Challenge-Based Learning as a Driver of Student Engagement: A Green Campus Case from Norway

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Abstract

Challenge-Based Learning (CBL) has emerged as a student-centered pedagogical approach that promotes active engagement with real-world problems through interdisciplinary inquiry and collaborative problem-solving. This paper presents a case study from the University of Stavanger, where CBL was integrated into a course aimed at engaging students in the (re)design of digital services for a more sustainable campus. Following the CBL framework, students identified localized sustainability challenges within the campus context, systematically investigated these issues through diverse research methodologies, and collaboratively developed actionable solutions to enhance the campus green transition. The study aimed to explore students' perceptions of their engagement throughout the CBL-integrated course. Drawing on qualitative data derived from in-depth student reflections, the findings reveal patterns of student engagement across three main dimensions: emotional, cognitive, and behavioral, showing how the CBL framework both encouraged and challenged different forms of engagement. Building on these empirically grounded insights, we propose evidence-based pedagogical recommendations for educators seeking to implement CBL while optimizing student engagement in higher education contexts.

Keywords: *Challenge-Based Learning, Sustainability, Green Transition, Digital Service Innovation, Student Engagement*

1. Introduction

The *twin transition*, which combines green and digital transformations, has emerged as a defining paradigm for sustainable development in the 21st century [6]. The green transition toward a carbon-neutral, resource-efficient economy is essential for combating climate change [7], while digitalization is reshaping society through new forms of innovation, communication, and economic activity [26]. The interconnectedness of these transitions calls for innovative pedagogical approaches that develop interdisciplinary competencies bridging sustainability and digital transformation. However, higher education systems globally remain largely siloed, with traditional disciplinary structures ill-equipped to address this green-digital convergence. As UNESCO's *Reimagining Our Futures Together* report [25] fundamentally redefines the futures of education, it delivers an urgent call to renew education by reimagining pedagogical approaches, fostering transformative learning, and equipping learners to navigate complex global challenges. We argue that Challenge-Based Learning (CBL) can serve as an innovative pedagogical approach to bridge sustainability and digitalization by engaging students in real-world problem-solving at their intersection. Unlike traditional pedagogies, CBL's emphasis on cross-disciplinary, solution-oriented learning mirrors the very nature of the sustainability-digitalization nexus it seeks to address. Grounded in experiential learning theory [14], CBL promotes active student engagement with real-world problems through interdisciplinary inquiry and collaborative problem-solving [18]. By immersing students in authentic, complex challenges, CBL reinforces the goals of education for sustainable development [24] by fostering key competencies such as systems thinking, critical reflection, and collaborative action [15], thereby preparing learners to navigate and drive the twin transitions toward a more sustainable and digitally connected future. This study explores student engagement dynamics within CBL through two key lenses: First, how do students perceive their engagement dynamics throughout the CBL-integrated course? Second, what evidence-based pedagogical implications emerge from students' engagement perceptions to inform educators and the design of future CBL training programs in higher education? By addressing these questions through qualitative analysis of student reflections, the research aims to both map the multidimensional nature

of CBL engagement and translate these findings into actionable frameworks for sustainability education innovation.

2. Theoretical Perspectives on Challenge-Based Learning (CBL) and Student Engagement

CBL is a teaching method that encourages students to work together across disciplines and solve problems that are relevant to real life. It promotes active learning through meaningful challenges [9][12][18]. As described by Nichols et al. [18], CBL begins with a real-world challenge that helps students build knowledge while also offering motivating and engaging learning experiences. In this approach, students are gradually given more responsibility for their learning through content that is both engaging and focused on the outcome as well as the learning process. The teacher's role is to guide, support, and encourage students while considering their individual needs, and the course materials should provide opportunities for interaction among students [21].

