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DEPARTMENT OF TEACHER DEVELOPMENT (ELAN)

CHALLENGE-BASED LEARNING FOR FOSTERING STUDENTS' SENSE OF IMPACT

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“Education is the most powerful weapon which you can use to change the world”

Nelson Mandela

All of my academic experiences have shaped me in ways that nothing else has. Thus, I always sensed that using education to make the world a better place is my calling. This graduation project allowed me to make my first contributions.

However, it would not have been possible without the help, wisdom, and support of some wonderful people. This letter is a tribute to them.

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What a journey.

ABSTRACT

As proactive societal impact has become a vital tenet of modern education, students and teachers are urged to use their learning experiences for making valuable contributions to society. However, to make such contributions, students must develop their sense of impact, a perception of power to make a difference. The educational framework of Challenge-based Learning (CBL) has great potential of strengthening the sense of impact in students. Nonetheless, CBL education needs to be guided and carefully designed. Therefore, this study formed design requirements and propositions for CBL education to foster students' sense of impact.

To come to these, analysis and exploration of three CBL cases was conducted within the context of the University of Twente. First, the analysis of the application of CBL features in the cases was administered. To support the case analysis, Mild, Moderate, and Intense CBL levels were defined for the components of Van den Akker's Curricular Spider Web model. Then, students' insights on how CBL courses can be designed to support their sense of impact were gathered through a reflection report analysis and interviews guided by the students' responses to pre-/post-CBL experience surveys. The data analysis resulted in preliminary design requirements and propositions, which were validated and refined according to what the teachers of the studied cases described as feasible in evaluation interviews.

As a result, nine design requirements for fostering students' sense of impact through CBL courses were developed. In addition, design propositions for each curricular component were defined, identifying CBL intensity levels that can support students in developing a sense of impact. The requirements and propositions are offered to teachers as support for the future design of CBL education.

Keywords: challenge-based learning, learner empowerment, sense of impact, course design

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1. INTRODUCTION

Our fast-developing world formed a culture of innovation in higher education (Lanford & Tierney, 2022). Such evolution was shaped by governmental and socioeconomic landscapes, development aspirations, and market dynamics (Gouda, 2020). In the past, education was mainly teacher-centred and focused on students acquiring academic skills (Gouda, 2020). However, over the years, higher education has been transformed by the competitiveness and the complexity of the 21st-century labour market into a more entrepreneurial student-centred environment (Gouda, 2020). While the development of entrepreneurial skills is still vital in higher education, universities across the globe have adopted a mission of proactively taking part and contributing to societal development (Chankseliani & McCowan, 2020). As a result, proactive societal impact became a vital tenet for modern education (Lanford & Tierney, 2022).

The urge for societal impact has caused the emergence of several innovative educational frameworks. One of such is Challenge-based Learning (CBL). CBL is a collaborative and hands-on framework for learning, where students, teachers, and stakeholders work with big societal ideas, ask essential questions, identify, explore, and solve real-world challenges, gain in-depth subject area knowledge, develop 21st-century skills, and share what they have learned with the world (Nichols et al., 2016). CBL is argued to be similar to earlier-developed educational frameworks like project-based and problem-based learning. However, CBL creates a more suitable environment for students to have a societal impact (Nichols et al., 2016; Yang et al., 2018; De Stefani & Han, 2022).

One of the higher education institutions that encourages societal impact and has adopted CBL into its educational practices is the University of Twente (UT). According to the UT's vision on education, the university endeavours to "stimulate a culture of personal development, enabling staff and students to make a valuable contribution to society" (University of Twente, n.d., p. 13). A way for the UT to facilitate the university's societal impact is developing the design of CBL courses to foster students in establishing a strong sense of empowerment and impact.

Learner empowerment describes learning individuals who are inspired and strongly motivated to act, make determined choices, and enrich their communities (Frymier et al., 1996; Etikariena & Widyasari, 2020). The dimension of empowerment that strongly relates to students' ability to have a societal impact is the intrinsic perception students develop as they feel that their actions and choices have the power to make a difference in their learning and their surroundings, called sense of impact (Frymier et al., 1996).

Several educational features common to CBL education (e.g., reflection, use of technology) showed a positive influence on students' perception of impact (Katz, 2002; Houser & Frymier, 2009; Ledbetter & Finn, 2013; Schmidt & Baumgarth, 2017; Santos et al., 2019; Etikariena & Widyasari, 2020). Nonetheless, it is unclear how CBL courses can be designed to facilitate institutions like the UT in fostering students' sense of impact and creating the desired societal impact. As described by Loohuis et al. (2021), to effectively introduce CBL into the university's practices, the framework must be integrated or adjusted to the ongoing education. Therefore, this project aimed to form design requirements and propositions for CBL courses that foster students' sense of impact within the context of the UT. This will inform and equip teachers and educational support staff who want to design CBL courses.

Furthermore, analysing how courses can foster students' sense of impact can provide a new perspective on the value of CBL for students and educators in higher education. Prior research on the effects of CBL environments in higher education explored the framework's influence on students' academic achievement and content knowledge transfer (Roselli & Brophy, 2006; Cordray et al., 2009; Hift, 2013; Malmqvist et al., 2015; Chanin et al., 2018; Rodriguez-Chueca et al., 2019), higher-order thinking skills (Yang et al., 2018; Yulianto et al., 2019), entrepreneurship skills (Gonzalez-Hernandez et al., 2020; Mulgan et al., 2016), and overall development of field competencies (Dieck-Assad et al., 2021). However, little research explores CBL's effects on students' intrinsic drives and perceptions of themselves. Purposefully designing CBL education to foster students' sense of impact and evaluating the effects of the educational design could considerably contribute to understanding the effects CBL has on students.

Therefore, the research question of this study was: *what are the design requirements and propositions for CBL courses that foster students' sense of impact?* Firstly, a literature review was conducted to define CBL educational components, clearly distinguish CBL from similar educational frameworks, and speculate how CBL courses could foster a sense of impact in students. Then, three UT CBL cases were analysed according to the educational components employed in the design. Consequently, a model of CBL intensity was developed, where mild, moderate, and intense applications of CBL educational features were defined to evaluate the intensity of CBL application in the courses. Then, quantitative and qualitative data analyses explored the sense of impact changes perceived by the students of each case. Moreover, the data revealed how the design of the courses influenced the students' sense of impact. Based on the collected data, preliminary design requirements and propositions were formed. Lastly, these were validated and refined according to evaluation interviews with the teacher and support staff involved in the design and execution of the analysed cases.

2. THEORETICAL FRAMEWORK

2.1 Challenge-Based Learning & Educational Design

Challenge-based learning (CBL) is a pedagogical framework that has the potential to empower students, as well as teachers, field experts, and community members, to actively address real, complex, and relevant-to-their-environment challenges while acquiring deep content knowledge and advanced soft skills (Apple Inc., 2011; Observatory of Educational Innovation, 2015; Nichols et al., 2016; Rodríguez-Chueca et al., 2019). A CBL experience is described in practical handbooks (e.g., Apple Inc., 2011; Observatory of Educational Innovation, 2015; Nichols et al., 2016) and scientific literature (e.g., Malmqvist et al., 2015; Cruger, 2017; Gallagher & Savage, 2020; Leijon et al., 2021) as a no one-size-fit-all educational framework. It is often argued that CBL has major process similarities with educational frameworks like project-based learning, problem-based learning, or general design thinking methodologies (Gibson et al., 2018; Conde, Rodríguez-Sedano, Fernández-Llamas, Jesus et al., 2020; Gallagher & Savage, 2020). However, certain educational features allow CBL to expand the similar frameworks and create a unique learning experience. To coherently differentiate CBL from project-based and problem-based learning and describe CBL educational features, Van den Akker's (2003) framework for curriculum design was used.

2.1.1 The Curricular Spider Web

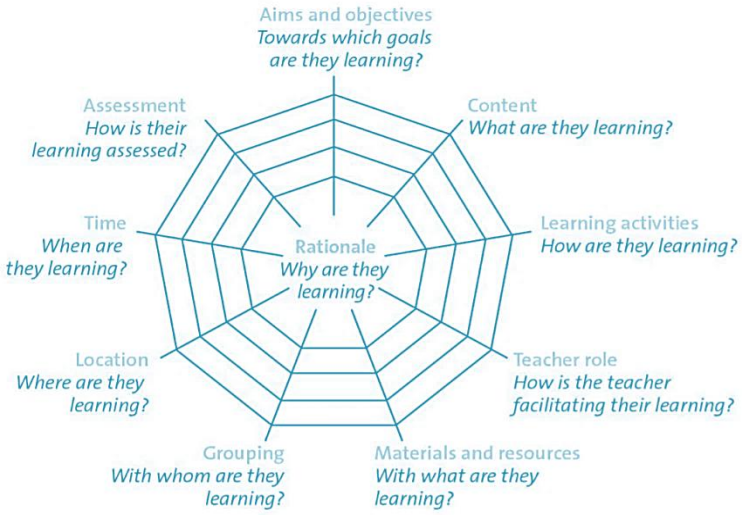
Strong curriculum design asks for the robustness of each curriculum component, tight interconnections between the curriculum components, and an alignment between these for creating balance and consistency within the learning plan (Van den Akker, 2009). To address these components, Van den Akker (2003) has introduced the Curricular Spider Web (Figure 1). According to the model, the learning rationale is the central link of the web and is surrounded by curriculum components such as learning aims and objectives, content, learning activities, teacher’s role, materials and resources, grouping, location, time, and assessment. The web metaphor illustrates the vulnerability of a curricular design: “every chain is as strong as its weakest link” (Van den Akker, 2009, p. 41). Thus, all ten components must be firmly

connected, providing consistency and coherence for the learning experience to ensure a successful curriculum plan (SLO: Netherlands Institute for Curriculum Development, 2018).

Figure 1

Curricular Spider Web

(SLO: Netherlands Institute for Curriculum Development, 2018 based on Van den Akker, 2003, p. 1)



Accordingly, the following section describes CBL educational components in light of the Spider Web model. Moreover, the main differences between project-based, problem-based, and challenge-based learning are discussed and summarised in Appendix A.

2.1.2 CBL Learning Rationale

The answer to the question “why are students learning?” accentuates the differences between CBL and similar educational frameworks. In project-based learning, students learn to solve a pre-defined problem by answering a driving question that embodies a project's goal (Mioduser & Betzer, 2007). In problem-based learning, students learn to solve a pre-defined ill-structured hypothetical case scenario (Hmelo-Silver, 2004). CBL expands the learning rationale of the two by calling students to learn to interact in and have an active immediate impact on the real world and wicked problems by designing solutions for actionable challenges of personal choice and relevance (Apple Inc., 2011; Nichols et al., 2016; Cruger, 2017; Conde, Rodríguez-Sedano, Fernández-Llamas, Jesus et al., 2020). Wicked problems are inherently

and socially complex, ever-evolving critical societal issues (De Stefani & Han, 2022) that cannot be ultimately solved, because the problem definition changes as the solutions create new ways of understanding the problem (Rittel & Webber, 1973). Notably, in CBL, students are presented with a pre-defined big idea (i.e., wicked problem) that can "often be correlated with curriculum themes" (Nichols et al., 2016, p. 32). Then, students define actionable challenges under the scope of the presented wicked problems (i.e., big ideas) that often require a local solution (Apple Inc., 2011).

To summarise, the CBL learning rationale includes interaction with the real world, active and immediate impact on the real world, broad big ideas, wicked problems, actionable challenges, challenges of personal choice and relevance, and solution designs.

2.1.3 CBL Aims and Objectives

When it comes to learning aims and objectives (LOs), CBL allows students to follow a flexible learning path in which they are independent in defining personal LOs (Apple Inc., 2011; Observatory of Educational Innovation, 2015; Nichols et al., 2016). Here, CBL adds to the similar educational frameworks to some extent. In project-based learning, students aim to generate and present a solution for a pre-defined project (Frank et al., 2003). In problem-based learning, students work to develop reasoning strategies relative to a pre-defined hypothetical problem (Hmelo-Silver, 2004). In both, students are bound to the scope of a project or a problem. In CBL, students are bound to their ideas of what they want to develop while learning. To form the LOs, students recognise the wealth of their existing knowledge and experience through facilitated reflection (Apple Inc., 2011). However, the acquisition of different 21st-century skills is usually offered as a broad learning objective defined by the teachers (Apple Inc., 2011; Nichols et al., 2016). Moreover, in CBL, students are usually activated to identify LOs related to the academic knowledge required to insightfully understand their challenges from various perspectives (Malmqvist et al., 2015).

In summary, in CBL, students are independent in defining personal LOs. To support the formation of personal LOs, student reflection on existing knowledge and skills is facilitated, and academic knowledge and 21st-century skills are encouraged.

2.1.4 CBL Content Knowledge

Content knowledge students gain within a CBL course somewhat coincides with similar educational frameworks. However, the subtle differences between them are crucial for defining the frameworks. Literature shows that project-based and problem-based learning courses can be designed to allow students to focus on gaining disciplinary, multi-disciplinary, inter-disciplinary, and trans-disciplinary knowledge (Perrenet et al., 2000; Mioduser, 2007; Leblanc, 2009; Stentoft, 2017; Brassler & Dettmers, 2017; Pindado et al., 2018; Braßler & Schultze, 2021; Century et al., 2020;). Although in CBL, students also gain disciplinary and multi-disciplinary knowledge, the framework encourages learners to go beyond their discipline and aspire to build an inter- or a trans-disciplinary knowledge base (Dieck-Assad et al., 2021).

In addition, the scope and type of information students gather as well as how the information gathering is approached highlight the differences between the three frameworks. In project-based learning, a group of students together gain academic knowledge defined by a presented project's scope (Barron et al., 1998), while in problem-based learning, each student is focused on gaining often abstract academic knowledge and mainly reasoning strategies defined by a presented problem's scope (Barron et al., 1998; Yew & Schmidt, 2011). In CBL, the content knowledge is defined by what the group decides they need to know for an in-depth investigation of the challenge (Apple Inc., 2011; Nichols et al., 2016). Then, each student individually gathers disciplinary content knowledge and soft skills, which are defined by the challenge investigation needs (Apple Inc., 2011; Nichols et al., 2016). After, the group comes together to combine the gathered information (Apple Inc., 2011; Nichols et al., 2016).

Therefore, CBL content knowledge is characterised by students independently gathering disciplinary knowledge (content and soft skills), a group of students combining their

disciplinary knowledge and building an inter-/trans-disciplinary knowledge base, and the scope of the knowledge being defined by students' challenge investigation needs.

2.1.5 CBL Learning Activities

CBL learning activities present how the framework extends similar educational structures. In project-based learning, students collaborate to inquire and learn within an often single-loop prediction, observation, and explanation cycle to complete a project (Hmelo-Silver, 2004). In problem-based learning, students formulate and analyse a presented problem through fact-identification, build reasoning strategies for generating hypothetical solutions, revisit the problem, and reflect on what they have learned (Hmelo-Silver, 2004; Kokotsaki et al., 2016). The learning activities of CBL partially employ and usually expand the features of project-based and problem-based frameworks.

A CBL experience is usually described by nine steps, categorised by three main phases that are accompanied by a cycle of documenting, reflecting, and sharing (Nichols et al., 2016). Figure 2 demonstrates the CBL learning process, which is also extensively described in Appendix B.

Figure 2

Challenge-based Learning Framework (Nichols et al., 2016, p.11)

In short, when starting their CBL experience, students individually engage with and try to understand a presented big idea, a wicked problem (Apple Inc., 2011). By understanding the wicked problem, students identify various challenges they can immediately act upon (Apple Inc., 2011; Nichols et al., 2016). Then, based on the challenges, students, teachers, and stakeholders of different disciplines and backgrounds form a multidisciplinary group (Apple Inc., 2011; Gallagher & Savage, 2020; Dieck-Assad et al., 2021; Leijon et al., 2021). The group collaborates to deeply investigate and fully understand their challenge while guided by their learning goals and guiding questions (Nichols et al., 2016). The investigation can take place via optional teacher-advised guiding resources and activities (e.g., participating in expert talks, lectures, and seminars, conducting research and interviews, making stakeholder analyses and calculations), but the students are strongly encouraged to go beyond the provided material (Nichols et al., 2016). Notably, students must be able to freely and actively engage with a large group of challenge-relevant stakeholders (Nichols et al., 2016) while investigating the challenge. A solid inter-/trans-disciplinary knowledge base is the outcome of such an investigation (Dieck-Assad et al., 2021). The groups are encouraged to use all the gathered knowledge to design multiple creative and innovative solutions to their challenge. Then, teams are asked to choose the most suitable solution and implement it in the real world (Malmqvist et al., 2015; Yang et al., 2018). After the implementation, the groups evaluate the solution by analysing its impact and effectiveness (Nichols et al., 2016; Yang et al., 2018). With every step, students are prompted to document all the processes, for instance, using video and audio journals, work plans, concept maps, and reports (Apple Inc., 2011). Moreover, every step is finalised by an opportunity to reflect on and document the learning process (Apple Inc., 2011; Cruger, 2017). At the end of the project, all the documents and reflection outcomes need to be shared with the world via open-source platforms (Apple Inc., 2011). This cycle will prompt students to constantly track their progress, reflect on their actions, and share their experiences with a broad learning community (Apple Inc., 2011).

Therefore, the main features of the CBL learning activities can be summarised by the following statements: individual students engage with a wicked problem (i.e., big idea),

individual students identify immediate actionable challenges, students form a group based on their actionable challenge, the group deeply investigates a challenge (incl. free engagement with relevant stakeholders), the group designs a consciously chosen solution, the group directly implements the solution in the real world, the group evaluates the effects of the solution, a cycle of reflecting, documenting, and sharing with the public follows the process.

2.1.6 CBL Teacher Role

The teacher role in CBL is often described as uncommon for education. In project-based learning, a teacher shares expertise and knowledge; however, the teacher is the ultimate knowledge facilitator who presents relevant content and expects the students to employ the presented information when approaching the project (Frank et al., 2003; Mioduser & Betzer, 2007). In problem-based learning, a teacher is often a role model for strategising and thinking (Hmelo-Silver, 2004). Whilst, three overarching roles typically describe a CBL teacher.

Firstly, a CBL teacher is a learning supervisor. Such a supervisor manages expectations for all the agents involved (i.e., students, stakeholders, other teachers) and facilitates the process (Nichols et al., 2016). This role is also consistent in project-based and problem-based learning (Ribeiro & Mizukami, 2005; Kokotsaki et al., 2016).

