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Analysing Student Motivation in Challenge-Based Learning in Higher Engineering Education Using the Self-Determination Theory

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ABSTRACT

Challenge-based learning (CBL) engages students in complex, real-life challenges, promoting responsibility for their learning. Existing research has identified several factors that contribute to students' motivation in CBL environments. However, prior studies have focused primarily on cognitive and metacognitive learning functions in active learning environments in higher engineering education. Further, affective/motivational functions regulate behaviors and emotions that arise during learning and stimulate affective responses that may positively, negatively or neutrally influence students' learning process, performance, and well-being. Thus, using Self-Determination Theory (SDT), this qualitative study examines engineering students' motivation in CBL environments. Twelve Master's level students from a research-intensive university in Sweden took part in semi-structured interviews discussing their experiences during different CBL courses studies. Analysis combined inductive and deductive approaches, identifying affective/motivational functions emerging from the interviews and analysing them based on SDT concepts. The qualitative thematic analysis identified motivations that emerged such as innovation, entrepreneurship, designing learning, practical experience, real-world problem-solving, and societal contribution through sustainability, grounded by Self-determination continuum. SDT's nutritient concepts of autonomy, competence, and relatedness were satisfied through structured tasks, mastery, learning, feedback, and positive social relationships. However, problematic areas such as a lack of rationale in tasks, absence of project choice, insecurity about professional rights, lack of feedback, limited growth opportunities, and negative social relationships frustrated students' psychological needs. The study suggests practical applications to support motivational needs in higher engineering education, including regulating emotions during learning.

Keywords: Challenge-Based Learning; Self-Determination Theory; Student motivation; Higher Engineering Education; Learning; Qualitative Study

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1. Introduction

The shift toward student-centered pedagogies in higher engineering education has prompted increasing interest in active learning approaches that support not only cognitive and metacognitive development but also affective and motivational engagement. Further, Challenge-Based Learning (CBL) has emerged as a promising methodology that emphasises real-world, interdisciplinary problem-solving, collaboration with external stakeholders, and the development of self-directed learning skills [1-3]. CBL aligns closely with the goals of engineering programs outlined in national policies such as the Swedish Higher Education Ordinance [4] and the Higher Education Act [5], which stress the ability of graduates to independently address complex problems, apply advanced knowledge, and consider social and environmental sustainability.

Despite growing evidence of CBL's effectiveness in promoting critical thinking and professional competencies [6-8], research on its impact on student motivation—a key determinant of academic engagement and persistence—remains limited [9]. Motivation is often taken for granted in higher education settings, even though many students struggle to meet the demands of self-regulated learning (SRL) without adequate support [10, 11]. This is particularly salient in CBL environments, where the complexity and openness of challenges can be both empowering and overwhelming.

Self-Determination Theory (SDT) offers a well-established framework for investigating student motivation in such contexts. According to SDT, motivation is fostered when three basic psychological needs are met: autonomy, competence, and relatedness [11-14]. The social and pedagogical environment shapes these needs and influences whether learners adopt intrinsic or extrinsic goals, internalise learning processes, and sustain engagement over time [15-17]. While SDT has been widely applied in school-level education, its application in higher engineering education—particularly in CBL settings—remains underexplored.

This study addresses this gap by investigating how engineering students experience motivation within CBL courses and how their psychological needs are either supported or hindered by the learning environment, grounded by SDT. Through this analysis, the study aims to provide deeper insights into how motivation operates in complex, real-world educational settings and to inform the design of learning environments that not only develop competencies but also sustain student engagement and well-being.

Specifically, this qualitative study with an interpretive approach, framed by SDT, and by employing semi-structured interviews with engineering students to explore their lived experiences and perceptions, addresses the following research questions:

1. What motivational factors guide engineering students' study practices in a CBL higher education context?

2. How does the CBL approach facilitate students' psychological needs for autonomy, competence, and relatedness?

2. Background

2.1. Challenge-Based Learning approach

Challenge-Based Learning (CBL) engages students with real-world, interdisciplinary problems often posed by external stakeholders. It emphasises applying theoretical knowledge through teamwork and project management [2, 18, 19]. While students value the relevance and autonomy of CBL, complex course structures and fragmented communication can hinder motivation by frustrating autonomy, competence, and relatedness [12-14]. For instance, Dutch university students appreciated interdisciplinary work but faced difficulties in disciplinary integration and team-building, while teachers struggled to foster competence [20]. In CBL ethics courses, key motivational factors included feedback, inclusivity, and ethical engagement. Teachers had to balance content with stakeholder expectations, especially when ethics conflicted with business goals [21]. Finally, CBL fosters motivation and skill development when supported by clear guidance, alignment between stakeholders, and structured learning environments.

2.2. Student motivation and teacher engagement in CBL

Autonomy-supportive teaching enhances intrinsic and identified extrinsic motivation, improving performance and well-being [13, 15, 22]. Teachers shape motivation through their strategies [23, 24]. Market-driven education often fosters extrinsic, credential-oriented goals, undermining satisfaction, engagement, and deep learning [25, 26]. CBL, by embedding learning in authentic contexts, counters this trend and enhances motivation [10, 27, 28]. However, high workloads, vague outcomes, and poor communication can reduce motivation [18, 29]. Finally, supporting self-regulated learning (SRL) through responsive environments and engaged teachers is essential [30, 31]. Teachers' motivation may also decline under institutional pressure, weakening autonomy-supportive practices [32].