Engagement is defined as the level of effort and emotional involvement a person shows while working on a task [19]. It includes enthusiasm and motivation, whether from within or encouraged by outside rewards. According to Fredricks et al. [8], engagement can be grouped into emotional, cognitive, and behavioral types. Emotional engagement is seen in how students feel during learning, such as when they are interested or anxious. Cognitive engagement involves students thinking deeply, focusing on complex ideas, and putting in mental effort. Behavioral engagement refers to students showing up, taking part in tasks, and staying focused, which often leads to better academic outcomes. Teachers can support this by using effective teaching strategies [8][20][23]. Engagement theory suggests that students are more likely to retain what they learn when they are actively involved in the learning process, which is best supported through real tasks, teamwork, and projects connected to real-world contexts [1][27].

In CBL settings, research shows that students tend to feel more motivated and engaged when learning is relevant to real-life situations [9][11][12]. Their engagement increases even more when they have opportunities to collaborate and take responsibility for their own progress [5][17]. When students are actively engaged in challenge-based online learning, their performance tends to improve [11]. Partnering with industry also seems to boost students' motivation and involvement [5]. Being part of team activities helps too, as working closely with peers can make the learning process more engaging [4][17]. According to Simón-Chico et al. [21], students became more behaviorally engaged after taking part in a CBL course, although their sense of agency didn't change much. Finally, Fredricks et al. [8][16] and Michel and Förster [16] explain that CBL encourages different types of engagement, including emotional, cognitive, and behavioral, especially when students are involved in project-based tasks.

3. The Case Study

The case study involves a ten ECTS course titled "Digital Service Modelling", part of the bachelor's degree program offered by the Department of Leadership and Service Innovation at the University of Stavanger (UiS) in Norway. The course explored strategic approaches to value creation through the theoretical development of service models. Specifically, it examined the transformation of traditional business models into digital formats, with emphasis on innovative digital models that enhance customer/user engagement and experience. Digital service modelling engages with complex, real-world challenges, including the transformation of traditional business models and the innovation of services aimed at creating customer value. CBL mirrors these complexities, providing learners with the opportunity to directly apply theoretical concepts to concrete, practical challenges. To bridge the gap between theory and practice, the course coordinator integrated CBL into the curriculum. In alignment with the sustainability agenda of UiS, the CBL-integrated course was designed around the mission of the green transition. This approach aimed not only to foster student engagement, but also to encourage students to address critical sustainability challenges on campus by (re)designing digital services that promote more sustainable practices within the university environment.

The course spanned ten weeks, comprising weekly structured sessions co-facilitated by the course coordinator and an CBL expert. This collaborative instructional approach ensured expert guidance through all CBL phases, from problem identification to solution prototyping, while maintaining pedagogical coherence across the curriculum. Each session lasted four hours, combining lectures with

collaborative teamwork activities. A total of 40 bachelor's students, all with no prior experience in CBL, participated in the course. Seven teams (5-6 students each) were strategically configured to leverage their diverse strengths, skills, and interests, while prioritizing gender balance, interdisciplinary collaboration, and cultural diversity.

4. Research Methods

We employed the case study method [28] as the primary research approach in our study. Our data consisted of 40 in-depth individual reflections, with each student providing a written account of their experiences throughout the CBL-integrated course. These reflections yielded qualitative insights into students' perceptions of their engagement with CBL, the challenges they encountered, and the development of their problem-solving competencies over the duration of the course.

Data analysis was conducted by both the course coordinator and the CBL expert, supported by AI tools, following a structured process of codification, categorization, and thematization [3]. We analyzed the student reflections using a deductive coding approach grounded in the Engagement Theory developed by Fredricks et al. [8] and Trowler [23]. We categorized the data into three dimensions: Emotional Engagement, Cognitive Engagement, and Behavioral Engagement.

In conducting this study, informed consent was obtained from all participating students, ensuring their full awareness of the research objectives and the intended use of their reflections. Strict adherence to ethical guidelines was maintained to safeguard participant privacy and confidentiality. All identifiable information was anonymized to protect student identities. The collected data were securely stored and utilized exclusively for academic and research purposes pertaining to course evaluation.