Secondly, in CBL, a teacher becomes a group coach who acts as a learning guide and prompts questioning and reflection (Conde, Rodríguez-Sedano, Fernández-Llamas, Gonçalves et al., 2020). The coach also participates in the learning process and becomes a co-researcher and a co-designer (Baloian et al., 2006; Chanin et al., 2018) whose existing expertise is confronted due to the wicked nature of the challenge (Nichols et al., 2016). Contrary to this, in project-based and problem-based learning, a teacher often becomes a project manager or a learning tutor who guides and directs the learning (Hmelo-Silver, 2004; Kokotsaki et al., 2016).

Lastly, in CBL, some teachers act as field experts and professional advisers. They are also expected to present their knowledge and advise student groups by providing an expert

perspective on the challenge keeping in mind students' independence within the learning process and its outcomes (Dieck-Assad et al., 2021).

Accordingly, CBL teacher roles include a learning supervisor (an expectation manager, a process facilitator), a coach (a learning guide, a co-researcher/co-designer/co-learner), and a field expert/professional adviser.

2.1.7 CBL Materials and Resources

Materials and resources students use throughout their CBL experience also add to project-based and problem-based frameworks. In project-based learning, specific learning materials are prepared by the instructor to describe the compulsory knowledge to be gained (Mioduser & Betzer, 2007). In problem-based learning, students are often free to identify and explore various learning resources (Hmelo-Silver, 2004). CBL expands on both as students are free to identify and explore various learning materials according to their personal learning objectives. The resources used within a CBL course are often referred to as guiding resources (Apple Inc., 2011; Nichols et al., 2016). Coaches can guide their teams in navigating good quality resources by offering a carefully compiled, focused set of relevant and credible resources (e.g., scientific literature, books, podcasts, websites, videos, databases, and contact information of experts) (Apple Inc., 2011; Pepin & Kock, 2021). However, all the presented guiding resources are optional for students to use. Usually, students are strongly encouraged to go beyond the offered material by independently investigating the various disciplines of their teams and compiling their own set of guiding resources (Tang & Chow, 2020; Pepin & Kock, 2021).

Moreover, when describing the materials and resources in CBL, the use and access to technology are often mentioned. However, project-based learning also describes the use of technical aids relevant to the learning process, such as tools for supporting project management, data collection, analysis, and modelling, and the arrangements of the collected information (Kokotsaki et al., 2016). In problem-based learning, a structured whiteboard is mentioned (Hmelo-Silver, 2004). In CBL, constant and flexible access to state-of-the-art

technology (Apple Inc., 2011; Nichols et al., 2016; Gibson et al., 2018; Gallagher & Savage, 2020) is mentioned. Gallagher and Savage (2020) summarise that in CBL, technology does not only support challenge-related communication and investigation but facilitates students in developing innovative state-of-the-art solutions to wicked problems (Gallagher & Savage, 2020). For example, by encouraging students and teachers to use state-of-the-art technology, CBL education supports open communication and collaboration, engagement with the public, information research, access, and sharing (Gibson et al., 2018).

Thus, CBL materials and resources are characterised by teacher-prepared guiding resources, optional use of the guiding resources, encouraged exploration of additional materials, and open access to state-of-the-art technology.

2.1.8 CBL Grouping

In project-based learning, student groups learn by collaborating with peers and sometimes local community members (Hmelo-Silver, 2004; Kokotsaki et al., 2016). There, a client is often involved as someone who gives feedback during the process and evaluation (Erdogan & Bozeman, 2015). In problem-based learning, students usually bring knowledge to their group and collaborate to approach the problem; since the problems are generally abstract scenarios, no clients or stakeholders are involved in the learning group (Hmelo-Silver, 2004). A model CBL group, however, highlights the innovativeness of the framework as it consists of students, *and* coaches (i.e., teachers), *and* stakeholders.

The role of a coach in a learning group has been described in the teacher role section as a co-learner/co-researcher/co-designer. Interestingly, the role of a stakeholder in a CBL group is of the same nature. CBL stakeholders are occasionally referred to as challenge providers who have a stake in the big idea and thus, are open to bringing it to the classroom and actively participating in the learning process (Nichols et al., 2016; Gudonienė et al., 2021; De Stefani & Han, 2022). As the challenge providers have the closest connection to the presented big idea, they at times become instructors who support the group in understanding the big idea and have the knowledge to validate the existence of the formulated challenges

(Nichols et al., 2016). However, the importance of the challenge providers to be open to building innovative ideas together with students and teachers, shifting their perspectives and beliefs, and generally becoming an active co-learner in a group is emphasised for the prosperity of a CBL experience (Nichols et al., 2016; Chanin et al., 2018).

As co-learning is often mentioned in CBL, so is the inter-/trans-disciplinary collaboration. Although such collaboration is possible in project-based and problem-based learning, there, groups can be both disciplinary and multi-disciplinary (Mioduser, 2007; Leblanc, 2009; Stentoft, 2017; Brassler & Dettmers, 2017; Century et al., 2020; Braßler & Schultze, 2021). To foster inter-/trans-disciplinary collaboration, a CBL group must consist of students from various disciplines so they can teach each other about the perspectives within their discipline to be able to cooperate when designing sustainable solutions (Observatory of Educational Innovation, 2015; Nichols et al., 2016; Gallagher & Savage, 2020; Dieck-Assad et al., 2021).

In summary, the features of CBL grouping are a multidisciplinary group of co-learners consisting of students, coaches, and stakeholders (i.e., challenge providers) and a fostered inter-/trans-disciplinary collaboration.

2.1.9 CBL Location and Time

Location and time of CBL also present how the framework becomes more than project-based and problem-based learning. Project-based learning describes semi-flexible time and location for learning activities, including classroom learning, self-regulated learning, and groupwork (Frank et al., 2003). Often, students can engage with the real world but frequently within a fixed time and location. Problem-based learning describes a more flexible time and location for learning activities, mainly including self-regulated learning (Hmelo-Silver, 2004). However, students must also join scheduled classroom discussions (Hmelo-Silver, 2004). A CBL experience “extends the classroom environment and necessitates access to the real world” (Nichols et al., 2016, p. 19). As learning continuously happens in the real world, the need for flexible time and location is created (Nichols et al., 2016). Moreover, this flexibility is

also strengthened by the nature of the guiding resources and activities since students must be able to flexibly decide when they want to participate in the offered learning activities, engage with self-directed learning, and collaborate with their groupmates.

To facilitate the described learning flexibility, a collaborative virtual workspace, where students can track their progress, collaborate, store documents, and flexibly learn should be available 24/7 (Nichols et al., 2016). In addition, a physical CBL workspace must allow for flexibility for learners to move efficiently from individual to group work and use available tools (Nichols et al., 2016).

In essence, CBL time and location are flexible for learning in the real world, engaging with the offered learning activities, and immersing in self-regulated learning and group work. A collaborative virtual and/or physical workspace is constantly accessible to students to foster learning flexibility.

2.1.10 CBL Assessment

In project-based learning, summative assessment mainly includes an evaluation of a project product administered by a teacher and/or a client (Erdogan & Bozeman, 2015). In problem-based learning, students' "deep learning of foundational knowledge and skills as well as mastery of the problem-solving processes" are mainly assessed (Chian et al., 2019, p. 3). In CBL, the challenge solution and content knowledge and skills acquisition are only a part of the assessment since more emphasis is often put on evaluating the learning process (Nichols et al., 2016). Interestingly, students and teachers are co-assessors of the learning process and together define the assessment procedure and criteria (Nichols et al., 2016; Cruger, 2017). Despite such freedom, certain expectations are posed for the assessment criteria. They must evaluate students' progress and decision-making. The student-defined learning objectives usually support the formation of the criteria, and the circular process of reflecting described by the learning activities evaluates the achievement of the learning goals (Nichols et al., 2016). Moreover, as the CBL learning activities require students to evaluate the effects of their solution, they are also encouraged to share successes and failures since both could support

future learners' decision-making (Nichols et al., 2016; Yang et al., 2018). Therefore, the ability to critically reflect on the process's successes and failures usually becomes a part of the assessment criteria (Apple Inc., 2011).

Nonetheless, challenge solutions could also play a part in CBL assessment. When evaluating CBL solutions, attention is usually paid to the design's creativity, innovation, and feasibility (Yang et al., 2018; Gallagher & Savage, 2020).

Hence, CBL assessment is characterised by the evaluation of a learning process, student and teacher-defined criteria (incl. students' progress, decision-making, solution creativity, innovativeness, and feasibility), and a critical reflection on process successes and failures. Moreover, students and teachers act as co-assessors of the process and together choose the assessment procedure,

Therefore, the CBL educational design provides an exceptional combination of educational features which are assumed to prompt real-world learning with a real-world impact.

2.2 Learner Empowerment

CBL, especially at the UT, aims to allow students to actively contribute to society. First, however, empowerment needs to be fostered to stimulate students to work with real-world communities and have real-world impact. Learner empowerment is a condition in which learning individuals feel inspired and strongly motivated to act and control the process and outcomes of their actions (Frymier et al., 1996). There are three dimensions to learner empowerment: 1) sense of competence, 2) sense of meaningfulness, and 3) sense of impact. In learner empowerment, competence refers to "the degree to which a person can perform task activities skilfully when they try" (Thomas & Velthouse, 1990, p. 672). Meaningfulness refers to the intrinsic value of the task goal in relation to an individual's ideals or standards (Thomas & Velthouse, 1990). Finally, the sense of impact refers to students' perception of their power to "make a difference" (Frymier et al., 1996, p. 184) and their perceived ability to make choices as they feel that their choices have an impact on their surroundings. As was described at the beginning of the study, developing this strong perception of impact is central to yielding

the active societal impact that innovative higher education institutions like the UT aim to establish in their educational practices when choosing to apply CBL. Therefore, this study focuses on fostering students' sense of impact through CBL courses.

2.3 CBL Education for Developing Sense of Impact

Studies have presented that students' sense of impact is developed via educational design features common to CBL. Scientific literature describes educational elements categorised by the CBL learning rationale, aims and objectives, teacher role, materials and resources, and assessment (as identified in the Curricular Spider Web) as crucial for supporting students' sense of impact. Thus, the following section describes the effect of these components on the sense of impact levels in students.

2.3.1 CBL Learning Rationale for Sense of Impact

Research showed that students' sense of impact increases in pedagogical approaches that expose students to real-world interactions and active experiences (Santos et al., 2019). As previously described, when following CBL education, students learn to interact with the real world and have an active and immediate impact on it. Santos et al. (2019) explain that by having concrete real-world experiences, students can make a significant difference in actual communities. Moreover, such learning experiences can reduce the psychological distance between the learned content and practice as they show how acquired knowledge can be directly applied in real life (Santos et al., 2019). Accordingly, CBL's emphasis on real-world interactions and active impact can presumably increase students' sense of impact.

2.3.2 CBL Aims & Objectives, Activities, and Assessment for Sense of Impact

Additionally, Santos et al. (2019) highlight the importance of promoting reflection in increasing students' sense of impact. Reflective environments create an opportunity for students to be aware of the impact their actions may have on the personal and professional lives of the people around them, consequently increasing their sense of impact (Santos et al., 2019). Within CBL, reflection is crucial. First, reflection is facilitated as students form personal

learning objectives. Moreover, a cycle of reflection accompanies all the CBL learning activities. Furthermore, students also are expected to critically reflect while evaluating their learning process and outcomes. Therefore, reflection tracked in CBL aims and objectives, learning activities, and assessment might positively influence students' sense of impact levels.

Aside from reflection, the attention paid to the innovation and creativity of the challenge solutions in assessment can potentially foster students' sense of impact. Etikariena and Widyasari (2020) concluded that students' sense of impact is firmly formed by educational environments, where students feel supported in their creativity and innovation. Promoting innovation and creativity in education allows students to take risks and implement new methods, procedures, or approaches when working on tasks (Etikariena & Widyasari, 2020). Students realise that their choices and actions directly impact their performance and outcomes. Therefore, the creativity and innovation criteria of the challenge solutions are assumed to positively affect students' sense of impact.

2.3.3 CBL Teacher Role for Sense of Impact

Furthermore, instructor communication behaviour showed to have a positive influence on students' feelings of impact. Houser and Frymier (2009) revealed that highly immediate and more approachable teachers make students feel they have more influence in the classroom. Approachable teachers increase students' engagement in the classroom as students feel more eager to pay attention, express ideas, and brainstorm together with the teacher increasing their perception of influence on the learning process (Houser & Frymier, 2009). Thus, a CBL coach's co-learner/co-designer/co-researcher role seemingly can increase a teacher's immediacy and positively affect students' sense of impact.

2.3.4 CBL Materials and Resources for Sense of Impact

Moreover, it was found that students are most likely to feel that their participation makes a difference when teachers encourage them to use technology for learning (Ledbetter & Finn, 2013; Schmidt & Baumgarth, 2017). When students have the freedom to choose from various personal and institutional IT infrastructures, they feel they are making a difference in the class

and have greater control of the learning process as they choose preferred learning platforms and electronic tools (Katz, 2002). Hence, CBL's emphasis on continuous access to state-of-the-art technology is expected to positively affect the sense of impact levels.

2.3.5 CBL Content Knowledge, Grouping, Location, and Time for Sense of Impact

No specific indications of content knowledge, grouping, location, and time components influencing students' sense of impact were revealed within this literature review.

Therefore, it is expected that embracing the features common to CBL learning rationale, aims and objectives, teacher role, materials and resources, and assessment as characterised by the CBL framework will positively influence students' sense of impact.

3. RESEARCH QUESTION AND MODEL

This study's goal was to formulate precise design requirements and propositions to assist educators in (re-)designing CBL courses for developing students' sense of impact. Design requirements and propositions are instruments that can steer the design of a course (McKenney & Reeves, 2019). Design requirements describe what should be accomplished by a course in a specific setting or for reaching a specific goal, while design propositions present possible ways of achieving the requirements (McKenney & Reeves, 2019). Therefore, the study's research question was: *what are the design requirements and propositions for CBL courses that foster students' sense of impact?*

4. RESEARCH DESIGN AND METHODS

4.1 RESEARCH DESIGN

To formulate design requirements and propositions, case context and student needs analyses (as described by McKenney & Reeves, 2019) were conducted based on the following UT cases: 1) New Technology Business Development (NTBD) bachelor level minor, 2) Leading Systematic Change (LSC) challenge package (consisting of two courses) within a master insert programme (extracurricular), and 3) Systems Engineering in Construction (SEiC) master level (curricular) course.

The context analysis was aimed at recognising and analysing the conditions, facilities, and resources relevant to the current application of CBL features in the cases. The analysis helped the researcher collect insights into how CBL components are incorporated into the current education at the UT and what boundary conditions CBL has within the educational institution regarding sense of impact. This consequently supported the student needs analysis.

The needs analysis aimed to investigate how students perceive their CBL experience, its effect on their sense of impact, and what they believe CBL education needs to have to foster their sense of impact. The analysis results created an understanding of how, according to the students, CBL courses can be designed to support sense of impact.

As a result of the analyses, preliminary design requirements and propositions for fostering students' sense of impact were formed. Design requirements and propositions change over time as they usually are validated, refuted, or altered (McKenney & Reeves, 2019). Therefore, the design requirements and propositions concluded by the study were also evaluated and refined with the case teachers to fit the UT context.

4.2 RESEARCH METHODS

4.2.1 New Technology Business Development Minor

4.2.1.1 Case Context Analysis. To understand the educational context of the minor, course-provided documents were collected for data analysis.

Procedure. Firstly, one of the minor teachers was invited for a short introductory meeting, where the researcher presented the goals, the design, and the procedure of this study. The teacher briefly described the educational design to explore whether the minor fits the requirements of this study. Then, various ways of collaborating to collect data for the research were discussed.

Before any data was accessed, an application had been submitted to the University of Twente's BMS Ethics Committee (application No. 220032). Once the committee approved the study's data handling methods, the data collection started.

Consequently, the teacher provided access to the minor's Canvas page. Notably, no student data was accessed during this phase of the study's case analyses.

Instruments. For NTBD, analysed documents included the minor's informational brochure, the minor's description in the university's study information system (OSIRIS), the syllabus, the assessment scheme, the minor's timetable, and the kick-off presentation. The documents were derived from the university's website, timetable, and the minor's learning management system (Canvas).

4.2.1.2 Students' Needs Analysis. To gain initial insight into students' needs regarding CBL course design for fostering sense of impact and gather input for the design

requirements and proposition, the NTBD minor's students' reflection reports were collected for data analysis.

Procedure. During the introductory meeting, it was discussed that the minor was already ending. Therefore, the teacher suggested collecting student data from the optional reflection assignments. Hence, a decision was made for the researcher to create a self-reflection report form for students that allowed them to present their perceptions of the educational components applied in the minor and how they affected students' sense of impact. The form was firstly shared with the teacher, who presented it to the students as the final reflection assignment. After, the teacher was asked to remove student names from the submitted reports to ensure anonymity and share them with the researcher.

Respondents. 26 students' reflection reports were used as input for the needs analysis.

Instruments. The self-reflection report form (Appendix C) questions were designed to prompt students' reflection on how the course set-up affected their sense of impact as they are based on the Learner Empowerment instrument's sense of impact dimension (Frymier et al., 1996). For example, the questions "did you see your coach and the module supervisor as your superior or as your peer in learning? why one or the other?" were based on the items that explored the relationship between the course instructor and the students (e.g., "I can influence the instructor", "I can make an impact on the way things are run in my class", "I can make a difference in the learning that goes on in this class").

4.2.2 Leading Systematic Change Challenge Package

4.2.2.1 Case Context Analysis. Similarly to the previous case, documents of the challenge package were collected for conducting the context analysis.

Procedure. Firstly, the researcher contacted one of the challenge package supervisors to schedule an introductory meeting. The three supervisors met weekly, so the researcher was invited to one of the meetings to present the goals, the design, and the procedure of the current

study. Then, similarly to the previous case, various ways of collaborating for data collection were discussed. Consequently, course documents were accessed and collected.

Instruments. For LSC, analysed documents included the challenge package's promotional and OSIRIS descriptions, the syllabi of the two modules within the package, the assessment criteria of both modules, the timetables, and the introductory presentations. These were collected from the university's website, timetable, and the Canvas environment of the challenge package.