2.3. Self-Determination Theory framework

SDT asserts that intrinsic motivation, personal development, and overall well-being are realised by satisfying three fundamental psychological needs: autonomy, competence, and relatedness. The fulfilment of these needs is shaped by social environments, which can either facilitate or thwart their satisfaction [12, 13, 15, 22].

In education, autonomy involves student choice and ownership of learning, facilitated by interest, value, freedom, and positive engagement. It is undermined by external controls such as rewards or punishments. Competence is characterised by the sense of having achieved proficiency (mastery) and success, satisfied in well-structured environments that offer challenges, feedback, creativity, and problem-solving opportunities. Relatedness encompasses a sense of connection and support (belonging), achieved through mutual respect and empathy. Undermining any of these needs damages student motivation and well-being [11].

Autonomy-enhancing environments provide choice, optimal challenges, clear rationales, and structure [33, 34]. Structure involves clear goals, consistent guidelines, and effective feedback [11]. Addressing autonomy and competence is crucial for CBL courses, as supportive and controlling behaviors impact student motivation and course success.

Motivation is not static; it can be facilitated by a learning environment that supports these needs, even if intrinsic motivation is lacking. According to Self-Determination Theory's Taxonomy of Motivation [11], **Figure 1**, amotivation occurs when individuals lack purpose, value, or competence [12-14]. External regulation, the lowest level of self-determined motivation, involves behaviors driven by external rewards or threats, exhibiting an external locus of control [12, 13, 35]. For instance, a student focused on grades rather than problem-solving is externally regulated. Introjected regulation is partially internalized but not fully accepted, driven by ego and avoidance of shame, demonstrating an external locus of control [25]. Identified regulation is more autonomous, where individuals value goals personally and accept them as their own, demonstrating an internal locus of control [12, 13, 35]. For example, a student working hard on CBL tasks for future success exhibits identified regulation. Integrated regulation represents the highest level of autonomy within extrinsic motivation, where external goals align with personal values and needs, leading to self-determined behavior [12, 35]. While closely related to intrinsic motivation, integrated regulation is characterized by personal outcomes rather than inherent enjoyment [12].

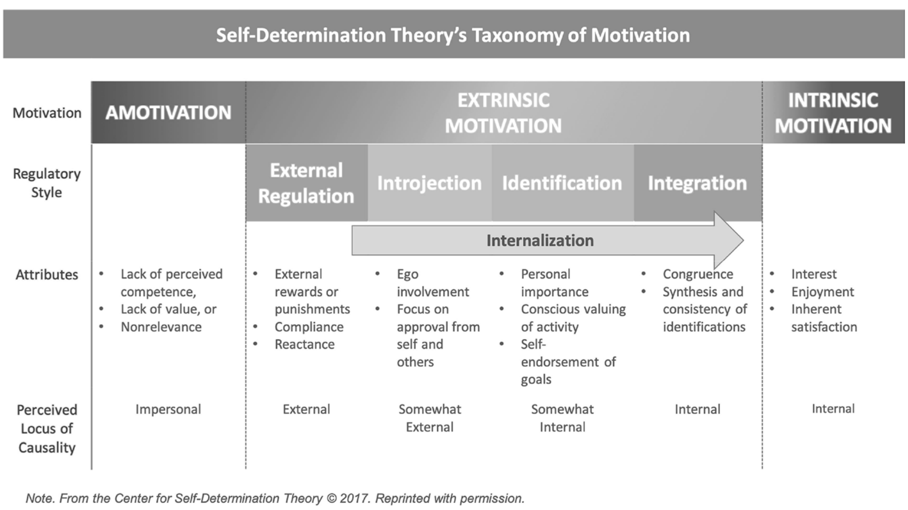

Figure 1. Self-Determination Theory's Taxonomy of Motivation.

3. Methods

3.1. Study Design

This study adopts an interpretivist paradigm with a constructivist ontological stance, asserting that reality is context-dependent and shaped through social interactions [36, 37]. Epistemologically, it follows a subjectivist approach, recognising knowledge as co-constructed through the interactions between researchers and participants [38]. This paradigm is particularly suited for exploring the complex and subjective nature of student motivation [39, 40].

Data were collected through semi-structured interviews with twelve participants, guided by a protocol that included general questions on study motivation and targeted queries based on self-determination theory. Thematic analysis [39] was employed to identify inductive themes, alongside theory-driven coding based on SDT [41-43].

3.2. Participants and Data Collection

Purposive sampling was used to recruit engineering Master's students with varied experiences in challenge-based learning (CBL) courses at the Royal Institute of Technology (KTH) in Stockholm. KTH was selected for its diverse CBL offerings and its emphasis on interdisciplinary, international, and sustainability-oriented education. Participants were recruited via course instructors who distributed invitation letters explaining the study's aims (see Supplementary Material). Students were eligible if they were enrolled in one of four CBL courses, which spanned innovation, urban development, ergonomics, and product development.

Twelve students (7 female, 5 male) participated in the research study after finishing their CBL course studies at the end of the Autumn semester 2024. To ensure diversity, participants were drawn from different course groups. Recruitment continued until theoretical saturation was reached, defined as the point at which no new themes emerged [44].

Interviews were conducted in English via Zoom, lasting 48-60 minutes. Before each session, participants provided written informed consent. Interviews followed a flexible structure that allowed participants to guide the conversation, with the interviewer ensuring that all relevant topics were addressed. All interviews were recorded, transcribed verbatim, and anonymised. Data collection and storage complied with the university's ethical guidelines.