5. Findings from the Engagement Dynamics

Table 1 outlines representative coded excerpts, categorized by emotional, cognitive, and behavioral engagement dimensions, which empirically illustrate the engagement patterns that emerged from the CBL-integrated course.

Table 1. Student engagement dynamics across the CBL-integrated course.

Engagement Type	Observed Patterns	Illustrative Quotes from Reflections
Emotional	Motivation through a growth mindset	"S*tarting this journey with a growth mindset helped me assure myself, even in the difficult moments, that I will be learning through real-world experiences and get new skills along the way*." (P4)
	Driven by supportive teamwork.	"*Working with a supportive team kept me engaged as we pushed each other to grow and stay on track."* (P19)
	From anxiety to confidence through peer support.	"*Initially, the open-ended nature of CBL felt overwhelming, but I gradually developed a mindset that embraced uncertainty as part of innovation. I learned to trust the process…Our 'no stupid ideas' rule created a safe space.*" (P15)
	Shared ownership and individual worth.	"*One thing that helped was how my teammates were…Most decisions were made by voting, which made things more efficient and inclusive. I felt everyone's voice mattered, including mine, even if I wasn't always the loudest in the room.*" (P26)

Engagement Type	Observed Patterns	Illustrative Quotes from Reflections
Cognitive	Metacognition achieved through reflecting on one's learning processes.	"*I've walked away from this course with more than just new skill...I've learned how to apply theory to practice, how to adapt when things change, and how to keep going even when it's hard. Most importantly, I've learned that collaboration doesn't mean losing your voice, it means using it in the way that supports the team at best.*" (P36)
	Critical thinking supported by the use of frameworks, models, and tools.	"*The fishbone analysis helped us break down root causes, not just symptoms…System Thinking helped us see problems as interconnected…The Six Thinking Hats structured our phases—we balanced facts, risks, and creativity.*" (P31)
	Special educational needs as unique cognitive assets.	"*Due to my dyslexia, I often face several challenges on the traditional courses, but in this course, I found that my strengths, such as creativity, visualization and innovation, were valuable assets…for visual learning and problem-solving through innovative and engaging methods*." (P5)
	Growth in patience and purpose.	"*I had to stop rushing to solutions and embrace ambiguity...I became more aware of the ethical responsibility to design inclusive and sustainable solutions*." (P34)
Behavioral	Facilitated active collaboration and communication.	"*I played a flexible role, balancing tasks and contributing wherever needed to support the team's success...We formed a complementary partnership, communicating consistently to maintain project cohesion.*" (P17)
	Interpersonal adaptation and dynamic role-switching in teamwork.	"*Although I am comfortable speaking and sharing my ideas, my biggest struggle was reading unspoken group dynamics and adapting to more reserved team members. This project forced me to actively listen, engage in structured collaboration, and refine my ability to integrate others input into my own thinking in a more flexible manner than ever before*." (P37)
	Quietness from self-doubt, not disengagement.	"*I tend to be a bit quiet...It is not necessarily due to a lack of engagement, but more about insecurity regarding my ideas and a fear of saying something wrong.*" (P13)
	Discomfort eased through supportive interactions.	"*Even though I felt uncomfortable with presenting in the first stage it became easier over time, as the interactions with my team, stakeholders and teachers developed."* (P7)