4.2.2.2 Students' Needs Analysis.

Unlike the NTBD minor, the timeframe of the LSC courses fitted within the current study's data collection. Therefore, it was possible to collect quantitative pre-/post-test data via an online survey. The survey allowed the researcher to build a preliminary understanding of how the students' sense of impact changed throughout the CBL experience. To expand on the survey results, a group interview was chosen for further data collection as the method allows participants to share, discuss, elaborate, and expand on their perceptions or competing viewpoints (Allen, 2017). Thus, the group interview provided more in-depth input for the needs analysis.

Procedure. Firstly, the researcher joined the last 20 minutes of the first LSC session to briefly introduce herself, the study goals, and the value of the study. Then, the supervisor who was leading the session posted the pre-CBL experience survey link in the Canvas announcements and the students were asked to voluntarily fill out the questionnaire within the given time.

The LSC supervisors planned data collection for their research project on creating value for challenge providers by integrating one challenge into two CBL courses. To avoid overloading the students with surveys and interviews, the decision was made to collaboratively collect student data. Thus, a combined survey was created, where students voluntarily completed a post-test for this study and answered some questions for the supervisors' research. The survey was distributed online via the Canvas announcements after the final assessment and a few days before the final LSC evaluation session planned by the

supervisors. During this session, the researcher had a group interview with the LSC students without the teachers' presence.

During the discussion, the students were firstly reminded of the goals of the current study and made aware of the learner empowerment and sense of impact concept definitions. Secondly, to activate reflection, the students were asked to briefly ponder how previously followed courses affected their sense of impact. To facilitate the reflection, a digital collaborative platform called Wooclap was used. First, the students were asked to indicate whether their sense of impact decreased or increased in the past two courses. Then, the researcher presented the differences between their pre-LSC and post-LSC survey results. After that, the students were asked to reflect on which parts of the LSC modules' educational design affected the presented changes. The reflection was also facilitated by Wooclap, where students posted various educational features of the courses that supported their sense of impact levels. The digital platform recorded the responses and presented them to the group. The responses were used as a guide for the discussion. In the discussion, the students also mentioned which parts of the courses can be improved to foster their sense of impact.

Respondents. Six students who followed both LSC courses filled out the pre-test survey, and four of them responded to the post-test. However, all the six students participated in the group discussion.

Instruments. For the pre-/post-tests, the sense of impact factor items were extracted from the revised Learner Empowerment questionnaire, where the sense of impact factor's reliability was defined to be .95 (Frymier et al., 1996). The extracted sense of impact scale consists of 16 items and is based on a four-point Likert scale (from 0 (never) to 4 (very often)). Both tests were shared via an online survey distribution tool called Qualtrics. The surveys contained an introductory message describing the study and data management. After the message, the respondents were asked to indicate data usage consent. Then, respondents were asked to consider their regular education for the pre-test while keeping their CBL experience for the post-test. The respondents were requested to share their email addresses

to connect the pre-/post-test data. The structure and the questions of the survey are presented in Appendix E.

With regard to the group interview, the information relevant to the discussion was presented to students via a PowerPoint presentation. The student reflection and discussion were facilitated by Wooclap and were slightly guided by the Curricular Spider web components. The content and the structure of the group interview discussion tools are presented in Appendix F. The interview data was registered in a notetaking form (Appendix D) and the described digital platform to assure the students of the response anonymity and safety.

4.2.3 Systems Engineering in Construction Course

4.2.3.1 Case Context Analysis. Correspondingly to the other two cases, the documents describing the educational context of the course's CBL application were collected as input for the context analysis.

Procedure. The researcher got in touch with the course teacher and scheduled an introductory meeting, where the goals, the design, and the procedure of the study were presented, and data collection was discussed. Consequently, the researcher accessed and collected necessary data.

Instruments. Like in the previous two cases, analysed SEiC documents included the CBL part's OSIRIS and Canvas descriptions, the CBL project guide and assessment criteria, the timetable, and the kick-off presentation. The documents were derived from the university's website, timetable, and the course's Canvas.

4.2.3.2 Students' Needs Analysis. Similarly to the LSC case, SEiC students' sense of impact needs were explored through pre-/post-survey data and interview discussions.

Procedure. The teacher invited the researcher to the CBL project kick-off session, where five minutes before the session break were devoted to the data collection. First, the researcher briefly introduced herself, the study goals, and the value of the study while providing a QR code to the pre-CBL experience survey. Then, the students were asked to voluntarily complete the questionnaire within the given time.

Similarly, the researcher was invited to the final presentation session to collect the students' post-CBL experience responses to the survey. This data was collected before the students were made aware of their grades.

After the pre-/post-data was matched and analysed and the course was fully finalised, the students were invited to focus group interviews. However, three individual interviews were conducted instead due to a lack of responses.

The interview structure fully imitated the one described for the LSC case. One interview was conducted in person, and two were held online according to the students' preferences and convenience.

Respondents. In this case, 19 students filled out the pre-test survey, and 11 responded to the post-test. 11 students were invited for the focus group interviews. However, only three students responded and were individually interviewed. These students experienced moderate sense of impact changes and appeared to represent the perceptions of students whose sense of impact changed only to some extent as they described educational factors that had a positive and negative influence on their sense of impact as well as the factors that maintained their perceptions of impact.

Instruments. The needs analysis instruments described in the LSC case were also used for the quantitative and qualitative data collection in the SEiC case (Appendices E-D).

4.2.4 Validating and Refining Design Requirements and Propositions

The earlier described needs analyses of the study helped define student-desired design requirements and propositions. However, the teachers' perspectives regarding these are essential to consider because they are well-informed to validate and evaluate the feasibility of adhering to the proposed design requirements and propositions when (re-)designing courses within the context of the UT. Therefore, evaluation interviews with case teachers were conducted to validate and refine the formed design requirements and propositions.

Procedure. After the case and needs analyses were concluded, the case-contact teachers received an email from the researcher presenting their case analysis report and inviting them for an evaluative discussion.

Firstly, the NTBD teacher was interviewed. This teacher was presented with a summary of how the minor's students' sense of impact changed. The main educational features that appeared to have affected the changes according to the students were highlighted. Then, the teacher was presented with a list of design requirements and propositions based on the overall study results. The teacher was asked to reflect on whether these can guide future CBL educational designs. In addition, the teacher in the lead of the minor design was also open to an interview after the researcher shared a summary outlining the results of NTBD students' needs analysis and the formed design requirements and propositions. During the interview, the minor designer was also asked to reflect on the feasibility of what was proposed by the study and suggest ways of achieving the presented design requirements. In addition, the teacher and the supervisor were asked for permission to use the title of the minor when describing the case in this study.

Secondly, the research team working on the LSC challenge package (i.e., LSC supervisors, research project manager, and an educational adviser with CBL expertise) were interviewed. Since the results summary proved helpful for such an interview discussion, the researcher shared the LSC-specific results summary outlining the study results and the design requirements and propositions formed based on the results of all three cases beforehand. The case and needs analysis reports allowed the interview participants to prepare for the discussion and focus on the most striking results during the discussion. The permission for using the title of the challenge package was also received.

Lastly, the SEiC course teacher was interviewed. The procedure of the interview was identical to the LSC one.

Respondents. In total, three interviews were conducted with two NTBD teachers, five members of the LSC challenge package team (i.e., three teachers, one project manager, and one CBL expert/educational adviser), and one SEiC teacher.

Instruments. Appendix G exhibits the structure of the interviews, while Appendices I-N present the context and needs analysis reports that the teachers received. The interview responses were registered via the notetaking form presented in Appendix D.

4.2.5 Data Analysis

In this study, qualitative and some quantitative data was collected. Qualitative data included course documents for context analyses, students' self-reflection reports, a student group interview, individual student interviews, and teacher interviews. Quantitative data includes students' pre-/post-test survey results.

4.2.5.1 Qualitative Data Analysis

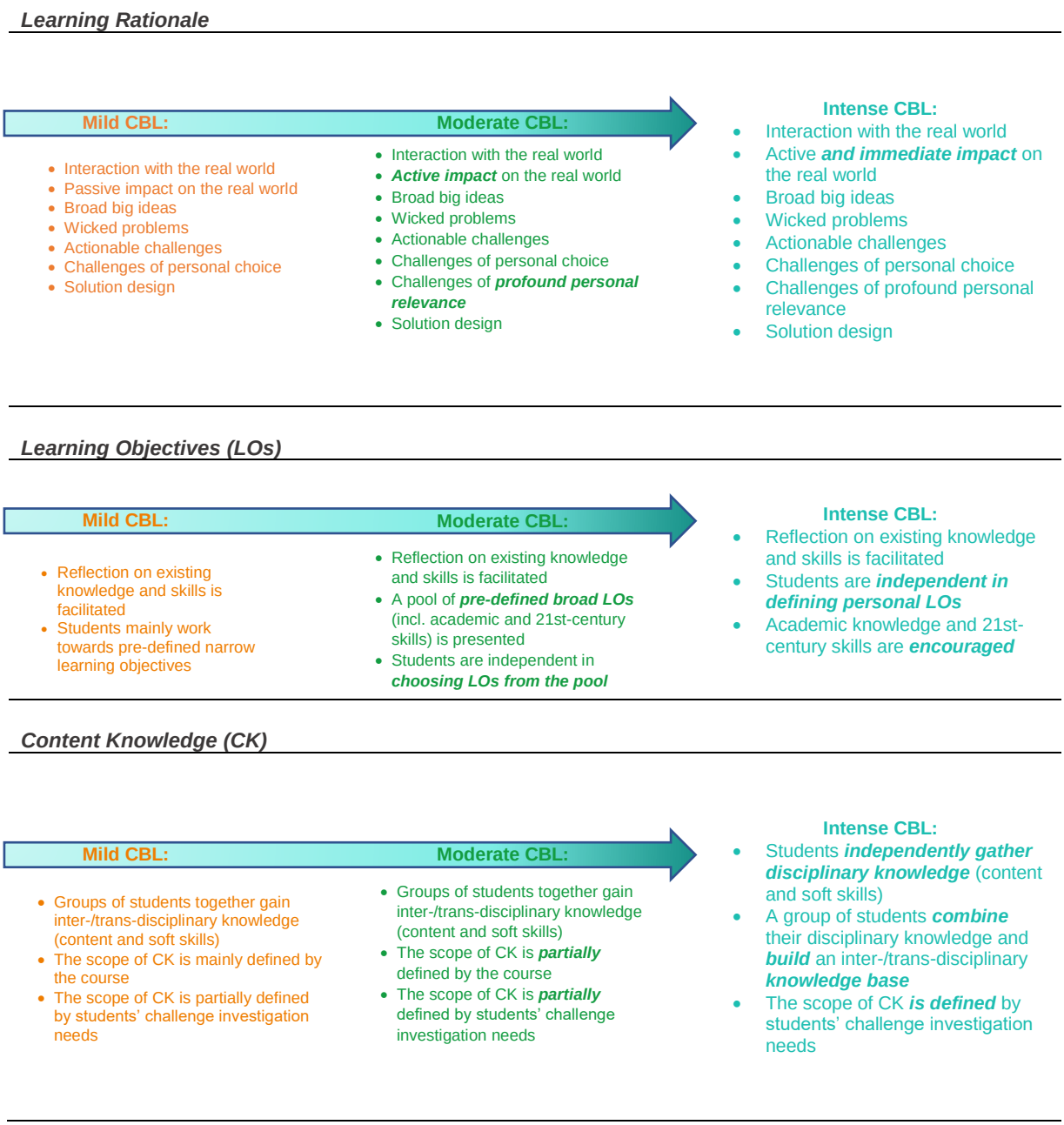
Context Analysis: Course Documents. The context analysis was conducted to describe the educational context of CBL courses. Mainly, this analysis attempted to define CBL elements employed in the cases. The elements of CBL education were described in the theoretical framework, and the main characteristics were defined. However, there is no one-size-fits-all approach to CBL. The study's literature review and the researcher's professional experience with CBL at the UT allowed her to witness and explore various ways the lens of the CBL framework is employed in higher education, specifically within the context of the UT. It is evident that different teachers emphasise different educational components of the framework. For instance, some teachers focus more on intensely applying the CBL learning rationale while moderately complying with the CBL teacher role and mildly applying the CBL grouping.

To potentially grasp and operationalise the different variations of approaching the framework, Mild, Moderate, and Intense CBL levels were defined for each educational component of the Curricular Spider Web. Therefore, a model of continuums defining the three levels was constructed (Figure 3) to support the study's data analysis. The construction of the model was supported by a CBL expert representative of the UT's Centre of Expertise in Learning and Teaching (CELT) and a CBL Teaching and Learning Fellow representative from 4TU.CEE.

The Intense CBL level descriptions were derived from the study's theoretical framework definitions described in the CBL Spider Web components. The Mild and Moderate CBL levels were deduced from the Intense level definitions based on the different CBL designs described in literature and present at the UT. Notably, more research needs to be done to evaluate the extent to which the model is suited to grasp the variations of CBL at the UT and in higher education.

Figure 3

Mild-Moderate-Intense (MMI) CBL Continuums Model



Learning Activities

Mild CBL:

- Students (individuals or groups) engage with a wicked problem (i.e., big idea)
- They identify an actionable challenge
- They deeply investigate a challenge (incl. scheduled engagement with the primary stakeholder)
- They design a consciously chosen solution
- They (indirectly/directly) implement the solution in the real world
- They reflect on the possible effects of the solution

Moderate CBL:

- Students (individuals or groups) engage with a wicked problem (i.e., big idea)
- They identify an actionable challenge
- They deeply investigate a challenge (incl. ***free engagement with the primary stakeholder***)
- They design a consciously chosen solution
- They (indirectly/directly) implement the solution in the real world
- They ***evaluate the effects*** of the solution
- A ***cycle*** of ***reflecting*** and ***documenting*** follows the process

Intense CBL:

- ***Individual students engage*** with a wicked problem (i.e., big idea)
- ***Individual students identify immediate*** actionable challenges
- Students ***form a group*** based on their actionable challenge
- The group deeply investigates a challenge (incl. ***free engagement with relevant stakeholders***)
- The group designs a consciously chosen solution
- The group ***directly*** implements the solution in the real world
- The group evaluates the effects of the solution
- A cycle of ***reflecting, documenting, and sharing*** with the public follows the process

Teacher Role

Mild CBL:

- A learning supervisor (expectation manager, process facilitator)
- Field experts and professional advisers

Moderate CBL:

- A learning supervisor (expectation manager, process facilitator)
- A ***coach*** (a ***learning guide***)
- Field experts and professional advisers

Intense CBL:

- A learning supervisor (expectation manager, process facilitator)
- A coach (a learning guide, ***co-researcher/co-designer/co-learner***)
- Field experts and professional advisers

Materials & Resources

Mild CBL:

- Teachers prepare guiding resources
- Students must familiarise themselves with the guiding resources
- Students are encouraged to explore additional resources
- Technology can be used

Moderate CBL:

- Teachers prepare guiding resources
- Students ***can choose to*** familiarise themselves with the guiding resources
- Students are encouraged to explore additional resources
- ***Open access to technology***

Intense CBL:

- Teachers prepare guiding resources
- Students can choose to familiarise themselves with the guiding resources
- Students are encouraged to explore additional resources
- Open access to ***state-of-the-art technology***

Grouping

Mild CBL:

- Students form a group of co-learners
- Inter-/trans-disciplinary collaboration is fostered

Moderate CBL:

- Students form a ***multidisciplinary group*** of co-learners
- Inter-/trans-disciplinary collaboration is fostered

Intense CBL:

- A multidisciplinary group of ***co-learners*** consists of:
  - ***students*** from different disciplines
  - ***coaches*** (teachers) from various disciplines
  - ***stakeholders***
- Inter-/trans-disciplinary collaboration is fostered

Location & Time

Mild CBL:

- Fixed learning in the real world
- Fixed T&L for the offered learning activities
- Flexible T&L for self-regulated learning and groupwork
- A collaborative virtual and/or physical workspace is accessible by schedule

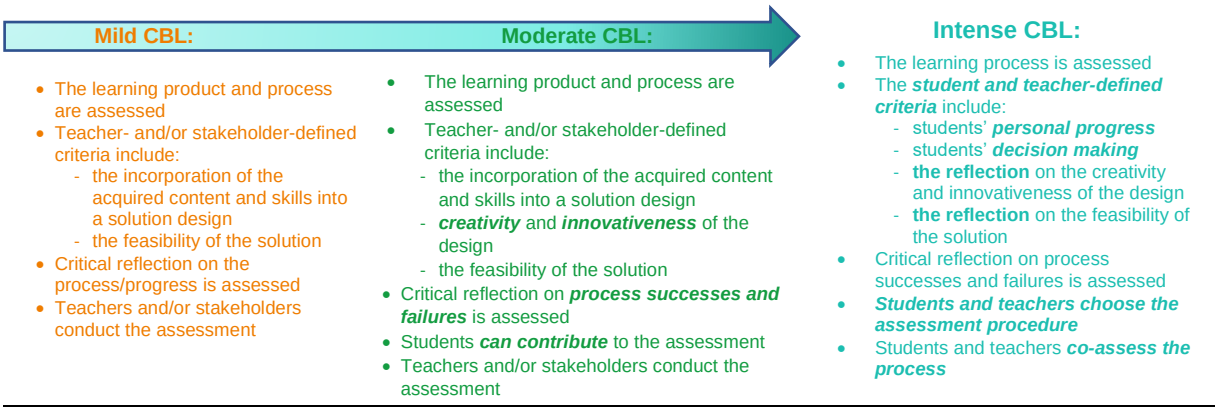
Moderate CBL:

- ***Semi-fixed*** learning in the real world
- ***Semi-fixed*** T&L for the offered ***learning activities***
- Flexible T&L for self-regulated learning and groupwork
- A collaborative virtual and/or physical workspace is accessible by schedule

Intense CBL:

- ***Flexible*** learning in the real world
- ***Flexible*** T&L for the offered ***learning activities***
- Flexible T&L for self-regulated learning and group work
- A collaborative virtual and/or physical workspace is ***constantly accessible***

Assessment



After the model was revisited, refined, and finalised, each case's document analysis was performed in the following order: NTBD, LSC, SEiC. With each case, the researcher got familiar with the content of all the collected documents before analysing them. Then, the documents were coded in the qualitative data analysis software called Atlas.ti. Firstly, the Curricular Spider Web components mentioned in the documents (i.e., learning rationale, learning objectives, […], assessment) were coded. The case teachers were contacted via email when some educational aspects were unclear or needed elaboration. After phrases indicating the educational component were coded, the researcher reviewed each code separately and appointed them to a level of CBL defined by the MMI CBL Continuums model. The codebook that supported data analysis and organisation can be found in Appendix H. Moreover, the coding results were elaborated upon in the summary reports discussed in the results section.