3.3. Teaching and Learning Activities

All four elective CBL courses shared a focus on self-regulated learning (SRL), requiring students to take initiative in group and individual work. Projects tackled real-world challenges, often in collaboration with external stakeholders, and included elements of sustainable development and innovation. Students applied methods such as design thinking, lean start-up, and the triple-layered business model canvas. Outputs included prototypes, business plans, and reflective learning logs. More detailed CBL courses' descriptions are provided in **Table 1.**

Table 1. CBL courses' descriptions.

CBL	Course I	Course II	Course III	Course IV
Course	Innovation & Product Development	Ergonomics in Challenge Driven Product Development	Innovations for the Emerging City, Openlab Multidisciplinary Project	Project Sustainable Urban Planning – Strategies for Urban and Regional Development
University	KTH	KTH	[1] Openlab (KI, KTH, SH, SU collaboration)	KTH
Disciplinary field	Mechanical engineering	Technology and Health	Mechanical engineering and multidisciplinary	Architecture, urban and regional planning or environmental science
Duration & credits	[2] One academic semester 22.5 ECTS	[2] One academic semester 7.5 ECTS	[1,2] One academic semester 15.0 ECTS	One academic semester 15.0 ECTS
Course form	Elective	Elective	Elective	Elective
Students' backgrounds & language of instruction	Swedish and international students, mainly enrolled in MSc program [xxx] / English (En)	Swedish and international students, mainly enrolled in Master's Programme [xxx]/ English (En)	Students from Sweden and other countries, enrolled at any academic level at one of [xxx]'s partner universities / English (En)	Swedish and international students, mainly enrolled in Master's Programme [xxx] / English (En)

Table 1. *Cont.*

CBL	Course I	Course II	Course III	Course IV
Number of students per group	5-7 multidisciplinary group	5-7 multidisciplinary group	5-8 multidisciplinary group	5-8 multidisciplinary group
Typical key external stakeholders	In the manufacturing sector, private industries, public organizations, and occasionally students are afforded the autonomy to generate their own project concepts	Municipalities in the Stockholm area and Municipalities in partner universities' areas. Pre-determined challenges	The Stockholm's municipality or the Stockholm's region (Openlab partners). Pre-determined challenges	The Stockholm's municipality or the Stockholm's region. The external stakeholders present the location for urban planning. The students come up with on their own challenge ideas
Challenges' themes	Digital platform for the mining and ore processing industry/developing industry tools for managing products	Public and private industrial ergonomics focusing in Sustainability and health	Design an organisation (health sector, transportation, safety, etc.) for multidisciplinary project cooperation	Urban, transport, and environmental planning and design
Assessment forms	Project, oral and written presentation	Lab assignments and reports; Project, oral and written presentation; written examination	Written and oral presentation of innovation project; Individual written reflection	Group work-project; Individual assignment; Seminars

Note: 1: Karolinska Institute, Royal Institute of Technology, Södertörn University, and Stockholm University, all located in the Stockholm Municipality and Region; 2: Sometimes also participating students from KTH Global Development Hub partner universities: Strathmore University of Kenya, UDSM of Tanzania, and Botho University of Botswana.

Seminars and supervision sessions supported project progress and encouraged critical reflection. Weekly coaching and written reflections facilitated professional and personal development. Students received feedback from teaching assistants, instructors, and stakeholders throughout. Assessment formats and accommodations for students with disabilities are detailed in the Supplementary Material.

3.4. Interview Protocol

The semi-structured interview guide included open-ended questions on students' learning motivation and specific prompts informed by self-determination theory (SDT). Topics covered include educational background, motivation for choosing CBL courses, and perceptions of autonomy, competence, and relatedness. Follow-up questions explored perceived facilitators and barriers to motivation. The guide was piloted with a peer and iteratively refined. All interviews allowed flexibility for participants to elaborate on their experiences. The full protocol is available in the Supplementary Material.

3.5. Data Analysis

Qualitative data analysis was conducted through two approaches: (1) inductive thematic analysis [39] to identify motivational patterns, and (2) deductive coding based on SDT constructs [13]. NVivo software supported the coding process.

The first phase involved multiple readings of the transcripts by the main and secondary authors, followed by initial coding focused on motives for engaging in CBL. Descriptive codes were refined collaboratively to ensure rigor and compiled into a shared codebook (see Supplementary Material). Emerging codes were grouped into broader themes using pattern coding, and a thematic map was developed to visualise interrelations.

In the second phase, themes were categorised according to the three SDT needs: autonomy, competence, and relatedness. Each need included both positive and negative themes—satisfaction and frustration—depending on participants' experiences. Sub-themes were developed inductively by clustering similar statements.

Autonomy: Themes included structure, rationale, task choice, and perception of professional roles.

Competence: Categories involved mastery, learning outcomes, feedback, and performance opportunities.

Relatedness: Included interpersonal dynamics among peers, teachers, and stakeholders, both supportive and challenging.

All coding was initially conducted by the main author and reviewed by co-authors. Regular discussions ensured agreement on theme categorisation. The team assessed findings in light of SDT literature to distinguish general motivational drivers from those specific to engineering students in CBL environments. Representative quotes were selected to illustrate each theme [36].

3.6. Trustworthiness

To ensure credibility and trustworthiness, the research process was thoroughly documented [47], and findings were illustrated with participant quotes. Participants were involved in validating the data through follow-up and debriefing sessions. Feedback from all authors helped refine the categories and improve analytical rigor [38, 48].

Confirmability was supported by applying the expert assessment framework of Creswell & Plano Clark [49]. The full research design, implementation, and results were reviewed by academic experts in engineering education, educational sciences, and the social sciences, who provided independent and ongoing feedback.