5.1 Emotional Engagement

Positive drivers of emotional engagement included motivation, supportive teamwork, trust, and shared ownership, as exemplified by the reflections from P4, P15, P19, and P26 shown in Table 1. A recurrent pattern emerged wherein multiple participants reported initial discomfort, manifesting as uncertainty toward open-ended problem-solving, which progressively evolved into confidence through cyclical iteration and peer support, as P15 noted. Emotional engagement followed a recurring stress-

to-growth pathway, highlighting how structured peer support, iterative learning, and inclusive team cultures can transform initial stressors into opportunities for development. For instance, P4 highlighted their motivation rooted in a growth-oriented mindset, where challenges were reframed as opportunities for skill acquisition and self-improvement. It was evident that team dynamics was the strongest predictor of emotional engagement. Participants who experienced positive emotional outcomes (e.g., P19 and P26) tended to benefit from balanced and effective collaboration. Conversely, those who encountered emotional challenges demonstrated the development of resilience. For example, P10 reflected: "*I felt both enthusiastic about our solution and frustrated by the lack of engagement from the group. Instead of letting my frustration hinder my progress, I channeled it into a productive task…which was a valuable learning experience*." Additionally, participants expressed pride in collaboration, highlighting the importance of psychological safety (e.g., P15's "*no stupid ideas*" rule) and democratic decision-making (e.g., P26's voting system). Team composition and dynamics played a pivotal role in shaping emotional engagement. It was observed that small, highly engaged teams fostered emotional well-being and productivity, whereas larger or unevenly contributing groups often induced stress.

5.2 Cognitive Engagement

Several cognitive engagement patterns emerged among participants throughout the course. First, metacognitive development emerged as a recurring theme, with participants articulating substantive cognitive shifts. For instance, P36's reflection depicted a progression from merely acquiring skills to engaging in more adaptive, collaborative, and reflective modes of thinking. Similarly, P12 described a transition from a "*solution-first*" to a "*problem-first*" approach, while P28 "*shifted from a linear to an iterative mindset.*" Second, the use of structured analytical tools demonstrably enhanced participants' critical thinking abilities. For example, P31 reflected on their ability to break down complex problems by applying structured analytical tools, such as the Fishbone Diagram, Systems Thinking, and Six Thinking Hats, to explore multiple perspectives. These analytical techniques provided much-needed structure for navigating problem spaces characterized by high ambiguity, effectively mediating the cognitive load associated with open-ended challenges. However, cognitive engagement tended to diminish when scaffolding frameworks were deemed impractical. A notable example is P35, who expressed clear resistance to the CBL approach, acknowledging its potential utility but critiquing it as employing "*non-effective methods*." This response suggests a potential misalignment between the pedagogical design and certain learner preferences, underscoring the importance of offering alternative or complementary frameworks to accommodate diverse cognitive and learning styles and to sustain engagement across a broader spectrum of students. Third, several participants highlighted the inclusive nature of CBL, particularly in supporting learners with specific educational needs. P5 shared that while traditional courses often presented difficulties due to their dyslexia, this CBL-integrated course uniquely supported students with dyslexia by recognizing and building on their strengths, "*such as creativity, visualization and innovation.*" This perspective was echoed by P20, who described CBL as "*refreshing*" and distinctly different from conventional teaching methods. By moving beyond conventional, text-heavy instruction, CBL creates opportunities for diverse learners to thrive, validating different cognitive strengths and learning preferences. Lastly, cognitive engagement among participants was characterized by an increased comfort with uncertainty and a heightened awareness of the broader implications of their learning. P34, for example, illustrated this through a shift from seeking immediate solutions to adopting a more thoughtful and reflective approach, accompanied by a growing ethical consciousness, particularly regarding the importance of designing "*inclusive and sustainable solutions.*"

5.3 Behavioral Engagement

Participants exhibited a range of behavioral engagement patterns, with diverse collaborative approaches reflecting varying degrees of structure, adaptability, and involvement. Echoing P17's reflection (see Table 1), some participants emphasized structured coordination and consistent communication to maintain project cohesion, while others adopted more flexible roles, stepping in where needed to support collective goals. Additionally, behavioral engagement was not always outwardly visible, as demonstrated by P13, where quieter participation stemmed from internal hesitations (e.g., fear of public speaking and making mistakes) rather than a lack of engagement. Over the duration of the course, as pointed out by P7, increased interaction with peers, stakeholders, and teachers gradually fostered greater comfort and participation, illustrating a developmental trajectory in