The reliability of the data was tested in two ways. Firstly, 10% of the collected documents was shared with a second coder to define inter-coder reliability. Secondly, to avoid misinterpretations and assumptions, the case analyses were summarised in a report and shared with the case teachers for validation, and some adjustments to the reports were made according to the teachers' comments.

Needs Analysis: Self-reflection Reports and Student Interviews. The needs analysis was based on NTBD students' self-reflection reports, student interview responses recorded in Wooclap, and the notes taken during the interviews. Four documents were formed

before the analysis, collecting the Wooclap responses and the notes summary created right after the student interviews. In total, 30 documents presenting students' perceptions of the sense of impact changes were ready for the analysis in the following order: 26 NTBD reflection reports, one LSC interview summary document, and three SEiC interview summaries.

The data for each case was separately analysed but followed the same procedure. The researcher firstly got familiar with the documents to prepare for the analysis. Then, the case documents were uploaded onto the Atlas.ti software, where phrases indicating sense of impact changes and the associated educational features were coded. The theoretical framework and case analysis results were used as a reference point for the coding procedure. The codes were grouped into themes defined by the Curricular Spider Web components. Finally, student needs analysis reports were produced for each case, describing the various educational features mentioned in the data and their effect on the students' sense of impact levels.

Refining Design Requirements and Propositions: Interviews. Similarly to the student interviews, the notes taken during the interview were summarised right after the discussions. Then, the three summaries were together uploaded to the Atlas.ti software. There, teacher concerns and recommendations were coded. The preliminary design requirements and propositions were used to code the data. However, since some of the re-occurring topics within the interviews presented new themes, new codes were created (e.g., required support, future research). Then, the researcher read each code's quotes and summarised them per topic in the results section.

4.2.5.2 Quantitative Data Analysis

Needs Analysis: Pre-/post-test Surveys. Quantitative data from the pre-test and post-test surveys was processed via a statistical software suite called SPSS. Firstly, as the responses ranged from never to very often, they were labelled with a corresponding number (never=0, […] very often = 4). In addition, the sense of impact measure had reverse items (i.e., 9: "I cannot influence what happens in this class", 11: "My contribution to this class makes no

difference", and 14: "I have no freedom to choose in this class"), thus, reverse scoring was used when labelling the responses, where never=4 and very often=0.

As the sample size of the collected pre- and post-test data was relatively small on both occasions (four LSC and 11 SEiC students), the data is not considered a statical representative of the sense of impact changes among students following CBL courses. Therefore, as the small sample size cannot allow for statistically fair factor and reliability tests, these computations were not conducted, and statistical conclusions were not derived. Moreover, the reliability of the extracted sense of impact items was not checked. This matter is further discussed in the limitation section.

The quantitative data solely played a role as an indicator of individual sense of impact changes among the students. Thus, only descriptive analysis results of the pre-/post-test survey for each student were compared. The revealed changes helped the researcher to guide the interview discussions and get insight into the tests-indicated degrees of sense of impact change.

4.2.6 Quality of the Study

Methodological and data source triangulations have strengthened the validity of the study. Methodological triangulation refers to the combination of various data collection methods and/or perspectives (Stake, 1995). Multiple data collection methods, including the document analyses, the reflection report reviews, the pre-/post-tests, the student interviews, and the evaluation interviews, were employed in this study. The course and student data were complemented by the evaluation interviews with the case supervisors to attend to the teachers' perceptions of the data analysis. Data source triangulation refers to the use of multiple data sources or the use of the same data collected at different times (Stake, 1995). The study used various data sources, including course documents, students' perceptions, and teacher evaluations.

Firstly, the qualitative research principle of member checking (Birt et al., 2016) was applied to secure the quality of the data analyses and validate the results. Thus, for the context

analyses, the data was summarised and shared with the course designers to avoid subjective assumptions by the researcher. Furthermore, the feasibility of design requirements and proposition formed based on the study findings were discussed in evaluation interviews with the teachers involved in the design and execution of education in the three cases. Moreover, inter-coder reliability has been inspected to support the reliability of the study's context analyses. The agreement between the two coders was defined by a Cohen's κ of .73.

For the needs analyses, the reflection reports data was coded multiple times and discussed with knowledgeable peers to gain perspective. In addition, the interviews made use of the guidelines presented by Cohen et al. (2007), where guiding questions were avoided, students' openness was encouraged as anonymity was guaranteed, and the reflective value of the interview was described. Moreover, the interview data was mainly recorded via notes to ensure data safety and strengthen the students' ability to freely discuss the courses. Thus, advice for taking interview notes described by Mack et al. (2005) was adhered to: the notes were firstly brief and representative of the main topic, abbreviations were used, and the notes were expanded on right after each interview. Furthermore, the Cornell Notes system was used (Pauk & Owens, 2010; Appendix D) to support the notetaking.

5. RESULTS

The results present the main findings associated with each case as well as the cross-case analysis that supported the formation of the design requirements and propositions. The case findings are organised according to the conducted analyses, presenting CBL course design within the UT context and the students' needs regarding sense of impact per case. The results are further cross-analysed, and design requirements and propositions are presented. Lastly, the feasibility of these is discussed in the validation and refinement section.

5.1 NEW TECHNOLOGY BUSINESS DEVELOPMENT MINOR

5.1.1 CBL Course Design within the UT Context

Appendix I presents a full report describing how NTBD minor's course design fits into the MMI CBL Continuums model (Figure 3). This section aims to summarise the NTBD case analysis report.

The CBL design of the NTBD minor was placed on different parts of the MMI Continuums (Figure 3) in each component of the educational design.

Seemingly, CBL was more *intensely* employed by the content knowledge, teacher role, and grouping components within NTBD. Notably, a team of teachers (incl. the minor's supervisor, coaches, and professional advisers) were working on the execution of the minor. Each teacher was able to take on multiple roles.

NTBD's CBL assessment fell *between the moderate and intense levels* as the learning process was central to the assessment, but the students were not the co-assessors of the process. Interestingly, the design solutions were not assessed, while a content-focused assessment seemingly allowed the students to show which knowledge they have successfully acquired and how they can practically apply it.

Moderate CBL intensity was mainly practised in the minor's learning rationale, location, and time.

NTBD's learning activities, together with the materials and resources, were defined as *"almost" of the moderate CBL level*. In learning activities, only some students could actively

evaluate the effects of the solution as only some directly implemented the solution in the real world while others did so indirectly. As the minor teacher highlighted, this was due to the time constraints of the minor. Regarding materials and resources, technology access was a debatable feature. In NTBD, the use of technology was seemingly encouraged. However, the students were not actively aware of the open access to the technology available at the university.

Lastly, the learning aims and objectives of NTBD fell bet*ween the mild and moderate CBL levels*. Even though the minor's learning objectives were quite broad, the students were not required to define personal learning objectives. Notably, reflection on existing knowledge and skills was somewhat facilitated via the content-focused assessment. The teacher mentioned that he observed it happen naturally when the students had to investigate the challenge and work on the content-focused assessment.

5.1.2 Students' Sense of Impact Needs

This section summarises NTBD's educational components that positively and negatively influenced students' perceptions of impact. However, a more detailed report on the results can be found in Appendix J.

The coding procedure of the self-reflection reports described in the data analysis resulted in two networks. The first network exhibits NTBD's educational design features that, according to the students, positively influenced their sense of impact (Figure 4). In contrast, the second one outlines the educational features of the minor that negatively affected their sense of impact perception (Figure 5).

Figure 4

Educational design features that positively influenced NTBD students' sense of impact

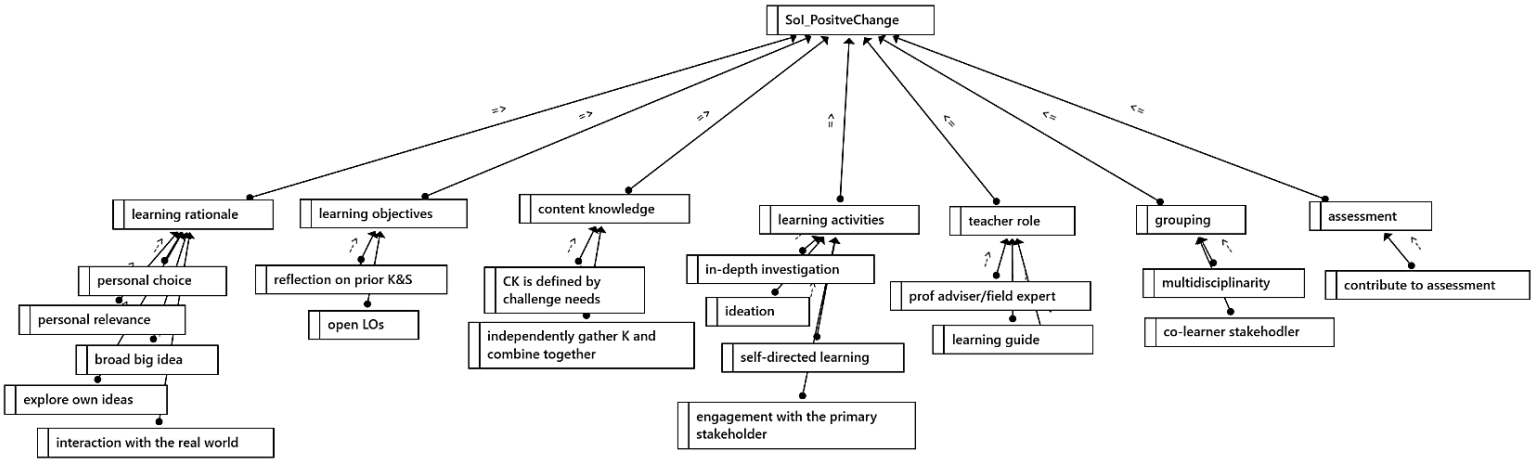
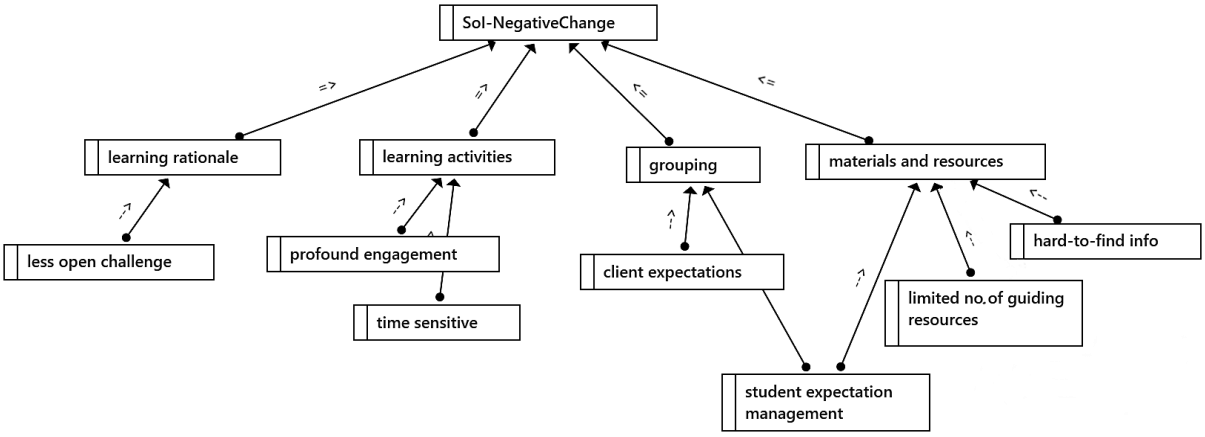


Figure 5

Educational design features that negatively influenced NTBD students' sense of impact



Learning Rationale. Broad big ideas, real-world interactions, challenges of personal choice and relevance, and idea exploration when designing solutions were described to positively influence NTBD students' perceptions of impact. With such educational features, the students could define their learning path, apply their knowledge and skills in the real world, and explore their interests while designing solutions to a challenge. On the other hand, some students mentioned that their challenge providers had a pre-defined outcome to the challenge, which hindered their ability to identify their learning focus. This negatively affected their feeling of impact.

Learning Aims and Objectives. Reflection on existing knowledge and skills allowed the students to recognise the value of their experiences. Thus, they were more determined to

take ownership of the learning and impact their surroundings (e.g., peers, teachers, stakeholders). In addition, NTBD students felt free to define and impact their learning due to the broad learning objectives of the minor.

Content Knowledge. Similarly, defining content knowledge to be acquired created a feeling of substantial impact on the learning among NTBD students. Moreover, independently gathering disciplinary knowledge and together creating an interdisciplinary knowledge base of the group required students to "defend" the value of the information they gathered and, consequently, recognise their direct contribution to the learning outcome.

Learning Activities. The self-directed in-depth investigation, freedom in engaging with stakeholders, and following the design cycle allowed NTBD students to adjust the learning pace to their needs, realise the effect of their choices on the learning, and explore own ideas. At the same time, engaging with the big idea while defining the challenge negatively influenced the students' sense of impact as it was too time-consuming and hindered their ability to design solutions and implement them in the real world.

Teacher Role. Reportedly, teachers' professional adviser and learning guide roles fostered NTBD students' sense of impact since the teachers did not narrate the learning process but were still there to rely on in difficult situations. Interestingly, as some of the students explained, if a coach were to actively contribute to the team's learning process as a co-designer, the team would expect the teacher to take over the course of action due to having more advanced expertise.

Materials and Resources. Reportedly, guiding resources offered in the minor were relatively narrow, "off the topic", or hard to find, which created a weak perception of impact on the learned content. Notably, some NTBD students did not seem to realise that the guiding resources were optional and that they were required to look for more resources.

Grouping. Multidisciplinarity and co-learning stakeholders reportedly allowed NTBD students to gain expertise from different or even conflicting perspectives, which seemingly strengthened their perception of having the ability to make a difference. On the other hand, the time investment required by interdisciplinary collaboration was not expected by the students

and caused frustrations. Moreover, some students expressed that their stakeholders were acting more like clients who had specific outcomes in mind; thus, they were hindered from exploring what influence they could have on the real world.

Assessment. The minor's broad assessment criteria focused on the learning process allowed NTBD students to adjust the evaluated deliverables according to the challenge's needs. Students described this approach to assessment as "a new challenge" that fostered a stronger sense of impact.

5.2 LEADING SYSTEMATIC CHANGE CHALLENGE PACKAGE

5.2.1 CBL Course Design within the UT Context

Appendix K presents a full report describing how the courses of the LSC challenge package fit into the MMI CBL Continuums model (Figure 3). This section aims to summarise the LSC case analysis report.

Just like in the NTBD case, the CBL design of the LSC challenge package was placed on different parts of the MMI Continuums in each component of a course design.

In the case of LSC, CBL was more *intensely* employed by the teacher role. The LSC teachers collaborated on the design and execution of the challenge package. Each teacher had multiple roles, including learning supervisors, professional advisers, and field experts. It was noted that the teachers tried to research and learn about the challenge and better understand it independently from the students. They aimed to support the student team by staying in close touch with the stakeholders and exploring various challenge-relevant content. However, the teachers did not join the student team in their group work.

Grouping, location, and time of LSC fell *between the moderate and intense levels of CBL*. With regards to grouping, a multidisciplinary group of co-learners was formed. However, seemingly, the teachers and stakeholders only at times joined the group learning process. As for location and time, the students were flexible to learn in the real world, engage with self-regulated learning, and do group work. However, the offered learning activities and a collaborative learning environment were accessible solely by schedule.

Moderate CBL intensity was mainly practised in the content knowledge of LSC.

LSC's materials and resources were *"almost" of the moderate CBL level* because the guiding resources contained a compulsory reading list. The other educational features fit well with the moderate CBL level description.

The learning aims and objectives, as well as the learning activities of the challenge package, fell *between the mild and moderate CBL levels*. The document analysis showed that the two courses of the challenge package differently approached the definition of the learning objectives. In one of the courses, the teacher defined quite broad objectives, while in the other, the learning objectives were relatively narrow and strict. Moreover, it was not observed that the students could choose which learning objectives to focus on. As for the learning activities, most of them fit with the moderate level description. However, as the students could only indirectly implement their solutions in the real world (i.e., give advice to the challenge provider) and ponder on the possible effects of their advice, LSC had features of a mild CBL level.

Finally, the learning rationale and the assessment employed by LSC's course design were better defined by the *mild CBL level*.

5.2.2 Students' Sense of Impact Needs

This section summarises the educational components that reportedly had positive and adverse effects on LSC students' sense of impact. However, Appendix L presents a more detailed report on the LSC students' sense of impact needs.

Firstly, to gain a general understanding of the sense of impact (SoI) changes in the LSC students, the mean results of the pre-test and post-test surveys for each student were compared based on the descriptive analyses of the survey results. Table 1 presents the revealed differences.

Table 1

The sense of impact level changes among LSC students

	Student 1	Student 2	Student 3	Student 4
Pre-test SoI	M=2.00 SD=.52	M=1.63 SD=.62	M=2.06 SD=.77	M=2.31 SD=1.08
Post-test SoI	M=2.81 SD=.40	M=2.44 SD=.63	M=2.94 SD=.57	M=2.69 SD=.79

Mean difference	.81	.81	.88	.38

The survey results showed an overall increase in the sense of impact levels among the LSC students. In the group interview, all six students who followed the LSC courses were asked to explain why they thought there was an increase and why some students perceived little sense of impact change. The group discussion resulted in two coding networks describing educational features that supported the increase in the sense of impact levels of LSC students (Figure 6) and features that hindered the increase (Figure 7).