4. Findings

A variety of motives for studying and learning through participation in CBL courses were identified. The students reported several motivations for learning and different types of regulation guiding their behaviors. These motivation categories allow us to address the first research question— what are the motivational factors that guide engineering students studying in a challenge-based HE educational context? The analysis examines the motives behind students' engagement and commitment to various CBL courses. The preliminary qualitative analysis categorised these motives into five distinct sub-categories. In the subsequent phase, these motivational factors were systematically arranged along a self-determination continuum informed by SDT, ranging from the most extrinsically motivated behaviors to those characterised by high levels of intrinsic motivation. This approach of situating motivations on the continuum facilitates a nuanced understanding of their relationship with students' self-determined motivation for learning. The findings, illustrated in **Table 2**, also contextualise students' behaviors (attributes) to the CBL environment and show how these are regulated by external or internal locus of causality [23].

4.1. Motivation to study CBL courses positioned on the Self-determination continuum

Extrinsic motivational aspects in student statements identified through the thematic analysis are positioned primarily on the extrinsic part of the scale of SDT continuum. Findings are presented in decreasing order of external regulatory power. An illustrative Self-determination continuum is presented as **Table 2.** format at the end of this section, summarising as well the findings, including direct students' quotes.

4.1.1. Development of innovation and social entrepreneurship skills, the goal of employability

In this category, students' behavior is driven by an externally imposed reward and compliance with the external stakeholders to achieve this goal is highly prioritised in **Table 2.** Students' motivation concerns an 'External regulation' behavior positioned into the self-determination continuum, indicating a form of extrinsic motivation experience. Students' learning and study were done for reasons such as eventual future employability, and not for their inherent satisfactions.

> *"I thought that the course would be a good opportunity because it was quite a long course, and you can develop some social entrepreneurship competencies for your further job... And this I think is how innovation usually works, when you have multidisciplinary... that you can... differently work together" (Student 2).*

Table 2. Emerging themes and quotations, aligned with the stages of the self-determination continuum as proposed by SDT [11].

Extrinsic Motivation				Intrinsic Motivation
External Regulation	**Introjected Regulation**	**Identified Regulation**	**Integrated Regulation**	
Development of innovation and social entrepreneurship skills "I felt I had to do something that would give me a job. Maybe there's an opportunity here…so, I felt I needed to know more maybe social entrepreneurship, and this was like a nice bridge between academic studies and something that you actually get to meet a proper challenge-provider, or someone who can give you work, or a job" (Student 6).	Designing a service "I thought this would be a good change so I could also experience designing a solution or a service. However, I didn't want to give something to the challenge-provider that they wouldn't use or not helping them." (Student 1).	Gaining practical experience "I was hoping this time to get practical experience on how to tackle urban planning-related projects. Me being interested in transport, but also planning in general, decided to go for this course." (Student 11).	Problem-solving attitude "As a student in innovation management and product development, I had to help them innovate their processes, coming up with some better features and a business plan, and to suggest improvements to their product development process… I would say precisely that I motivated to be a problem solver, involving into brainstorming new solutions" (Student 4).	Contributing to society through sustainable solutions "The challenge that was given to us, it was definitely enjoyable. The challenge was to come up with a solution in order to help the waste collectors in Gaborone city...the waste was containing some germs. I found the challenge as an opportunity to contribute to our society, people's health, and environment through a sustainable solution" (Student 5).
Attributes:	Attributes:	Attributes:	Attributes:	Attributes:
future employability and compliance with the stakeholders	public self-consciousness and focus on approval from both self and external stakeholders	personal significance of investigating the conscious appreciation of the nature of CBL courses, the self-endorsement of goals, and the willingness to take action is crucial	alignment of CBL course values with students' future professional identities; synthesis of identifications such as current students' selves as being engineers and future selves	interest and enjoyment; inherent satisfaction of students' contribution to the society through the CBL courses

4.1.2. Designing a service, goal competence in designing services

This theme also includes an internal motive, indicating 'Introjected regulation', valuing the positive effect of learning new knowledge (e.g., design thinking, project-based design) offered by the challenge-driven courses. Students expected to learn and develop design thinking to design a solution or service for different societal problems, which would be accepted immediately by the challenge stakeholders for deployment.

> *"I thought that it was, like, interesting to work with a municipality. . . it was more that I wanted to do like a good project for the municipality more. Because we should present it for the municipality and not just for the class. So, it was that motivated me the most." (Student 12).*

> *"I wanted to learn more about how we apply design thinking for solving like non-medical problems and the problems that have more to do with society. So, it was a good thing to reflect on how we do it in healthcare and innovation for tangible products that have a lot of like engineering components to it. So, that was the motivation." (Student 3).*

4.1.3. Gaining practical experience, goal personal career enrichment

In this category, students' experiences have been internalised, shaping an internal dialogue that aligns with the perceived value of CBL courses. This process reflects an "identified" form of extrinsic motivation, where students recognise and appreciate the value of engaging with real-life problems as a means to gain practical experience. Motivation under external regulation has been internalised and made relevant to the individual through explicit connection to the course or personal learning goals.

> *"So, for me it was: how can I bring biodiversity conservation and these kinds of nebulous, very academic things I've been loosely kind of exposed to, into a practical context, and how can that become a project." (Student 9).*

4.1.4. Problem-solving attitude

This theme is focused on a problem-solving attitude. In this category, informants not only personally recognised and identified with the value of challenge-driven education. In addition, they expressed interest in innovation management and product development, finding these values to be congruent with other core interests, such as problem-solving.

Despite objections from external stakeholders about the limited project budget, the personal importance of the implication of socio-real-life problem-solving motivated to take the CBL course.

