research aim of this study is to investigate the sense of agency in constructing knowledge through solving complex engineering design problems. The initial phase of the study (exploratory) looked at how PBL settings supports student agency. The results showed that students are comfortable in working in to solve the engineering problem assigned to them. However, these findings do not display sufficient information on the sense of creating knowledge in a complex problem scenario. Other dimensions of agency such as self-efficacy (effort to take up challenge), competency beliefs (understanding of course content), opportunity to influence (own studying), to name a few are required to obtain a full picture on the student self-agency in knowledge creation.

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