Figure 6

Educational design features that positively influenced LSC students' sense of impact

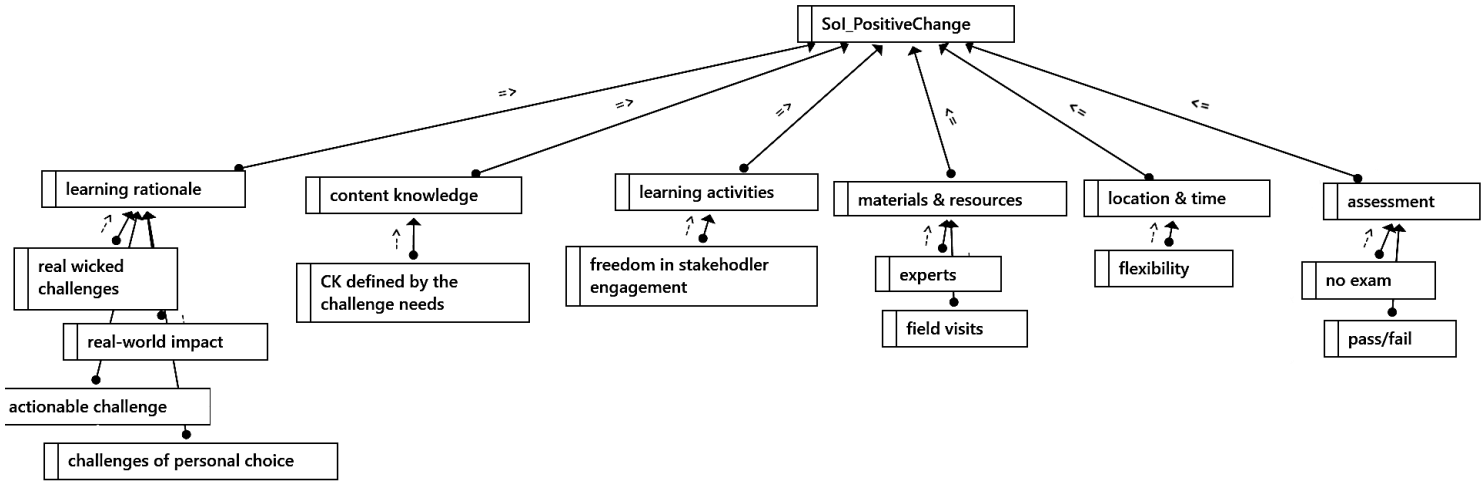
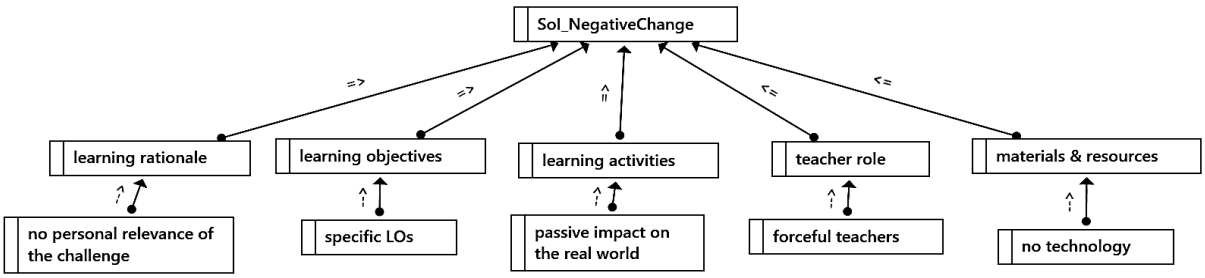


Figure 7

Educational design features that negatively influenced LSC students' sense of impact



Learning Rationale. Wicked problems, actionable challenges of personal choices, and aiming to have a real-world impact supported LSC students in recognising the value of their ideas, contributions, and choices for their immediate surroundings. Nonetheless, some

students could not closely relate to their challenge as the presented wicked problem was relatively narrow.

Learning Aims and Objectives. LSC students reported that narrow learning objectives were not closely related to their challenge and required them to spend time on corresponding assignments instead of choosing to invest in the challenge investigation.

Content Knowledge. The freedom to define the knowledge acquired within the courses gave LSC students a stronger feeling of impact on the learning process as they were "in control of" what they were learning.

Learning Activities. Flexibly and freely visiting the challenge provider's workplace, asking questions, and gaining a more in-depth understanding of the challenge facilitated open stakeholder engagement and made LSC students feel that they were "becoming experts on the challenge", whose choices in solution design could make a crucial difference. However, the students also mentioned that forming an advice report instead of designing and implementing actual solutions to actively affect the real world decreased their sense of impact. The students explained that they did not know what was going to happen with their advice as "it might just end up in someone's desk drawer".

Materials and Resources. Field visits and "having access to different field experts" allowed LSC students to recognise the importance of their learning as they first-hand witnessed how the experience can be used in the real world. Nevertheless, not being able to use technology within the challenge scope hindered some students from exploring their interest in state-of-the-art technology.

Teacher Role. LSC students perceived that some professional advisers would express strong opinions and create expectations on how the solutions must be designed, which developed a weak feeling of control over the learning and its outcomes: "we sometimes felt like we had to please the teachers".

Location and Time. Partial freedom when following the modules made students realise that their choices directly affected the progress, process, and outcomes of learning.

Assessment. Not having an exam and being evaluated on a pass or fail bases allowed LSC students to be more determined in making own choices.

5.3 SYSTEMS ENGINEERING IN CONSTRUCTION COURSE

5.3.1 CBL Course Design within the UT Context

Appendix M presents a full report describing how the SEiC course design fits into the MMI CBL Continuums model (Figure 3). This section aims to summarise the analysis of the SEiC case. The CBL part of the SEiC also applied CBL features on different levels of the MMI Continuums.

The content knowledge within the CBL part of the course was placed *close to the intense CBL level* because it was not expected that students would independently gather disciplinary knowledge and combine it later. However, students could choose to do so.

The teacher role, and materials and resources could mainly be well-defined by the *moderate CBL level* definitions. Notably, only one teacher took on the CBL teacher roles. Moreover, the technology feature of the CBL materials and resources stood out as the use of technology was not encouraged by the course.

The learning objectives and assessment of the CBL experience within SEiC fell *between mild and moderate CBL levels*. Although the students were presented with broad learning objectives, they did not need to define own learning aims. Moreover, creativity and innovativeness of the design were encouraged but only somewhat assessed.

The course design's learning rationale, learning activities, grouping, and location and time were depicted by the *mild CBL level* features. However, a couple of the features stood out. In the course's CBL learning activities, the students were not expected to actively share their results with the public. However, they were asked to submit a proposal for a challenge competition, which could be considered as sharing with the public aligning the feature with the intense CBL level. Regarding the grouping analysis, the challenge provider was defined as a client. This could contradict the "part of the team" CBL stakeholder feature described by the literature.

5.3.2 Students' Sense of Impact Needs

This section shortly describes how SEiC's CBL course components influenced students' sense of impact, while Appendix N expands the findings in more detail.

The mean results of each student's pre-test and post-test surveys were compared to provide an overview of the sense of impact (SoI) changes among SEiC students (Table 2).

Table 2

The sense of impact level changes among the SEiC students

	S1	S2	S3	**S4**	**S5**	S6	S7	**S8**	S9	S10	S11
Pre-test SoI	M=3.31 SD=.48	M=2.50 SD=1.27	M=2.69 SD=.48	**M=2.50 SD=.50**	**M=2.56 SD=.73**	M=2.38 SD=.89	M=2.44 SD=.81	**M=2.06 SD=.93**	M=1.88 SD=.96	M=1.81 SD=.66	M=1.88 SD=.62
Post-test SoI	M=2.56 SD=1.21	M=2.19 SD=.40	M=2.75 SD=.45	**M=2.63 SD=.73**	**M=2.88 SD=.62**	M=2.88 SD=.72	M=2.94 SD=.68	**M=2.69 SD=.95**	M=2.56 SD=.81	M=2.88 SD=.72	M=3.06 SD=.44
Mean difference	-.75	-.31	.06	**.13**	**.31**	.50	.50	**.63**	.69	1.06	1.19

The survey results showed that students of the SEiC course experienced the sense of impact changes differently. The change was negative for some students, while it was moderate or relatively positive for others. Interview discussions were planned to understand the results. Unfortunately, due to the lack of responses, it was only possible to interview students 4, 5, and 8. Thus, the insights on the moderate changes in the sense of impact levels were explored in depth.

As a result, three coding networks were created summarising educational features that reportedly increased (Figure 8), maintained (Figure 9), and decreased (Figure 10) SEiC students' perceived sense of impact levels.

Figure 8

Educational design features that positively influenced SEiC students' sense of impact

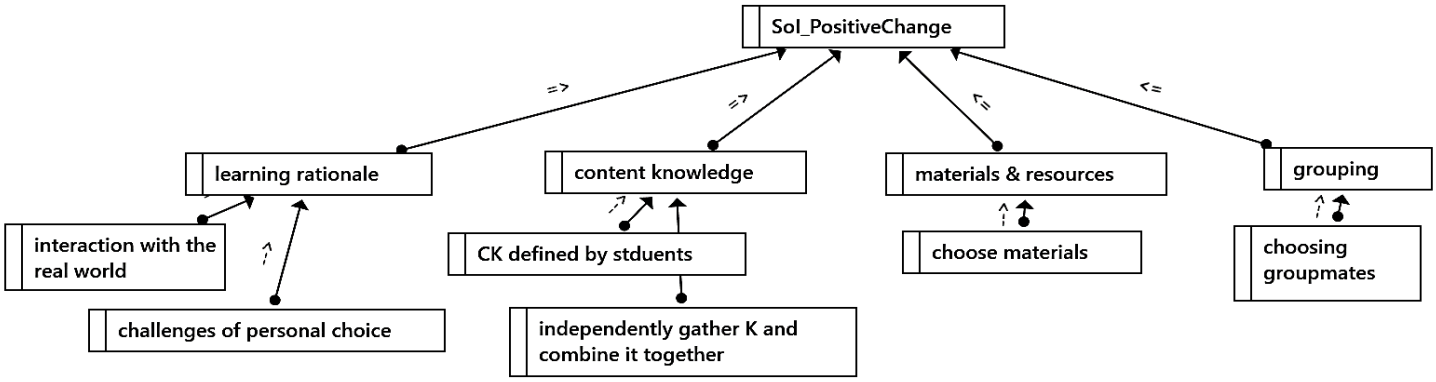


Figure 9

Educational design features that maintained SEiC students' sense of impact

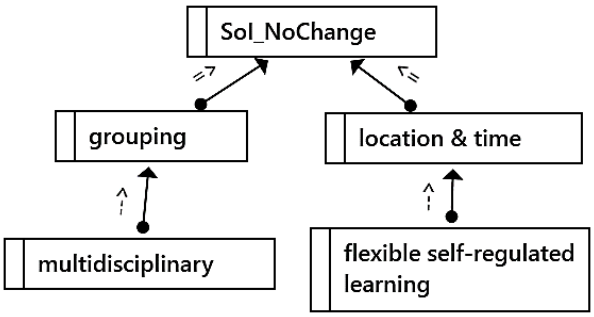
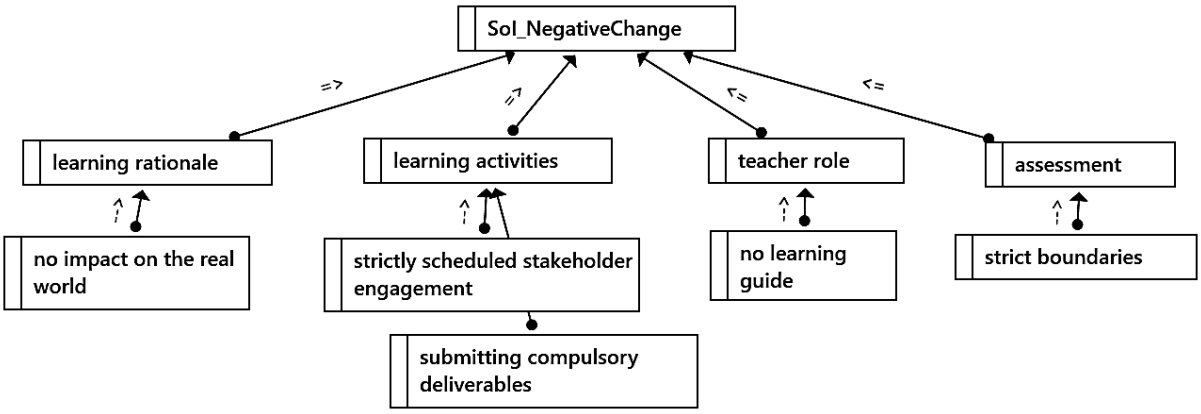


Figure 10

Educational design features that negatively influenced SEiC students' sense of impact



Learning Rationale. Challenges of personal choice and interaction with the real world reportedly allowed SEiC students to strongly feel the impact of their choices on the scope, progress, and outcomes of learning. However, the students did not perceive they could influence the real world since the stakeholders seemingly already defined the challenge's end solution design.

Content Knowledge. Defining content knowledge to be acquired, independently gathering disciplinary knowledge, and collaborating to build an interdisciplinary knowledge base fostered SEiC students' sense of impact as they could define which information to prioritise and form innovative ideas.

Learning Activities. Limited access to the challenge providers and submitting compulsory deliverables caused SEiC students to perceive a limited impact on the investigation and scheduling throughout the learning experience.

Teacher Role. SEiC teacher's tendency to be distant from the students' decision-making and not guide the learning made the students think that they had little influence on the teacher's behaviour and could not rely on him in difficult situations.

Grouping. Selecting groupmates created a stronger sense of impact among SEiC students because they felt the responsibility for their choices and needed to be comfortable with the consequences of the choice, while multidisciplinary groups maintained the sense of impact levels. Notably, the students also described that having groups of students from the same field but different intradisciplinary tracks and prior experiences is also perceived as multidisciplinarity and is widely applied at the UT.

Materials and Resources. SEiC students expressed that feeling encouraged to choose materials in challenge investigation positively affected the sense of impact levels.

Location and Time. Flexibility in self-regulated learning and group work, reportedly, is almost always offered in higher education and maintains students' perceptions of the impact on learning.

Assessment. Lastly, having rather strict practical requirements of the final report "pulled the feeling of control" from the students as they could not thoroughly justify their choices when being assessed.

5.4 CROSS-CASE ANALYSIS

5.4.1 Preliminary Design Requirements for Fostering Students' Sense of Impact

According to McKenney and Reeves (2019), design requirements are closely tied to the long-range goals of a design and, thus, shape the design itself. This section describes the CBL course design requirements for fostering a sense of impact revealed in the study's data analyses.

In the needs analyses, students discussed that providing advice and being unable to actively implement their solutions in the real world hindered their perception of impact. This indication emphasises the value of *implementing CBL solutions in the real world* to support students' sense of impact.

Secondly, active interaction with the real world showed to be valuable for students' sense of impact. The case students described how active investigation in the real world (e.g., free stakeholder engagement, field visits) allowed them to feel their impact on the learning process and their surroundings, while the students who had less freedom in engaging with their stakeholders perceived less impact. In addition, the wickedness of CBL problems highlights the value of students' contributions (i.e., ideas, work, choices) to understanding and solving real-world issues and increases the sense of impact. Thus, creating a learning environment where *students can actively learn from the real world* by engaging with stakeholders and working on authentically complex issues fosters students' sense of impact.

As was presented in the needs analyses, students who could start with broad big ideas and choose which challenge to focus on experienced an increase in their sense of impact levels, while students who worked with narrowly defined challenges perceived less impact. Therefore, allowing students to *define their challenges* increases a sense of impact in students.

Moreover, the students described that reflecting on their existing expertise and defining the content to be acquired facilitated their perception of impact as they could define the direction of their learning process based on their own choices. In addition, broad learning objectives allowed the students to feel their impact stronger as they could choose what content they want to focus on. In contrast, students who worked with narrow learning objectives perceived a weak sense of impact as they had to invest time on gathering information unrelated to their challenge. Thus, to foster students' sense of impact, CBL courses should *allow students to define the content to be acquired*.

Finally, students described flexibility in deciding when to study, do research (i.e., self-directed learning), and do group work as factors that promote sense of impact. However, the students mentioned that, according to their experience, this flexibility is not unique to CBL courses; it is widely practised in higher education institutions. Furthermore, having an option to attend course-offered learning activities also allowed the students to feel their impact on the learning process as they felt their responsibility for the outcomes of their learning process. Moreover, emphasising the learning process in assessment supports students' sense of

impact as they explain, justify, and reflect on personal choices made throughout a CBL experience. Therefore, *allowing students to be independent and flexible when learning* is recommended for fostering students' perceptions of impact.

The students also reported that exploring their ideas and interests positively affected their sense of impact levels. For example, the students mentioned that following a design cycle allowed them to brainstorm and dive into various ideas. Moreover, some students mentioned that not being able to realise the personal relevance of the challenge created a weaker perception of impact as they found it hard to explore personal interests within the scope of the challenge. Thus, *idea and interest exploration* scaffolds students in perceiving their impact.

The students' needs analyses highlighted the benefit of *inter-/trans-disciplinary collaboration*. As the case students reported, having the option of firstly independently gathering disciplinary knowledge, then sharing the information with their group, and combining all the collected multidisciplinary expertise to build the group's knowledge base was a factor that positively influenced their sense of impact levels. Therefore, encouraging and facilitating inter-/trans-disciplinary collaboration is a valuable CBL design requirement for fostering a sense of impact in students.

Lastly, the teacher's role in *scaffolding the learning process* was frequently mentioned in describing the influence of a CBL course on the students' sense of impact. The students explained that with being exposed to various viewpoints and learning materials, they perceived a strong impact as they could expand their learning and make informed decisions. However, the students also described that having disorganised narrow lists of guiding resources and not being explicitly aware of facilities available outside the scope of the followed courses (e.g., guiding activities, technology) hindered their perception of impact. Moreover, the students indicated that spending extreme efforts on the first phases of the CBL process prevented them from having an active impact on the real world. These findings hint that teachers need to carefully facilitate the learning process.

In addition, some students were not explicitly aware that they were expected to go beyond the offered learning materials when working on their challenge, which interfered with

their sense of impact development. Moreover, the students described that some of the challenge providers already had a pre-defined outcome. This weakened the students' sense of impact. Hence, student and stakeholder expectations management are crucial in allowing students to maintain and develop their sense of impact.

Furthermore, the students frequently mentioned the teacher role as a learning guide in relation to their sense of impact. For example, it was shared that having a teacher guiding their team in a time of need created a stronger sense of impact, while students who did not have such a guide felt a weak sense of impact. Therefore, to support students in their perceptions of impact, it is valuable for teachers to carefully support students and guide them throughout their CBL experiences.

In summary, to foster a sense of impact in students, CBL course design can be guided by the following requirements:

- Students should have an impact on the real world
- Students should be able to interact with the real world
- Students should be able to define their challenge
- Students should be able to define the content to be acquired
- Students should be independent and flexible when learning
- Students should be able to explore their ideas and interests
- Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base
- Teachers should carefully scaffold the learning process

5.4.2 Preliminary Design Propositions for Fostering Students' Sense of Impact

Design propositions describe ways of reaching design requirements (McKenney & Reeves, 2019). The levels identified by the MMI CBL Continuums model (Figure 3) can be used to form cohesive advice on how the identified design requirements can be met. However, the CBL levels applied in the analysed courses are firstly outlined in Table 3.