> *"Especially, I became more sensitive and said to myself that it deserves to contribute somehow to their hard hands work, ignoring sometimes companies' interests and budget limitations. The fact that I would engage with a real problem of workers regarding their health, their lives and sustainability at the same time motived me to go power and design the whole research process with my team smoothly" (Student 7).*

Students' synthesis and consistency of professional identifications as an engineer identity concerns an 'Integrated regulation' behavior.

4.1.5. Contributing to society through sustainable solutions

Finding meaning and making a contribution was the only motive to pursue CBL courses identified by students. Meaning was typically associated with the specific tasks and functions carried out. A student identified the challenge as very interesting and enjoyable during his engagement in the CBL course.

Student 10 enjoyed the idea of being free to choose a challenge that engaged with a specific municipality and where he could make a clear contribution.

> *"I found those two courses to be the most interesting and enjoyable. And I really liked the idea of getting to work with a municipality and contribute to its local society and in a more project-based form. The challenge was the development of stakeholders' collaboration with the municipality through social sustainability. . . Helping the municipality of [xxx] to be in charge with real-estate companies in a sustainable way" developing the area of [xxx]" (Student 10).*

This category emphasises a sense of personal meaning, in these cases resulting in a contribution to society through a sustainable solution. In this category of experience, the student 5 values the challenge as a worthwhile contribution to public health and environment, as well as to the development of a public benefit. This is associated with 'Intrinsic motivation' in the self-determination continuum **Table 2.**

4.2. Students' Psychological Needs

This section addresses the second research question: How does the CBL approach facilitate students' psychological needs for autonomy, competence, and relatedness? Drawing on SDT, the study explores how specific course elements and learning experiences either supported or hindered the satisfaction of these needs. The findings are structured according to SDT's core components—autonomy, competence, and relatedness—and are illustrated with participant narratives to highlight the motivational dynamics within CBL environments.

According to SDT, the self-determination continuum captures the degree of internalization of motivation, with intrinsic motivation being optimal for well-being and engagement. This form of motivation is sustained when individuals experience autonomy, competence, and relatedness. The satisfaction of these needs fosters psychological growth and intrinsic engagement, while their frustration can lead to diminished motivation and disengagement [23].

Participant responses demonstrated clear connections to these three needs. When autonomy, competence, and relatedness were supported, students expressed positive experiences and increased motivation. Conversely, when these needs were thwarted, they reported frustration and decreased engagement. **Table 3** presents the key factors that influenced the fulfilment or frustration of these psychological needs in the context of CBL.

Table 3. Emerging factors affecting the three psychological needs postulated by SDT [11].

Psychological Needs Experienced and Satisfied by Engineering Students in CBL Courses					
Autonomy		**Competence**		**Relatedness**	
Satisfied by					
consistency in rules and guidelines informational support	Structure	feeling of having control over the tasks self-fulfilment by being able to persist to their own ideas sense of success through students' self-confidence	Mastery	sense of belonging and engagement with educators and external stakeholders, coupled with mutual respect and a nurturing environment students' group cultural background and diversity	***Positive relationships between students and teachers/stakeholders***
meaningful choices and tasks	Optimal tasks provision	development of competences and skills	Learning		
		performance feedback	Feedback		
Frustrated by					
no meaningful justification for the projects' tasks highly specified work descriptions	Rationale	no informative or constructive feedback neither from teachers nor from external stakeholders frequent teachers' rotation in the classroom	Feedback	sense of disconnectedness or rejection because of students' conflicts into their groups & braking promises and rules from the external stakeholders awkward relationship between students and societal actors (e.g., municipality and private companies)	***Negative relationships between students and teachers/stakeholders***
pre-defined challenges lack of a conducive learning environment	Choice				
lack of knowledge about who owns innovation rights	Professional rights	restrictions caused to limited data provided by external stakeholders restrictions due to limited budgets for optimal sustainable solutions	Opportunities for growth and performance		

4.2.1. Autonomy

Structure

Autonomy is usually associated with self-determination. However, students also noted that autonomy can be strengthened by having clear and consistent rules and guidelines. Clear communication with information support about what applies from teachers and stakeholders has a further positive effect on autonomy. Without clarity, freedom becomes difficult to relate to, which means that the task tends to become overwhelming.

> *"Freedom with the constraints of practicality, and sort of reality. We want solutions to work in real life. So, we do need to listen to people who know the system better, who know the realities better to support us" (Student 1).*

Rationale

On the other hand, one limit is reached where instructions and rules become too specific and detailed. Students felt frustrated when the course management did not provide any meaningful justification for the activities or project tasks given. In some cases, a very specific description of what students should do was given, such as what to read, monitoring of attendance, a daily study diary and a tight timetable.

> *"I felt that they could have engaged more into all the groups and guided us better providing more clear rationale on our work… Which I believe wasn't exactly available from the professors and with the industrial supervisor" (Student 4).*
> *"It was a written exam. But it was limited and tight. It was five hours to be precise" (Student 5).*
> *"Attendance sheet. And then write what you learned every lesson. It's like almost as if I was in school, you know? . . . you failed the course if you didn't fill in this thing." (Student 6).*

Optimal task provision

Teachers and external stakeholders facilitated the learning process by providing the students with a feeling of autonomy through meaningful choices and tasks engaging their interests.

> *"The teacher and the challenge-providers welcomed our idea, and we could continue to develop the final questions for the interviews" (Student 7).*

Choice

Sometimes, tensions among students or between teachers and students arose depending on the choice of challenge to work on. In the CBL courses investigated, there are usually one or more stakeholders who provide one or more challenges. The student groups can then choose which challenge they want to work on, and here it is difficult for the course management to give all students their first choice. If a student did not feel that they had been able to work on what they wanted, the feeling of autonomy decreased, resulting also to some students' dropout from the courses.