students' collaborative behaviors. Interestingly, cultural identity and interpersonal dynamics emerged as influential factors in shaping participants' engagement. For example, P37 shared a personal account of navigating cultural and social differences while collaborating with peers from a different cultural background. Despite being naturally articulate and confident in expressing ideas, P37 encountered difficulties in interpreting subtle group dynamics and adapting to the communication styles of more reserved teammates. These experiences prompted P37 to adopt a more intentional approach to listening, engage in structured collaboration, and become increasingly receptive to integrating diverse perspectives into their own thinking. The findings emphasize the critical role of adaptability in collaborative learning contexts. Participants who dynamically adjusted their roles and contributions (e.g., P17 and P37) were consistently more effective in navigating challenges and fostering successful collaboration. This adaptive behavior functioned not only as a compensatory mechanism for addressing team imbalances but also as a catalyst for individual skill development. In the context of CBL, where ambiguity and evolving demands are inherent, such responsive role-taking emerged as a key factor in sustaining team performance and achieving shared goals.

6. Discussion

Drawing on the findings, we revisit the two research questions and address them through the lenses of emotional, cognitive, and behavioral engagement to inform pedagogical practice.

In response to the first research question: **Emotionally**, students perceived engagement as a continuous progression, with emotional engagement in CBL being dynamic and evolving over time. Initial anxiety in facing complex, undefined problems gave way to motivation and confidence when peer support, psychological safety, and iterative learning were present. As P15 reflected, "I gradually developed a mindset that embraced uncertainty as part of innovation", highlighting the evolution from discomfort to adaptive confidence. Similarly, P4's growth mindset framed challenge as opportunity: "Even in difficult moments, I will be learning… and get new skills along the way." These patterns reflect a stress-to-growth pathway, aligning with Fredricks et al. [8], who position emotional engagement as involving not only interest and enthusiasm but also resilience and perseverance through discomfort. Team dynamics emerged as the most influential factor shaping emotional experience. Supportive collaboration, trust, and inclusive decision-making drove engagement and belonging. P19 described how "a supportive team kept me engaged," while P26 highlighted how voting ensured "everyone's voice mattered, even if I wasn't the loudest." These findings suggest that emotionally safe and democratically structured teams enhance not only motivation, but also agency and psychological security. **Cognitively**, students' reflections illustrate that cognitive engagement in the CBL-integrated course was a dynamic multidimensional experience. Participants demonstrated increasing metacognitive awareness, shifting from surface-level participation to deeper, reflective thinking. For example, P36 described moving beyond skill acquisition to understanding how to apply theory adaptively and collaboratively. These changes align with Fredricks et al. [8], who define cognitive engagement as sustained mental effort toward mastering complex ideas. The use of structured, analytical tools was central to students' development of critical thinking. P31 noted how these methods helped "break down root causes, not just symptoms," which enhanced their ability to navigate ambiguity. However, not all students responded positively; P35 critiqued the methods as "non-effective," highlighting the need for pedagogical flexibility. This suggests that cognitive engagement may suffer when scaffolding lacks alignment with students' learning preferences or needs. **Behaviorally**, students' reflections reveal that behavioral engagement in the CBL-integrated course was both adaptive and context-sensitive. Rather than fixed roles, students often navigated a range of involvement, adjusting their actions in response to team dynamics, communication needs, and personal comfort levels. P17 described playing a "flexible role" and emphasized "consistent communication" to support team cohesion, while P37 reflected on learning to adapt communication strategies to better align with more reserved peers. These behaviors demonstrate what Skinner and Belmont [22] identify as active engagement, which occurs when students demonstrate sustained effort, participation, and cooperation in response to social and instructional demands. Importantly, behavioral engagement was not always externally visible. P13 shared that quietness often stemmed from self-doubt, not disengagement, while P7 reported increased comfort and participation over time as relationships with peers and teachers developed. This development illustrates the role of relational trust in enabling behavioral growth and reflects Trowler's [23] argument that engagement is shaped by context and influenced by a sense of interpersonal belonging.