Table 3

CBL Intensity Levels of NTBD, LSC, and SEiC Cases

Curricular Component	NTBD CBL Levels	LSC CBL Levels	SEiC CBL Levels
Learning Rationale	Moderate	Mild	Mild
Learning Aims and Objectives	Mild ∿ (between) Moderate	Mild ∿ Moderate	Mild ∿ Moderate
Content Knowledge	Intense	Moderate	∿ Intense
Learning Activities	∿ (almost) Moderate	Mild ∿ Moderate	Mild
Teacher Role	Intense	Intense	Moderate
Materials and Resources	∿ Moderate	∿ Moderate	Moderate
Grouping	Intense	Moderate ∿ Intense	Mild
Location and Time	Moderate	Moderate ∿ Intense	Mild
Assessment	Moderate ∿ Intense	Mild	Mild ∿ Moderate

The following section presents CBL course design propositions for fostering students' sense of impact in light of the study's case and needs analyses.

Learning Rationale. Throughout the analyses, the students of all three cases indicated the influence of the elements described by the CBL learning rationale. These included interaction with the real world, active impact on the real world, broad big ideas, wicked problems, actionable challenges, challenges of personal choice, challenges of personal relevance, and solution design. The students described that these features of education allowed them to explore own ideas and interests and develop perceptions that they can make a real impact in their learning, lives, and surroundings. In addition, narrow presented problems and passive impact on the real world seemingly negatively affected the students' sense of impact levels. Therefore, to foster students' sense of impact, adhering to educational features described by the *moderate level of CBL* learning rationale is important. The features include:

- Interaction with the real world
- Active impact on the real world
- Broad big ideas
- Wicked problems
- Actionable challenges
- Challenges of personal choice
- Challenges of personal relevance
- Solution design

Learning Objectives. The relation of learning objectives to students' sense of impact was determined by the findings of the NTBD and LSC needs analyses. In the NTBD case, reflection on existing knowledge and skills together with broad learning objectives were found to foster students' sense of impact. As the students described, by such reflection, they felt the value of their experiences and perceived to have a higher impact on their surroundings (e.g., peers, teachers, stakeholders) and the learning outcomes. These students also expressed that the broad nature of the learning objectives gave them the freedom to define their learning path, which strengthened their feeling of impact. In addition, LSC students mentioned that strictly narrow learning objectives seemingly negatively influenced their perceptions of impact because they felt required to do corresponding assignments instead of investing more time into the challenge. Hence, building a CBL course *between mild and moderate CBL levels* on the *learning objectives* continuum can already support students in increasing their sense of impact levels. The educational features include:

- Reflection on existing knowledge and skills is facilitated
- Students working towards pre-defined broad learning objectives

Content Knowledge. When it came to content knowledge, the students felt the support of their sense of impact as they defined the scope of the content knowledge within their CBL experience. According to LSC students, defining content knowledge to be acquired gave them a stronger feeling of impact on the learning process as they were "in control of" what they were

learning. Moreover, the students' sense of impact was stronger as they independently gathered disciplinary knowledge (content and soft skills), combined their gathered knowledge, and built an inter-/trans-disciplinary knowledge base. For instance, NTBD and SEiC students reported that as they were "defending" the value of the gathered information to the groupmates, recognising its added value to the group's knowledge base, and combining all the gathered information to build interdisciplinary solutions, their sense of impact was stronger. Therefore, the study findings revealed the value of adhering to the *intense CBL level* concerning *content knowledge* that is defined by the following educational features:

- Students independently gather disciplinary knowledge (content and soft skills)
- A group of students combine their disciplinary knowledge and build an inter-/trans-disciplinary knowledge base
- The scope of the content knowledge is defined by students' challenge investigation needs

Learning Activities. The effect of learning activities on students' sense of impact was identified in relation to some model-described elements. These include investigation in the real world, direct implementation of the solution design in the real world, and the design cycle process (incl. in-depth investigation, solution design, evaluation, and reflection), which fall between moderate and intense CBL levels. For example, through real-world investigation, the students felt the weight of their choices, the control over their learning, and the growth of their challenge-relevant expertise. In the meantime, having too many deadlines during the CBL experience and engaging with a stakeholder only on limited and strictly scheduled occasions negatively affected the students' sense of impact. In addition, not being able to directly implement the designed solution decreased the students' sense of impact because they could not predict whether the stakeholders would consider the student-advised solution. Moreover, investing time on deeply engaging with the challenge at the expense of implementing solutions in the real world decreased students' perceptions of impact. At the same time, students must be able to explore their challenge's personal relevance to feel a stronger sense of impact.

Thus, having *well-facilitated learning activities* between the moderate and intense levels of CBL is essential in fostering students' sense of impact. These learning activities include:

- Students deeply investigate a challenge (incl. free engagement with relevant stakeholder)
- Students design a consciously chosen solution
- They indirectly implement the solution in the real world
- They evaluate the effects of the solution

Teacher role. The teacher role was also frequently mentioned by the case students. The role of a process facilitator who manages expectations (incl. students, stakeholders, and other teachers) and provides access to various guiding resources is crucial for supporting a sense of impact in students. As the students described the negative influence of stakeholders having a pre-defined outcome, professional advisers imposing their ideas onto the students, and students not being aware that they need to explore additional resources, CBL education needs to have a teacher who carefully manages the expectations of all the parties involved. Moreover, the learning guide role was emphasised in the findings. The students mentioned that having a coach to rely on in difficult situations and to support their learning progress encouraged their feelings of impact while having teachers being strongly distant from the learning process weakened the perceptions of impact in students. In addition, the teachers in the NTBD and LSC cases co-learned and co-researched along the students to provide support to the teams when needed. Furthermore, the students reported that exposure to various field experts and professional advisers benefited their feelings of impact. Nonetheless, since the students described the negative effect of some field experts' attempts to steer student learning, teachers (as well as coaches) need to be aware that they should not lead the learning process and define the outcome. Henceforth, shaping a CBL course according to the *intense CBL level* of the *teacher role* is beneficial for students' sense of impact. Thus, the CBL teacher roles that foster sense of impact in students are:

- A learning supervisor (expectation manager, process facilitator)

- A coach (a learning guide, co-learner/co-researcher who can support the students when asked)
- Field experts and professional advisers

Materials and Resources. In relation to materials and resources, the students described several factors that negatively affected their sense of impact. For instance, a narrow hard-to-find list of guiding resources limited their ability to investigate their challenge in-depth. In addition, seemingly, some students also did not realise the access they had to IT infrastructures, which limited their ability to explore personal interests. Some students did not realise that they were free to explore materials and resources outside of what was offered. Nonetheless, the students who were explicitly aware that they could explore information and facilities beyond what was offered enjoyed the freedom. Moreover, it was described that having access to field experts and engaging in field visits increased the students' perceptions of impact as they first-hand witnessed how the gathered knowledge and skills can be used in the field. Thus, designing CBL education according to the *moderate level* on the *materials and resources* continuum can foster students' sense of impact. By presenting students with extensive sets of guiding resources and learning facilities (e.g., available technology) in an organised manner and explicitly encouraging them to explore additional materials and resources, teachers can scaffold students in developing the sense of impact. Therefore, the educational characteristics of CBL materials and resources that foster sense of impact are:

- Teachers prepare an extensive list of guiding resources
- Students can choose to familiarise themselves with the guiding resources
- Students are explicitly encouraged to explore additional resources
- Teachers should describe how and where students can access technology

Grouping. Regarding grouping, the case students expressed the importance of having multidisciplinary student teams to maintain their sense of impact levels. Notably, it was described that having groups of students from the same field but different intradisciplinary tracks and prior experiences is also perceived as multidisciplinarity. In addition, choosing own groupmates reportedly positively affected sense of impact levels. Moreover, the students

expressed that having a stakeholder as a co-learner team was perceived to positively affect their sense of impact levels. However, the students did not think that having a teacher as a part of the team who actively designs the solutions would allow them to increase or maintain their sense of impact because the teacher's rich expertise might hinder students from exploring the field by themselves as they would always rely on the teacher. Therefore, to foster a sense of impact, a CBL educational design must fall *between the moderate and intense levels* on the *grouping* continuum:

- Students form a multidisciplinary (incl. different tracks/prior experiences) group
- Stakeholders are co-learners
- Inter-/trans-disciplinary collaboration is fostered

Time and Location. As was described earlier, the case students perceived the ability to flexibly engage (e.g., ask questions, pay visits) with relevant stakeholders positively influenced their sense of impact levels. Moreover, the students described that having the freedom to decide if they want to follow scheduled learning activities increased their feeling of control over the learning as they felt like the progress, process, and outcomes of learning were heavily affected by their own choices. In addition, flexibly self-regulating the learning process and group work was described as a factor in maintaining the students' perceptions of impact. Reportedly, such flexibility in self-regulated learning and group work is almost always offered in higher education, which usually strengthens their perception of impact. Therefore, applying educational features that fall *between the moderate and intense CBL levels* on the *location and time* continuum is beneficial for fostering students' sense of impact. These include:

- Students form a multidisciplinary group of co-learners
- Stakeholders are co-learners
- Inter-/trans-disciplinary collaboration is fostered

Assessment. A few features of CBL assessment were highlighted as important factors that can foster students' sense of impact. For instance, students of the three cases mentioned the importance of evaluating the learning process in supporting their sense of impact. The students who felt that they could defend their learning progress and outcomes due to the

flexible assessment techniques (e.g., pass/fail, process-oriented assessment criteria) were more determined in their decision-making. On the contrary, the students who perceivably were assessed on the outcome of learning and had quite assignment requirements lost their feeling of control and impact. In addition, even though the students were not involved in the evaluation process, by being assessed on the process, the students felt their contribution to the assessment. Thus, emphasising the assessment on the learning process within CBL education fosters students' sense of impact. This feature is common to all the described CBL levels. However, this study did not reveal the influence of the other CBL assessment features on students' sense of impact.

5.5 VALIDATING AND REFINING DESIGN REQUIREMENTS AND PROPOSITIONS

The preliminary design requirements and propositions were discussed, validated, and evaluated based on their feasibility with teachers and support staff involved in the design and execution of the analysed cases. Overall, adhering to the proposed design requirements was relatively feasible and desirable. Nonetheless, concerns and recommendations emerged from the evaluation interviews. These are described in this section.

Real-world impact. As courses in higher education are bound to a specific time frame, it is not always possible to "squeeze in" the real-world implementation of the designed solutions. If more time can be assigned to a CBL course (e.g., two quartiles), real-world implementation becomes more feasible and desirable. Nonetheless, it was noted that the perception of what real-world impact means can be pretty flexible. When students engage with stakeholders, ask critical questions, and share their opinions, they already have an impact on the real world as they have the power to influence the perceptions of the stakeholders. Thus, the first design requirement was re-formulated into *"students should explicitly be made aware of their real-world impact"*, and additional propositions for CBL course design were formed. *Conducting impact tests* by asking challenge providers to explicitly and honestly share how the CBL experience with the students affected their work might allow students to realise that they had a real-world impact. Nonetheless, even field professionals cannot always have an active

impact in their field. Thus, *students must be facilitated to learn from possible disappointments and failures*.

Stakeholder engagement and expectations. The interviewed teachers stressed the importance of creating value in a CBL experience for stakeholders and preventing possible risks of allowing students to engage with the real world. Teachers mentioned that, in principle, the more stakeholders are engaged with a CBL experience, the richer the CBL experience is for everyone involved. However, it was also explained that giving students the freedom to engage with different real-world stakeholders creates risks. Firstly, a CBL classroom is a learning environment where students must be able to make mistakes and learn from failure. However, the teachers described that when real-world companies and professionals are invited to participate in the learning, students take on the risk of their mistakes negatively influencing their odds when facing the job market after graduation as prospective employers might get a negative impression of the students. Secondly, as students engage with stakeholders/prospective employers, they will try to showcase their talents, ideas, and work, which might hinder students' ability to collaborate fruitfully and be open to compromise. In addition, the question of intellectual property appears. If students manage to design or plan a solution that a company desires to use, the ownership of the solution design might become unclear. Furthermore, real-world stakeholders can be unpredictable. Some might lose interest in a CBL project or lack time to actively engage with students. To harness such risks, the following propositions were suggested for the teacher role and grouping to carefully facilitate and manage the relationships between students, stakeholders, and teachers and the expectations of all the parties involved. Firstly, teachers should establish clear expectations and rules of engagement for all the parties involved. It was suggested that *all CBL learners sign contracts* (e.g., among student team members, between challenge providers and student teams, between students and teachers, between teachers and challenge providers), where expectations, personal gains, general rules of routine meetings (e.g., when, how often, where), and clause of using student work can be outlined and agreed upon. Moreover, it was strongly

recommended for *teachers to have regular meetings with students and stakeholders* to actively manage the expectations throughout the experience.

Broad learning objectives. The need for flexibility in learning objectives was understandable for teachers from a theoretical point of view. Such flexibility is usually possible in extracurriculars. However, the flexibility will be difficult to achieve in curricular courses because they are bound to the learning objectives of their umbrella programmes. While working on their University Teaching Qualifications (UTQ), teachers get trained to align a course's learning objectives with what the university wants to achieve and develop to facilitate programme/faculty/university-wide coherence. Thus, the educational adviser suggested forming higher-order thinking objectives instead as it will allow teachers to facilitate learning flexibility while still promoting the learning objectives of their programme/faculty/university.

Defining the learning focus. Like the students, the teachers mentioned that letting students define the challenge from a presented big idea is time-consuming. Since education in universities is often designed with time constraints, letting students invest too much time into defining the focus of their work might hinder the learning process. Therefore, it was described that *teachers must be alert and guide students in defining the focus* by activating students' decision-making (e.g., through practical sessions and discussions).

Guiding resources. Although providing students with extensive lists of various guiding resources that include literature, experts, and micro-lectures is feasible, the scope and sustainability of such resources should be kept in mind. Firstly, the *guiding resources should facilitate students in truly looking beyond their expertise*. Secondly, the teachers should ensure that the information presented to the students is always *up to date and relevant*. This can be challenging as time constraints do not allow teachers to continuously revisit and revise the offered materials. Therefore, a suggestion was made to set up a *network of experts* from various fields and backgrounds who can give expert talks to all students at the UT. In such a way, the offered perspectives are more likely to be versatile, and information is more likely to be up to date. Moreover, the value of field visits was confirmed as they also allow students to

be exposed to professional perspectives and realise under which real-world conditions their solutions need to function.

Teacher teams. In the interviews, some teachers explained that working as a team on a CBL curricular design made the process more manageable. Thus, based on their experience, they suggested having *weekly meetings with the course design team* to keep track of the progress and tackle occurring obstacles.

Assessment. The teachers also discussed that in collaborative frameworks such as CBL, tackling the assessment of individual learning and progress can be troublesome, especially when students are expected to gain specific content knowledge after finalising a course. Thus, the teachers described the worth of *dedicating a part of a course to gaining and assessing content knowledge in a more traditional manner*. For instance, the Investigate phase defined by CBL requires students to dig deep into their challenges and gain various academic skills. Thus, students could follow a series of mini-courses during the phase and be assessed on the academic knowledge they gained just before they start combining the gathered knowledge with their peers. As an alternative, the teachers suggested focusing half of an offered course on gaining academic knowledge whilst focusing the other half of the curriculum on a CBL experience.

Required support. The teachers described that designing education, especially while embracing CBL, is a wicked problem by itself. When an existing course is re-designed, a hasty application of CBL features can negatively affect the prevailing balance of the course. Therefore, teachers must have time and resources to mindfully prepare for a course re-design. The interviewed teachers described different support systems that could make the change process smoother. Hence, an additional design requirement is formed: *teachers should get support when designing CBL education*. The teachers suggested a few design propositions. Firstly, it was mentioned that having some *guiding tools* to support the re-design process would be beneficial. For instance, teachers could attend *hands-on sessions*, where they share and learn how to practically implement CBL features in curricula. Secondly, having the *support of an educational adviser with CBL expertise, a student assistant*, and *other UT teachers*

reportedly greatly assists the design of a CBL course. In addition, it was mentioned that acquiring stakeholders or field experts who are ready to join a CBL experience can be difficult. For now, teachers usually use their professional network for that. However, a suggestion was made for the UT to assemble *a database of professionals and alumni* from the university's network, which future CBL course designers can refer to.

MMI Continuums. Teachers expressed interest in using the MMI CBL Continuums model (Figure 3) to guide the described design requirements. However, they also noted that design propositions would be more comprehensible if they were formed in complete actionable sentences describing what should be done instead of the statements that define the proposed CBL levels.

Future research. The interviews revealed topics valuable to explore in prospective studies. These are elaborated upon in the future research chapter.

6. DISCUSSION

This study explored approaches to CBL course design that can positively contribute to the sense of impact perceptions among students within the context of the UT. The following chapter reflects on the formed design requirements and propositions from theoretical and practical perspectives.

As was discussed in the earlier chapters of the study, CBL expands on similar educational frameworks like project-based and problem-based learning by extending classroom learning into learning in the real world and allowing students to make a meaningful contribution to societal issues, which potentially strengthens students' ability to be more determined and proactively impacting their surroundings.

Nonetheless, fostering students' sense of impact through CBL courses is a complex process that requires guidance. Therefore, this study formed design requirements and propositions for guiding the design of future CBL education. According to McKenney and Reeves (2019, p. 140), “the design requirements give more guidance on what is to be accomplished in a specific setting, whereas the design propositions inform how that can be done”.

6.1 CBL DESIGN REQUIREMENTS FOR FOSTERING STUDENTS' SENSE OF IMPACT

Based on the study results, preliminary design requirements for shaping CBL courses were formulated and refined based on the earlier described evaluation interviews. The following section describes these in light of existing literature on innovative education.

Students should explicitly be made aware of their real-world impact

The study results reinforce the importance of students' ability to witness their influence in real-world communities with regard to the sense of impact increase described by Santos et al. (2019). Literature on experiential learning (Mason & Arshed, 2013; Bradberry & De Maio, 2018) expands the findings by describing how students hold greater responsibility and accountability for their choices and actions when producing outcomes in an authentic environment. To achieve real-world influence in a CBL course, students should be able to

implement and evaluate their solutions in the real world. However, it is not always feasible within the context of higher education. Therefore, an alternative way of approaching the real-world impact is making it explicit to the students by describing how stakeholders (e.g., challenge providers) were affected by their CBL interactions.