> *"We weren't the ones choosing which challenge to participate in... we were not actively participating in choosing the challenge and choosing our teams... So, I frustrated... for example when they didn't place me in this like... dietetics groups, for fighting obesity" (Student 3).*
> *"Then later on we became five in the group... She was behaving a bit strange at the beginning... the reason was... I think that she did not like the challenge that gave to us so much. It seems that she did not show so much interested in and enjoyable on it and she had other courses as well to pass, told me!" (Student 7).*

Students also claimed that in many cases there was a lack of a conducive learning environment for the tasks assigned to them. Specifically, health and safety issues and laboratories' distance from the main campus were mentioned.

> *"...did not provide a suitable environment to*

> *work well. And I would say that the location of the M building, it's at the far end of the campus, which cost some extra time to reach the project room. It was so stressful!" (Student 4).*

Professional rights

A feeling of reduced autonomy also arose when the students felt that they were not informed in advance about the rights and ownership of their ideas. The students experienced both uncertainty and anxiety during and after the course as they could not influence the situation.

> *"We discovered that the clinic wanted to take our project and present it to someone else. And I felt like we can't do all this work and then just give it to someone, if we want to continue with it. . . In the end, we didn't know anything about the… like, who owns the rights? Felt stupid! If we pursue our idea… so, now we don't speak. But if we'd ended our course on terms that we knew who owns the idea, the copyright, all these… how do you say, judicial… like laws and stuff, royalties, contracts would be better" (Student 6).*

4.2.2. Competence

Mastery

With regard to competence, satisfaction was expressed through a sense of mastery, showing students' self-confidence and commitment to their challenges.

> *"I think to do your tasks well that's a very big motivational factor. It became an obsession. . . because I wanted to illustrate exactly what was in here [points to head], not come with some like... oh, this is a piece of paper and I draw it here. I wanted to bring out the whole thing and: Bam! This is what we are going to do. Yeah, it says maybe something about myself" (Student 6).*

A sense of competence also arose for the students when they were able to persist with their ideas they developed. The fact that external stakeholders supported and/or teachers listened to them with respect also increased the students' group self-fulfilment and strengthened students' satisfaction.

> *"We surprised them with how hard we were going to...work our ideas. And we found some common ground with them. When we came with our idea, we got a lot of like respect" (Student 6).*

Learning

Students' competence need was also supported by teachers' ability to facilitate their development of competences and skills through providing them with new knowledge.

> *"I learned new things like sustainability, cognitive ergonomics methods, risk management, and design thinking. But yes, since all of these were great to study and learn and very helpful when you integrate all of these into the project and it was very practical skills and competences and knowledge" (Student 7).*

Feedback

Students' satisfaction was supported by teachers' ability to facilitate their development of competences and skills through providing them with appropriate tools and performance feedback. External stakeholders facilitated learning by providing guides on how to master the challenges' tasks at hand. Some external stakeholders also seem to downplay evaluation and reflection, promoting students' effectance.

> *"So basically, we always tracked our progress, we always had meetings in person or online. We continuously took feedback from our professor, industrial supervisor, and the other students' groups." (Student 4).*

On the other hand, students felt a bit frustrated when feedback was neither informative nor constructive from both by teachers nor external stakeholders.

> *"... Feedback, I think it wasn't as much effective. Because it was mostly about: Remove this and add this. But you can solve that by just giving like five bullet points… the ideas would have resulted in being better if we decreased the feedback on the content of the presentation and more like dig into the problematics" (Student 3).*

Finally, some students reported from a course where their teachers rotated from one project group to another every week, an act which created confusion. As the teacher changes, they had to inform the teachers from the beginning of their work which was seen as waste of worktime, which was also problematic regarding the progress, synthesis, and feedback of their challenges' work.

> *"I think if they had assigned one of the teachers as like a supervisor for the project and not to change teachers every week, then he would have been able to follow everything and give a little bit better suggestions or better guide and feedback to the team" (Student 2).*

Opportunities for growth and performance

Some students mentioned that they only had restricted data to work on as the external stakeholders did not provide them with more, and the students were not allowed to access their original resources, resulting in limited opportunities for growth and performance.

> *"... providing us more customer data, would help us provide better solutions for their project... But unfortunately, I would feel that the team members at the end, when we were not able to get the whole data that we needed, we were a bit disappointed. And the amount of care we had for the project went down." (Student 4).*

However, students felt very frustrated when their more radical, progressive and critical solutions to the challenges they were asked to work on were not accepted by the external stakeholders and some teachers. It was experienced in several cases that one had to accept to work with the more consumerist/commodity solutions provided by the external stakeholders, limiting the students' free choice. The change projects the students signed up for became more of a developmental work where one was expected to follow the given rules to be successful.

> *"We set up many critical questions that would be solved... why can't the daily activity center use other facilities that are in near proximity that are in kind of like ownership of the city? Of course, the stakeholders found all of these said millions of times and did not want us to work on that direction" (Student 3).*
> *"… We've tried it already; we can't do anything about it. We need to focus on spreading the awareness. And how are you going to spread the awareness? Create some marketing material. Which marketing material? Brochure... I disappointed a lot!" (Student 2).*

4.2.3. Relatedness

Positive relationships between students, teachers, and external stakeholders

Students' relatedness need was satisfied by the sense of belonging and connection. This was achieved when all members in the group showed each other respect and caring through their active engagement in the learning process. Different students' group cultural background and diversity were highly appreciated by the students' satisfaction with teachers and external stakeholders' relatedness need as well.