In addressing the second research question, several evidence-based implications for educators emerge, leading to actionable recommendations across the three dimensions of engagement. To

enhance **emotional engagement**: First, educators must intentionally design emotionally intelligent teams through thoughtful pedagogical strategies, particularly in teamwork and emotional scaffolding. Norms like "*no stupid ideas*" (P15) and inclusive voting practices (P26) should be established early to build trust. Second, educators should normalize emotional discomfort in CBL and provide structured reflection points, allowing students to reframe early anxieties as part of growth. Finally, peer scaffolding should be a core design element, as it transforms uncertainty into innovation and frustration into resilience. Overall, emotional engagement in CBL is not passive. It is a carefully designed and nurtured process. When educators support students' emotional journeys through inclusive teams, reflective structures, and open dialogue, engagement deepens both cognitively and emotionally. Students then emerge not just as learners but as resilient problem-solvers. To foster **cognitive engagement**: First, integrating cognitive scaffolds can empower students to manage open-ended challenges more effectively [9]. Second, allowing space for cognitive diversity is crucial. As P5 shared, CBL enabled them to leverage strengths associated with dyslexia, such as creativity and visualization. This highlights the value of inclusive design. Educators should therefore provide multiple entry points for problem-solving and reflection to ensure that students with varied cognitive profiles remain engaged. Finally, fostering ethical and future-oriented thinking is essential. P34's growing awareness of inclusive and sustainable design demonstrates how CBL can promote not only cognitive skills but also wider societal and moral reasoning [2]. Together, these findings show that when thoughtfully designed, CBL can foster cognitive engagement that goes beyond task completion to promote adaptive thinking, inclusivity, and ethical responsibility, which are key goals for 21st-century higher education. To strengthen **behavioral engagement**, the findings highlight the value of fostering culturally responsive, emotionally supportive, and flexible collaborative environments. Educators should normalize diverse behavioral expressions of engagement and design scaffolds that support both expressive and reserved learners. Encouraging adaptive role-taking, as seen in students like P37, promotes not only team balance but also personal development. Structuring collaborative processes to allow for dynamic participation, reflective dialogue, and interpersonal feedback can help students grow as communicators and collaborators. These are essential outcomes for success in CBL and beyond.

7. Conclusion and Pedagogical Recommendations

This study has explored how students perceived their engagement dynamics within a CBL framework and identified pedagogical strategies to enhance engagement across emotional, cognitive, and behavioral dimensions. Drawing on student reflections and guided by frameworks from Fredricks et al. [8] and Trowler [23], the analysis revealed that emotionally safe teams, structured cognitive tools, and flexible behavioral roles played central roles in sustaining engagement. Students demonstrated emotional growth through peer support, cognitive development via analytical tools, and behavioral adaptability through active collaboration and task ownership. These findings highlight the importance of designing CBL environments that address the full range of student engagement. When engagement is nurtured through inclusive group norms, such as "*no stupid ideas*," rotating team roles, and scaffolded cognitive tools, students evolve into reflective thinkers, resilient collaborators, and ethically minded problem-solvers. Peer support and constructive feedback can further reduce stress and strengthen coordination, especially for quieter students or those facing external demands.

Ultimately, this study reinforces that engagement in CBL is complex, holistic, and highly responsive to intentional pedagogy. With thoughtful design, CBL can move beyond participation to foster meaningful, transformative learning experiences in higher education. While these results are promising, they stem from a single course with a relatively small sample, which may limit the generalizability of the findings across different disciplines, institutions, or cultural settings. Additionally, although AI-assisted analysis enables rapid processing of large text datasets, it may overlook subtle linguistic nuances that human interpretation could capture. Future research could benefit from a longitudinal design or a mixed-methods approach to validate and build upon these insights.

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