Students should be able to interact with the real world

The study also confirmed that allowing students to work on authentically wicked real-world problems within education advances students' sense of impact. In line with the arguments presented by Santos et al. (2019), trying to design solutions for such problems supported students in recognising the value of own ideas, knowledge, and experiences in the real world. In addition, actively learning and conducting research in the real world fostered a sense of impact. Engaging with stakeholders openly and freely was revealed to be a high-stake instance of real-world investigation. The study findings support the educational theory behind service-learning. Engaging with worldly people of diverse educational, professional, cultural, and social backgrounds provides students with the opportunity to receive valuable information from numerous perspectives (Rhodes, 1997 in Yorio & Ye, 2012). Consequently, students are prompted to further self-awareness, self-development, self-efficacy, and self-confidence in personal expertise (Astin & Sax, 1998; Eyler & Giles, 1999 in Yorio & Ye, 2012). Furthermore, Bradberry and De Maio (2018) argue that warranting students to learn within real-world experiences develops a feeling of active participation and influence.

Students should be able to define their challenge

The study showed the value of allowing students to define the focus of their challenge in supporting the sense of impact in CBL education. Here, broad big ideas were described as an essential consideration for the sense of impact increase. Broad big ideas allow students to choose the focus of their learning by choosing own challenges and determining learning objectives. Presumably, these factors characterise the learning information as essential and ultimately rewarding and, as concluded by Houser and Frymier (2009), are positive predictors of students' feelings of impact.

Students should be able to define the content to be acquired

In addition, identifying content knowledge to be acquired within a CBL course permits students to take ownership of learning. As Bradberry and De Maio (2018) illustrate, when students have to take ownership of learning and applying the course material, their control over the learning progress and motivation increase. In line with what was described by Santos et al. (2019), this study revealed that by reflecting on existing knowledge and experience when defining content knowledge, students recognise the worth of their experiences for making a difference.

Students should be independent and flexible when learning

The results show that when students can flexibly decide when and where to learn and do group work, their sense of impact strengthens. Academic literature describes that such a flexible positioning for learning promotes a strong sense of responsibility and advanced time management skills among students and prepares them for life-ng learning practices even after graduation (Bunn et al., 2018).

Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base

Inter- or trans-disciplinary collaboration is an important design requirement for fostering students' sense of impact. Forming multidisciplinary student groups is an optimal and often feasible way of facilitating inter-/trans-disciplinary collaboration in higher education contexts. This study illustrated that in multidisciplinary groups, students feel a stronger sense of impact as they are fostered to assess the value of own knowledge and expand it with the input from their peers. This is in line with what Ackerman (1989 in Ivanitskaya et al., 2002) and Buregyeya et al. (2021) present as benefits of multidisciplinary student teams. In addition, interdisciplinary collaboration fosters a sense of impact since it allows students to independently collect knowledge and combine their findings to achieve the learning outcomes. According to literature, as students start sharing perspectives of their disciplines and try integrating them

into other perspectives, innovation and creativity are enhanced (McNair et al., 2011; Field et al., 1994 in Ivanitskaya et al., 2002; Buregyeya et al., 2021).

Students should be able to explore their ideas and interests

The study findings also highlight the student-experienced benefits of exploring own ideas and interests when discussing sense of impact. The results showed that students found it empowering to engage with challenges that have personal relevance as they felt like they were able to explore topics interesting to them. White and Nitkin (2014) state that educational frameworks such as transformative, experiential, and self-directed learning depend on active engagement with a topic of interest. Undoubtedly, this is also true for CBL. Just like these approaches "transform impulses and feelings into purposeful action" (Dewey, 1938 in White & Nitkin, 2014, p. 4), CBL can create an environment for students to be empowered to accept challenges they are passionate about.

Furthermore, the study showed that students feel a strong sense of impact when they brainstorm and explore ideas. This can be explained by what the theoretical framework described regarding creativity and innovativeness affecting sense of impact (Etikariena & Widyasari, 2020). In addition, studies on experiential learning explain the power of allowing students to explore curious topics, experiment, and reflect (Adeniji-Neill, 2012; Mason & Arshed, 2013).

Teachers should carefully scaffold the learning process

"While a goal of learning is for the student to grow academically and socially, the goal of teaching is to inspire and guide students" (Rosebrough & Leverett, 2011 in White & Nitkin, 2014, p. 5). Accordingly, the salience of teacher roles as a process facilitator and a learning guide for students' sense of impact is highlighted in this study. Firstly, teachers need to support students' investigation endeavours as process facilitators. For example, teachers should prepare focused, sustainable, and time-resilient sets of credible resources (e.g., scientific literature, books, podcasts, websites, videos, databases, the contact information of experts) as well as a set of exemplary learning activities (e.g., independently attending lectures,

seminars, expert talks) to show the extensive reach a CBL experience can have. Notably, as students mentioned the benefit of having open access to technology, the resource list could outline different digital tools and hardware that students have access to within their context. This would foster students' freedom in choosing preferred IT infrastructures to support learning, as was described by Katz (2002). Overall, the teacher-presented materials, resources, and activities should expose students to various viewpoints, fostering a sense of impact in students. In addition, a CBL teacher needs to carefully manage student and stakeholder expectations to encourage and facilitate student control over the learning process. In student expectation management, emphasis can be made on the prospects of exploring materials and resources beyond what the teacher offers. In stakeholder expectation management, stakeholders should be made aware that there could be no pre-defined outcomes or direction if they choose to offer a problem for CBL education.

The theoretical framework defined high teacher immediacy as a factor facilitating students' sense of impact (Houser & Frymier, 2009). The study results confirmed the notion as students expressed the significance of having a coach supporting and guiding the teams when in need. This is further explained by Schwartz (2004), who noted that while having an extremely high sense of impact and empowerment, students can become overwhelmed by possible choices and feel that they are being exploited instead. Thus, teacher immediacy and the teacher guiding role should be promoted in CBL course design to promote a sense of impact in students.

Teachers should get support when designing CBL education

Educational change that occurs from the urgency to innovate and develop teaching practices to keep pace with the transformation of student needs requires teachers to adapt by revesting their teaching identity and constantly gaining new professional skills (Vähäsantanen, 2015). However, keeping up with the change and fulfilling day-to-day responsibilities is challenging and highly demanding (Vähäsantanen, 2015). Similarly, as was expressed by the case teachers, adapting to students' sense of impact needs and effectively using CBL when

(re-)designing courses can be difficult. Therefore, higher education institutions such as the UT should establish informative and practical support systems for practically advising teachers who employ CBL in their education. As the teachers suggested, this support can include hands-on sessions where CBL practices are shared, assistance and supervision of educational advisers, student assistants, stakeholder databases, and tools that guide CBL course design.

Therefore, design requirements for fostering students' sense of impact through CBL education are as follows:

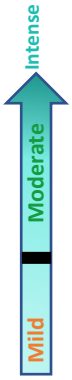
- Students should explicitly be made aware of their real-world impact
- Students should be able to freely interact with the real world
- Students should be able to define their challenge
- Students should be able to define the content to be acquired
- Students should be independent and flexible when learning
- Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base
- Students should be able to explore their ideas and interests
- Teachers should carefully scaffold the learning process
- Teachers should get support when designing CBL education

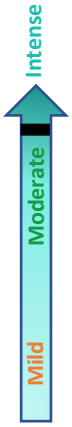
6.2 CBL DESIGN PROPOSITIONS FOR FOSTERING STUDENTS' SENSE OF IMPACT

The study results revealed that envisioning CBL course design from a perspective of varying intensity levels is a useful well-perceived tool for guiding (re-)design of education at the UT. Thus, to guide teachers in complying with the described design requirements, the CBL MMI Continuum levels can be used to outline design propositions for fostering students' sense of impact through CBL education. However, some adjustments were needed due to the study findings. As a result, Table 4 presents design propositions in a form of level-described educational features that are recommended (DOs) or should be avoided (DON'Ts) when aiming to foster students' sense of impact. The black line on the continuums indicates the advised levels of CBL according to the propositions. Moreover, the table presents how the formed design requirements are aligned with the propositions.

Table 4

CBL design propositions for fostering students' sense of impact

Educational Component & Design Requirements Supported	CBL Level	DOs	DON'Ts
CBL Learning Rationale supports: • Students should explicitly be made aware of their real-world impact • Students should be able to freely interact with the real world • Students should be able to define their challenge • Students should be able to explore their ideas and interests		☑ Students should be presented with broad big ideas ☑ Big ideas should be wicked ☑ Students should be able to choose their challenges ☑ Students should be able to identify the personal relevance of their challenges ☑ Students should be able to design challenge solutions ☑ Students should be able to interact with real-world stakeholders ☑ Students should explicitly realise their impact on the stakeholders through impact tests ☑ Students should be facilitated to learn from failures	☒ Students should not be presented with narrow problems ☒ Students' impact should not be passive or implicit
CBL Learning Objectives supports: • Students should be independent and flexible when learning		☑ Students should be facilitated to reflect on existing knowledge and skills ☑ Students should work towards learning objectives of higher-order thinking	☒ Learning objectives should not be narrow
CBL Content Knowledge supports: • Students should be able to define the content to be acquired • Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base		☑ Students should be able to independently gather disciplinary knowledge (content and soft skills) ☑ Students should be able to define the content knowledge to be acquired ☑ A group of students should be able to combine their knowledge and build an inter-/trans-disciplinary knowledge base	

CBL Learning Activities support: • Students should explicitly be made aware of their real-world impact • Students should be able to freely interact with the real world • Students should be able to define their challenge • Students should be able to define the content to be acquired • Students should be independent and flexible when learning • Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base • Students should be able to explore their ideas and interests		☑ Students should be able to personally engage with a big idea ☑ Students should be able to investigate the challenge by freely engaging with relevant stakeholders ☑ Students should be able to design a consciously chosen solution (e.g., follow the design cycle) ☑ Students' solution designs should have an explicit impact on the real world ☑ Students and stakeholders should be able to evaluate the effects of the solution ☑ Students should be able to cyclically reflect on the process and outcomes of learning	☒ Students should not spend time on the Engage phase at the expense of solution implementation ☒ Stakeholder engagement should not be limited (e.g., not 1-2 times during a course) ☒ CBL experiences should not have too many deadlines
CBL Teacher Role supports: • Teachers should carefully scaffold the learning process		☑ Teachers should be learning supervisors who manage the expectations of students, stakeholders, and professional advisers ☑ Teachers should regularly meet with stakeholders and students to discuss the progress and timely tackle obstacles ☑ Coaches should be learning guides and co-learners who are there for students to rely on in difficult situations ☑ Coaches should be more alert at the beginning of a CBL experience and make sure that students have time left for solution implementation ☑ Teachers should take on the role of field experts and professional advisers ☑ A CBL course is easier to manage if a team of teachers works on the design and execution ☑ The team should meet weekly	☒ Teachers should not be extremely distant from the student teams ☒ Teachers should not attempt to define the direction and outcomes of the CBL process

CBL Materials & Resources support:

- Students should be independent and flexible when learning
- Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base
- Students should be able to explore their ideas and interests
- Teachers should carefully scaffold the learning process

☑ Teachers should prepare a focused list of guiding resources

☑ The guiding resources should always be relevant and up to date

☑ The guiding resources should facilitate students in looking beyond their expertise

☑ The guiding resources should describe where and how IT facilities can be accessed

☑ Expert talks and field visits should be offered within a CBL experience

☑ Students should be able to decide whether they want to familiarise themselves with the guiding resources

☑ Students should explicitly be encouraged to explore additional resources

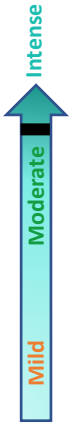
☒ The guiding resources should not be narrow and limited

☒ The guiding resources should not be hard to find

☒ Students should not be implicitly expected to explore additional resources

CBL Grouping supports:

- Students should explicitly be made aware of their real-world impact
- Students should be able to freely interact with the real world
- Students should be able to collaboratively build an inter-/trans-disciplinary knowledge base
- Teachers should carefully scaffold the learning process



☑ Students should be able to form a multidisciplinary group

☑ A multidisciplinary group can consist of students from different tracks of the same field

☑ Students should be able to choose their group mates

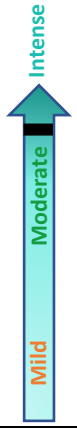
☑ Inter-/trans-disciplinary collaboration should be fostered

☑ Stakeholders should become co-learners

☑ CBL learners should sign contracts that outline expectations, personal gains, general rules of routine meetings (e.g., when, how often, where), and clauses of using student work

☒ Stakeholders should not have pre-defined outcomes in mind

☒ Stakeholders should not be introduced as clients

CBL Location & Time support: • Students should be independent and flexible when learning		☑ Students should be able to flexibly learn in the real world ☑ Scheduled learning activities should be offered ☑ Students should be able to decide whether they want to attend the offered learning activities ☑ Students should be able to decide when they want to do group work and learn independently	
CBL Assessment supports: • Students should be able to define their challenge • Students should be able to define the content to be acquired • Students should be independent and flexible when learning • Students should be able to explore their ideas and interests • Teachers should carefully scaffold the learning process	Any level	☑ The learning process should be assessed ☑ A part of a course could be dedicated to assessing content knowledge in a more traditional manner (e.g., Investigate phase, the first half of a course)	☒ Learning product requirements should not be strict
Support for CBL Teachers: • Teachers should get support when designing CBL education		☑ Teachers should have access to tools that can guide the (re-)design of CBL education ☑ Teachers should have access to a database of professionals and UT alumni who are willing to join a CBL experience as stakeholders ☑ Teachers should be able to attend informative hands-on sessions ☑ The sessions should share practical tips for implementing CBL ☑ Teachers should be able to get support from an educational adviser with expertise in CBL ☑ Teachers should be able to involve additional support (e.g., student assistants)	

In summary, to foster students' sense of impact through CBL education, a course design should be guided by the earlier outlined design requirements. To comply with the requirements, the described design propositions (Table 4) should be used to design future CBL courses.

7. LIMITATIONS

The results of this study must be interpreted with some limitations in mind. These are acknowledged below.

Firstly, the quantitative data analysis aimed to determine whether joining CBL courses increases a sense of impact in students was administered. For that, pre- and post-tests were conducted using a Sense of Impact scale derived from a Learner Empowerment instrument. However, due to the *small sample size*, the study cannot statistically show whether CBL education increases students' sense of impact and indicate the reliability of the extracted sense of impact scale. Therefore, the quantitative data was used only as an indication and the data analysis was mainly based on the qualitative data collected.

Secondly, although 11 SEiC students filled out the sense of impact surveys, the case's students' needs analysis was based only on the perceptions of three students. According to the pre-/post-test results, some SEiC students perceived a weaker or more substantial sense of impact after completing the course. However, the researcher could only get perspective from three students whose sense of impact changed moderately. Hence, the analysis of the *SEiC course* should be taken with caution due to the *low number of participants* in the qualitative data collection. Nonetheless, the interviewed students described various instances of SEiC's course design and their effect on their sense of impact, which expanded the data collected from the other cases.

The third limitation concerns the *reliability* of the qualitative data analysis regarding students' sense of impact needs. Inter-coder reliability was not determined for the analysis because the researcher could not find a seconder coder with sufficient knowledge of course design and the sense of impact concept. Nonetheless, during the final evaluation interviews, teachers expressed that the study's findings made sense in light of what was done in their courses.

Lastly, the *disregard for boundary conditions of extracurricular and curricular educational designs* should be considered. In higher education, curricular courses have stricter boundary conditions and expectations dictated by institutional regulations regarding learning

objectives, academic skills development, scheduling, and assessment. In the meantime, extracurricular courses have more flexible conditions and less strict expectations. Since SEiC was a fully curricular course, NTBD was an independent minor, and LSC was extracurricular, the research analysed CBL courses of different types. However, the boundary conditions of the cases and the differences between them were not explored in detail. Thus, it is unclear whether all of the formed design requirements and propositions suit both, curricular and extracurricular courses.

8. FUTURE RESEARCH

The described limitations can be used to inspire future research. First, quantitative and qualitative studies should be conducted to explore relationships between CBL courses and learner empowerment components (i.e., sense of impact, meaningfulness, competence). As was described in this study, CBL is distinguished from similar educational frameworks by its feature of real-world learning and societal impact. Thus, creating empirical evidence proving or disproving CBL's potential to empower learners is vital for understanding the framework and its effects. Secondly, it is valuable to investigate the differences in possibilities of fostering a sense of impact and other components of learner empowerment with boundary conditions of curricular and extracurricular education. Such insights would allow teachers to make course design decisions informed by the goals of a course and the feasibility of applying CBL educational features.

Future research can also be stimulated by the findings of this study. The logical next step is to design a CBL course according to the design requirements and propositions formed in this study. The design study can explore questions that arose from the evaluation discussions with the case teachers and the educational adviser. For instance, it was unclear if some of the identified design requirements have a stronger influence and are more valuable to consider when designing CBL education to foster a sense of impact in students. This should be investigated in future CBL design studies. Elaborating on the design will further explore the feasibility of complying with the design requirements and propositions in education. In addition, the design can be followed by an evaluation of its effects on students, including sense of impact. Consequently, more evidence can be produced on the relations between CBL educational design and students' sense of impact.

The context analysis of the three UT cases confirmed that CBL features could be adjusted, combined, and administered in various ways. Hence, there is more to learn about methodological variations in CBL education and their influence on student learning. The Mild-Moderate-Intense CBL Continuums model (Figure 3) showed to be helpful in categorising CBL course design. Thus, the model should be further studied to evaluate the extent to which it can

grasp the variations of CBL and possibly operationalise the framework's application in current education. This can considerably contribute to the scientific understanding of CBL.

The teacher evaluation interviews also revealed practical applications of the model. First, the teachers argued that the continuums could be used to gradually steer the education of the UT towards CBL and increase the acceptance of the framework among the university's teaching community. For instance, when a course is being re-designed, teachers could be advised to slowly integrate CBL into the course by guiding the process with the mild CBL level. On the other hand, when a new course is designed, the intense level of CBL could be applied right away. Nonetheless, the model does not consider the role of constructive alignment. So, it is uncertain whether a CBL course should adhere to only one level of intensity or if the levels can vary among the educational components. Thus, the principle of constructive alignment in deciding the intensity of CBL educational components needs to be explored to inform teachers and educationalists better. Lastly, the teachers expressed an interest in guiding their courses' (re-)design via an interactive tool based on the MMI CBL Continuums model. Thus, future research can use the model to create a guiding tool where a CBL level can be identified, for instance, based on boundary conditions and long-range goals.