> *"I felt belonging to the team, as I was an active student. There was a good communication among us and the teachers. We care each other during the course and we were aiming to study as a team and help*

> *the workers with the challenge- solution" (Student 7).*
>
> *"We had an exchange student from Tanzania; And then we had a guy who came from Ethiopia who lives in Sweden. And he took us out to dinner, so we had a lot of fun encounters in the group. We kind of build a good team based on members' interests and background...it was funny and interesting to work with!" (Student 6).*

Positive relationships were also achieved when teachers and stakeholders facilitated the students' learning process through their feedback.

> *"So initially the external stakeholder, she was very nice, and we started enjoying what we talked to her about and we enjoyed getting the feedback from her... So, all our conversations were very respectful and very formal. No problems with like the professionalism that we had (Student 4).*

Negative relationships between students, teachers, and external stakeholders

Several factors contributed to student frustration. Specifically, those who felt isolated or rejected by their peers were more prone to disengage from the internalisation process and diminish their intrinsic motivation for learning. Factors such as students' conflicts in their teams without teachers' intervention, students dropping out of students from their teams, and breaking promises and rules from external stakeholders, seemed to thwart students' social-relatedness need.

> *"I should have involved the teacher in this conflict. But I know that teachers do not intervene. However, they mentioned that they could split a group into two, but I don't think in this situation it was good. The student written contract was never followed as well!" (Student 2).*
>
> *"In our group, we were lacking two team members, because they did not enjoy the challenge that engaged with. Two girls dropped out, and if more of us like left the group it would really put others into an uncomfortable situation making disorders in the group" (Student 3).*

Less good relationships were obtained when it was felt that the stakeholders were not very interested in their work.

> *"I felt disappointed in the sense that we were keeping on updating the stakeholders that on our final presentation it will be required. So, they just responded that they accepted the invitation, but then towards the end... it didn't happen as we expected. They did not attend!" (Student 5).*

Finally, negative relationships between public and private stakeholders brought students into quite unpleasant situations, resulting in a lack of trust and communication among them.

> *"We did have some mail-communication with JM, a big company, but they... as I said, they didn't really have time to talk to us... And we never heard any more... We felt it was kind of ironic since we discussed it during the interview with the municipality. They were like: Well, this is only our side of the story... But yeah, I mean, private actors in a way... Because they can gain something from this, but I don't think that the private actors feel that way. So, there's really no incentives for them to help us... Yeah, I would definitely say economical differences." (Student 10).*

5. Discussion

5.1. Students' Motivational Functions and Motives

At the policy level, student motivation in higher education is increasingly framed in instrumental terms—such as employability, innovation, and entrepreneurship—rather than personal and disciplinary development [50]. Dearing [51] argued that universities adopting market-driven models encourage students to see themselves as investors, seeking a return on educational investment rather than pursuing intrinsic academic goals. Morris [52] found that this policy orientation can undermine student autonomy and intrinsic motivation, as it promotes decisions based on anticipated income rather than personal interest.

Students who are motivated by the desire to produce usable services and interact meaningfully with teachers and stakeholders may find their autonomy constrained when pressured to grasp concepts immediately and "get things right." In contrast, courses framed around optimal challenges—where learning is gradual and consolidation of knowledge is encouraged—are more likely to support autonomy.

Motivations driven by a desire to apply theoretical knowledge, gain practical experience, or solve real-world societal problems appear to foster deeper engagement with CBL courses. Students' willingness to act, as defined by higher-quality motivation and performance, is enhanced in environments that support practical application and stakeholder interaction [11, 53].

Moreover, some students demonstrate intrinsic motivation through their identification with engineering as a problem-solving discipline and a desire to make a meaningful societal contribution. Real-world and unsolved challenges are particularly effective in triggering intrinsic motivation and engagement [18, 54]. Competencies such as creativity, social entrepreneurship, and sustainability—critical for industry engagement—also serve as motivational drivers [8, 9, 26].

These findings align with Identity-Based Motivation Theory, which posits that when academic challenges reflect students' envisioned future selves, motivation and persistence increase [55, 56].

5.2. Students' Psychological Needs

Autonomy

Students' autonomy was supported when they were provided with meaningful choices, clear course objectives, and opportunities for dialogue. Appreciation of real-life challenges and freedom in the CBL process enhanced learning motivation [10, 27, 57]. Consistent with SDT literature [33, 34], autonomy was undermined in overly controlled environments [52] or when teachers monopolised learning processes [58].

Conversely, autonomy was fostered when teachers trusted students' abilities, communicated the rationale behind tasks, and encouraged exploration [59, 60]. Predefined challenges or excessive structuring diminished autonomy and led to frustration [61-63]. Environments lacking psychological or physical support—such as poor facilities—also negatively impact autonomy [54, 64].

Students expressed frustration when denied professional ownership of their project work. Autonomy was higher when students could explore their ideas, supported by respectful and open communication [58, 65]. A lack of ethical or legal frameworks to recognise students' rights over their work further limited autonomy [21, 66].

Competence

Students' competence was supported by feedback, iterative guidance, and opportunities to develop ideas in collaboration with teachers and stakeholders. Effective feedback and challenge management were crucial for skill development [10, 21, 24, 27, 57].

However, competence was hindered by limited institutional resources and incoherent external stakeholder input [67]. Students felt constrained when commercial interests overshadowed the exploration of broader societal solutions [20]. These findings echo research suggesting that external policies and market-driven education can suppress inquisitive learning and perceived competence [32, 50, 68].

Relatedness

When students experienced mutual respect and meaningful engagement with teachers and stakeholders, their relatedness needs were fulfilled. Positive interpersonal relationships promoted belonging, communication, and care [10, 21, 27, 57, 69].

However, team conflicts negatively affected relatedness and motivation. Students who experienced misalignment in group efforts felt frustrated [21]. Although proactive conflict management is common in Swedish HEIs [70], this study highlights the need for improved group management training for both teachers and stakeholders.

Finally, a lack of trust among the triad of students, teachers, and external stakeholders diminished relatedness. Trust is essential for knowledge exchange and collaboration [71, 72], and is fostered through regular, open, and interactive communication [73, 74].

6. Implications for Engineering Education

Research on dropout in engineering education, especially in CBL courses, reveals that students' motivation is often compromised when their autonomy, competence, and relatedness needs are not met. Applying SDT provides a framework for fostering intrinsic motivation and reducing externally controlled behaviors [9, 26, 75, 76].

This study reinforces the significance of three roles in CBL course design [77], such as: (a) the academic teacher, responsible for knowledge acquisition and assessment, (b) the coach, focusing on skills and group dynamics, and (c) the organiser, managing external stakeholder interaction.

Teachers and course designers can strengthen CBL implementation by supporting students' autonomy, structuring learning environments around meaningful choices and challenges, and providing constructive feedback. Stakeholders must be prepared to understand student needs and engage respectfully.

To foster competence and self-efficacy, higher education institutions should offer access to resources (e.g., literature, digital tools), mentorship and coaching, and peer learning networks.

Self-regulated learning (SRL) strategies, including metacognitive prompts and self-assessment, can further support students' motivation. Emphasising mastery rather than performance goals promotes deeper engagement [43]. Ultimately, fostering environments that prioritise curiosity, confidence, and societal contribution helps engineering students develop critical thinking skills needed for transformative learning.

7. Limitations and Future Research

While theoretical saturation was reached, the qualitative design limits generalisability. Findings are context-specific to Master's level CBL courses and shaped by participant perspectives - engineering students - at a research-intensive Swedish university. Each student articulated multiple, interconnected motives for engaging with CBL, which were not quantified but thematically analysed. Future studies should incorporate quantitative methods using validated SDT instruments to assess motivation and need satisfaction across broader populations, conduct comparative studies of CBL implementation across different institutions, explore equity and inclusiveness by assessing accessibility for students from diverse backgrounds, and investigate longitudinal effects of CBL and pedagogical interventions on motivation over time. This would complement the rich qualitative insights by providing broader statistical trends. Such research can guide institutional policies and instructional strategies, ensuring that CBL practices support diverse learners and educational goals.

8. Conclusions

This study aimed to investigate how CBL environments in Swedish higher engineering education influence student motivation. The study identified five distinct motivational profiles of students along the self-determination continuum: (1) extrinsic motivation based on course requirements (promote employability), (2) introjected motivation driven by the desire to maintain personal standards and stakeholder's requirements, (3) identified motivation through connection to meaningful work (gaining practical experience), (4) integrated motivation aligned with students' engineering identity, and (5) intrinsic motivation for challenge and enjoyment (societal contribution). These profiles revealed that students' motivation was dynamic, influenced by a complex interplay of personal values, peer collaboration, course design, and the authenticity of the learning experience. Thus, CBL environments can foster a range of motivational orientations depending on how these contextual and pedagogical factors are structured.

Further, addressing how the CBL approach facilitates students' psychological needs for autonomy, competence, and relatedness, the study's analysis showed that these needs were variably supported within the CBL environment. Autonomy was generally enhanced by the open-ended nature of projects, but sometimes undermined by insufficient structure. Competence was strengthened when feedback and assessment criteria were clear by the teachers and external stakeholders, but vague expectations and misaligned evaluation practices detracted from students' confidence. Relatedness thrived in peer interactions, yet students expressed a need for more consistent and supportive instructor engagement. These findings emphasize that while CBL holds the potential to meet core psychological needs, intentional design and facilitation are crucial to ensure these needs are consistently addressed.

By systematically linking our findings to both research questions, this study contributes a nuanced understanding of how CBL environments influence engineering students' motivation. The analysis of data highlights that motivation is not only a product of individual disposition but also shaped by the educational ecosystem in which students operate. Therefore, fostering sustained motivation in CBL requires a deliberate balance between autonomy-supportive practices, scaffolding for competence, and meaningful student - educator - external stakeholder relationships.

In conclusion, the effectiveness of CBL in promoting student motivation hinges on thoughtful course design that supports psychological needs and aligns learning experiences with students' academic and professional identities. These insights offer valuable implications for educators and curriculum developers aiming to enhance motivation, engagement, and learning outcomes through challenge-based approaches in engineering education.

Author Contributions

Conceptualisation, P.P., A.P. and J.B.; methodology, P.P.; software, P.P.; validation, P.P., A.P. and J.B.; formal analysis, P.P.; investigation, P.P., A.P. and J.B.; resources, P.P.; data curation, P.P. and J.B.; writing—original draft preparation, P.P.; writing—review and editing, P.P.; visualisation, P.P.; supervision, A.P. and J.B. All authors have read and agreed to the published version of the manuscript.

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The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee's guidelines of the ROYAL INSTITUTE OF TECHNOLOGY, KTH.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. However, the extracted data from the analysis process are available in the supplementary material.

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Conflicts of Interest

The authors declare no conflict of interest.

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