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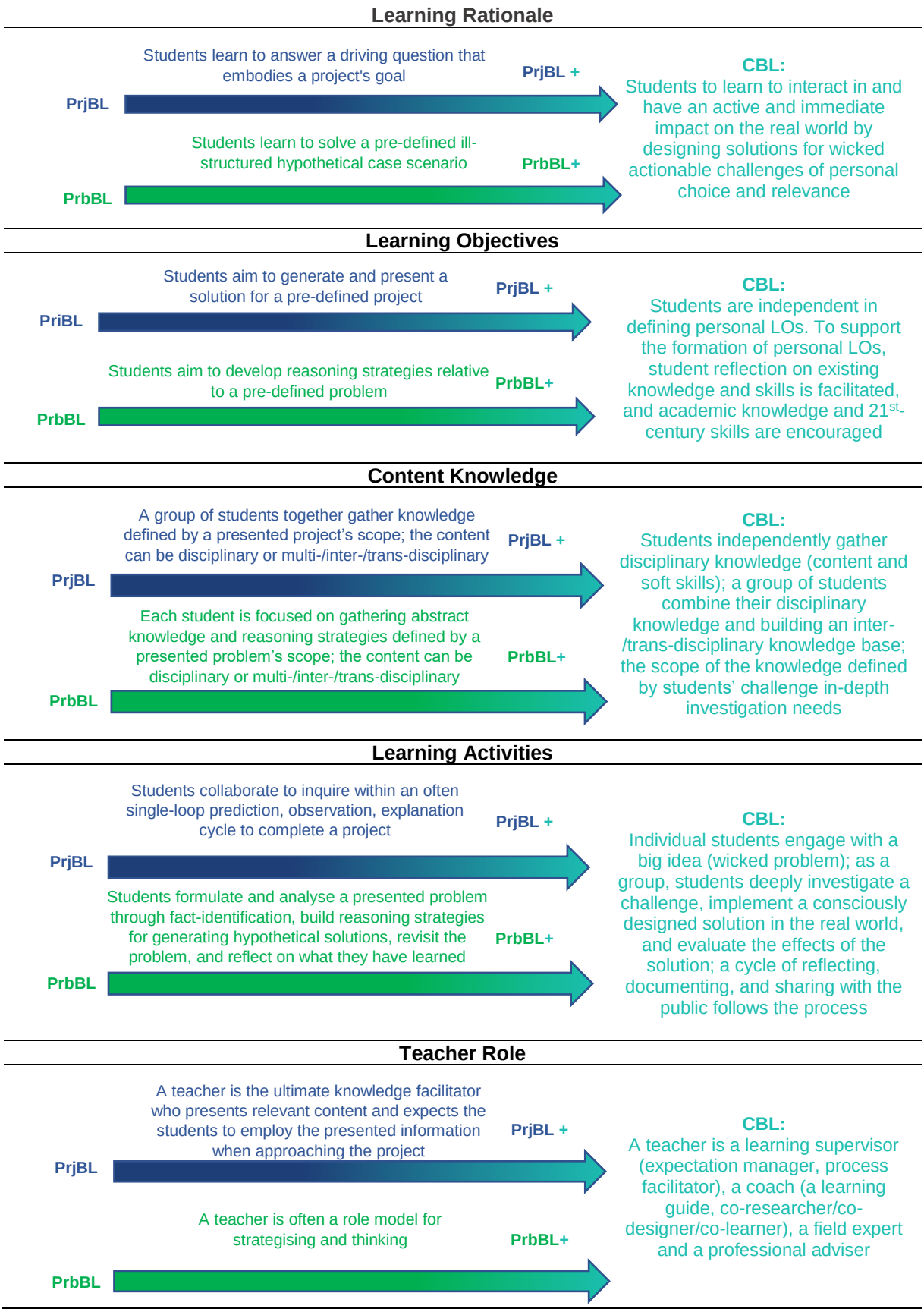
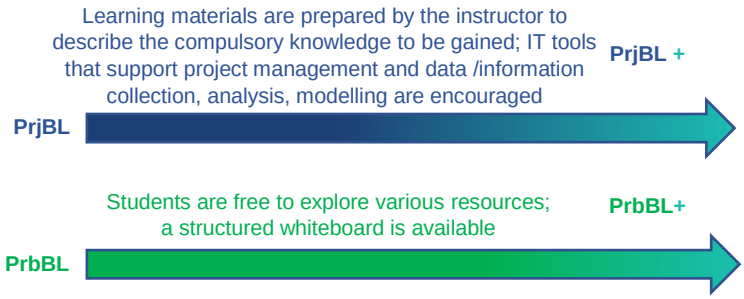
10. APPENDICIES

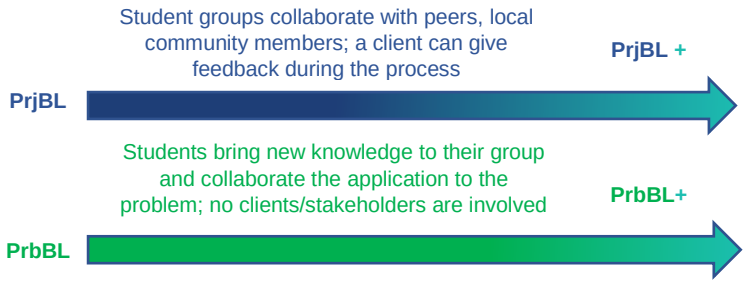
10.1 Appendix A: PrjBL-CBL; PrbBL-CBL Curriculum Continuums



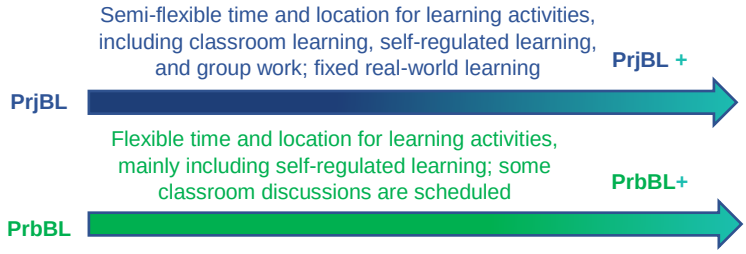
Materials & Resources



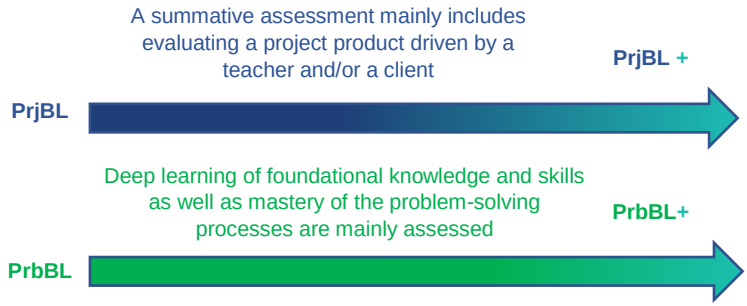
Grouping



Location & Time



Assessment



10.2 Appendix B: Challenge-based Learning Process

The overarching characteristics of a CBL experience include processes of engaging with an introduced problem, investigating different instances of the problem, and acting to solve the problem. Figure 1 presents the most recent educational framework for CBL. According to Nichols et al. (2016, p. 11-13), a CBL experience is divided into three interconnected phases: Engage, Investigate, and Act. Each phase includes three essential steps that prepare learners to move to the next stage. All the nine steps of the process are accompanied by an ongoing process of documenting, reflecting, and sharing.

Figure 1

Challenge-based Learning Framework (Nichols et al., 2016, p.11)

Phase 1, Engage, encourages students to move from an abstract Big Idea to a concrete actionable Challenge through a process of Essential Questioning (Nichols et al., 2016, p. 31-35). First, the process is initiated as a Big Idea, a general topic that can be identified by the instructor (Apple Inc., 2011, p. 8). The Big Idea has to be important on a global scale and be broad so students can find real personal meaning when looking for problems within its scope (Nichols et al., 2016, p. 31). Additionally, the Big Idea has to prompt students to gain deep multidisciplinary content knowledge and understanding required by the course that they are following (Apple Inc., 2011, p. 9). For example, teams can be presented with the idea of Climate Change. Secondly, students work together with their coach (i.e., the teacher) to formulate broad Essential Questions (Nichols et al., 2016, p. 32). These questions create the link between the students' lives and the Big Idea (Apple Inc., 2011, p. 10). As they are being answered via research, the questions will help students in contextualising and personalising the Big Idea (Nichols et al., 2016, p. 32). Answering the questions will also stimulate students to learn about the fundamentals of the introduced topic (e.g., what is climate change? why is it occurring? what are fossil fuels?). The end product is a single Essential Question that is relevant to the student team (Apple Inc., 2011, p. 10). The Essential Question can be descriptive. For instance, "how can I reduce the impact of my use of fossil fuels on my planet?" would be the final Essential Question connected to the Big Idea of Climate Change. In the third step of the phase, students turn the Essential Question into a call to action, a Challenge that invites students to develop a local solution to a global problem (Nichols et al., 2016, p. 33). Here, the coach must make sure that his teams' Challenge is immediate, actionable, and feasible to solve within the timeframe of the course (Apple Inc., 2011, p. 10). The Challenge has to describe what students want to achieve without indicating a precise solution. It is vital that students do not yet think of a solution as it would hinder their investigative process. An example of a Challenge would be reducing your university's use of fossil fuels. When the Big

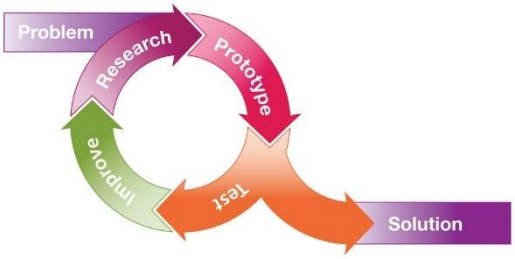
Idea is explored, Essential Questions are answered, and a Challenge is formulated and accepted by the team, Phase 2, Investigate starts.

The Investigate phase asks all learners to plan and participate in a learning journey that explores the needs of the project, addresses academic requirements, and builds the foundation for a Solution (Nichols et al., 2016, p. 36-40). First, students formulate sets of Guiding Questions that point toward the knowledge the team will need to develop a solution to the Challenge. The question sets represent the needs of each group member for their perspective discipline (Nichols et al., 2016, p. 12). Even though the questions will continue to emerge throughout the experience, the coach's responsibility is to make sure the students develop an extensive list of Guiding Questions as this will guide their learning and ultimately the validity of their solutions (Nichols et al., 2016, p. 37). Categorising and prioritising the questions create an organised learning experience (Nichols et al., 2016, p. 12), where students start the second step of the phase: identifying and engaging in Guiding Activities and making use of Guiding Resources to answer the Guiding Questions. These activities and resources include any methods and tools that help each student acquire the knowledge needed to answer the Guiding Questions and to come closer to an innovative, insightful, creative, and realistic solution (Nichols et al., 2016, p. 12; Apple Inc., 2011, p. 12). Guiding Activities may include participating in lectures and seminars, conducting research and expert interviews, and making stakeholder analyses and calculations. Guiding Resources are the tools (and people) that are of use in the Guiding Activities (e.g., lectures, stakeholders, experts, surveys, questionnaires, formulas, etc.) Coaches are their team's guide in navigating resources available to them (Apple Inc., 2011, p. 12). A coach can support students' work by offering the Guiding Resources, a focused set of relevant and credible resources that he/she has chosen (e.g., scientific literature, books, podcasts, websites, videos, databases, contact information of experts). The third step of the investigation phase involves the student team coming together with the coach and stakeholders sharing findings, analysing the learned lessons, and building a foundation for the eventual identification of solutions (Nichols et al., 2016, p. 12). When finalising the Investigate phase, students should have an extensive list of Guiding Questions, answers to these questions through participating in various Guiding Activities and using reliable Guiding Resources, and a good base for possible challenge solutions based on the combined analysis of all the findings. These will allow learners to move to the final step of their CBL experience, the Act phase.

Phase 3 is aimed at acting on the Challenge by developing evidence-based solutions which are implemented in real life, evaluated based on the results, reflected upon, and shared with the public (Nichols et al., 2016, p. 40-42). First, learners collaboratively create solution concepts based on findings made during the Investigation phase. Using the design cycle (Figure 2), learners will prototype, test, and refine these solution concepts (Nichols et al., 2016, p. 13).

Figure 2

Engineering Design Cycle (Eddleman, 2016)



Although the learners will come up with multiple suitable solutions, the student team needs to select a single solution to develop (Apple Inc., 2011, p. 13). The chosen solution needs to be organised into a work plan for implementation (Apple Inc., 2011, p. 13). In the second step, the solution needs to be implemented in real life, where the solution can have an impact on the stakeholders (Nichols et al., 2016, p. 41). Lastly, the phase asks students to assess the effectiveness of their solution, make adjustments, and sometimes even deepen subject area knowledge via evaluation (Nichols et al., 2016, p. 13). Here, students need to clearly understand the outcomes of the solution by asking themselves reflective questions (e.g., did anything change? did it change the way the students had thought it would? how did the stakeholders react to the solution?) and analyse whether the solution had the desired effect. The phase Act demands students to select a solution, implement it in real life with real people, and evaluate the impact they have had.

Every step is accompanied by a constant process of documenting, reflecting, and sharing (Nichols et al., 2016, p. 42-43). Every student is required to document all the experiences that occur throughout the process using video and audio journals, work plans, concept maps, reports, etc. Such documentation should also include frequent reflections where learners step back and think deeper about every experience. The coach ensures that the end of each process phase offers an opportunity for reflection. At the end of the project, all the documents and reflection outcomes need to be shared with the world via open-source platforms (Apple Inc., 2011, p. 13). Notably, students are encouraged to share failures, as well as successes as these will allow future learners to use the team’s experience for building their own (Nichols et al., 2016, p. 40). This cycle will prompt students to keep constant track of all the processes, reflect on their actions, and share with a broad learning community.

10.3 Appendix C: NTBD Reflection Report Form

REFLECTION REPORT

Dear students,

Please submit your individual learning achievements before Friday this week by answering the following questions:

- Do you feel like you had an impact on and control over how things were done in your team and the success of the project? If yes, how do you think the module's set-up affected your sense of impact? If not, what could the module have had to support your sense of impact?
- Did the module allow you to explore your ideas? What about your passions and/or attitudes? If yes, how did the module encourage you? If not, what could have been done better?
- Did you feel like the experiences during the module allowed you to develop skills that you would find valuable when pursuing a career? If yes, how these experiences and skills were developed by the module? If no, what in your opinion was lacking?
- Were you autonomous in accomplishing your goals and performing tasks throughout the module? How do you think the module's set-up affected your autonomy?
- Did the module allow you to be creative and go beyond the basic requirements? If yes, what was the set-up's effect? If not, what do you think was missing?
- Did you see your coach and the module supervisor as your superior or as your peer in learning? Why one or the other?

Please submit your answers in an e-mail to your coach.

Note that we use this information to improve the course and to make an inventory on the skills this module enables students to develop.

10.4 Appendix D: Notetaking Form

Template based on Pauk et al. (2010) "The Cornell System: Take Effective Notes

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Essential Question

Main Ideas / Key Words

Notes

Summary

10.5 Appendix E: Pre-/post-test Qualtrics Surveys

Page 1 (pre-test & post-test introductory messages)

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Dear student,

You are being invited to participate in a research study titled Challenge-based Learning for Developing Students' Sense of Impact. This study is the graduation project done by Adina Imanbayeva within the Educational Science and Technology master's programme.

The purpose of this research study is to develop design requirements and propositions for a Challenge-based Learning (CBL) course for it to foster students' sense of impact. CBL is an innovative educational approach that is being applied in your course. Sense of Impact is a dimension of Learning Empowerment that refers to the degree to which individuals perceive they can make a difference in their environment. The study intends to see how different characteristics of a CBL course affect students' Sense of Impact.

Your participation in this study is entirely voluntary, and you can withdraw at any time by contacting the researcher. You are free to share any questions, comments, or concerns by contacting the researcher.

The current survey is a pre-/post-test measure that will identify students' Sense of Impact levels. It will take you approximately 3 minutes to complete the survey. The survey will also ask you to indicate your name and contact details. The researcher will use these to connect the pre-test data to the post-test one and invite you to focus group interviews at the end of the course. If you do not wish for the researcher to have your name or contact information, you are free to indicate so in the survey.

Your answers in this study will remain confidential to the best of the researcher's ability. To minimise any risks, only the researcher will have access to the survey data, the research publication will not indicate any individual names, and the data will be coded in future storage.

Study contact details for further information:
Adina Imanbayeva, a.imanbayeva@student.utwente.nl

- ○ I consent, begin the study
- ○ I do not consent, I do not wish to participate

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Dear student,

At the beginning of your CBL experience, you were invited to participate in a research study titled Challenge-based Learning for Developing Students' Sense of Impact* (the graduation project done by Adina Imanbayeva within the Educational Science and Technology master's programme) and fill out the Sense of Impact measure before starting the experience.

Now, while filling out this post-test survey, I would like to ask you to think about your current feelings regarding the impact you have. It will take you approximately 3 minutes to complete the survey. The survey will also ask you to indicate your name and contact details. These will be used to connect the pre-test data to the post-test one and invite you to focus group interviews after the course. If you do not wish for the researcher to have your name or contact information, you are free to indicate so in the survey.

Your participation in this study is entirely voluntary, and you can withdraw at any time by contacting the researcher. You are free to share any questions, comments, or concerns by contacting the researcher.

Your answers in this study will remain confidential to the best of the researcher's ability. To minimise any risks, only the researcher will have access to the survey data, the research publication will not indicate any individual names, and the data will be coded in future storage.

*The purpose of this research study is to develop design requirements and propositions for a Challenge-based Learning (CBL) course for it to foster students' sense of impact. CBL is an innovative educational approach that is being applied in your course. Sense of Impact is a dimension of Learning Empowerment that refers to the degree to which individuals perceive they can make a difference in their environment. The study intends to see how different characteristics of a CBL course affect students' Sense of Impact.

Contact details for further information: Adina Imanbayeva, a.imanbayeva@student.utwente.nl

- ○ I consent, begin the study
- ○ I do not consent, I do not wish to participate

Page 2 (pre-test & post-test instruction)

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For this pre-test, please think about your overall impression as a student in your regular classroom. How do you generally feel when following any course?

Never Sometimes Often Very often

UNIVERSITY OF TWENTE.

For this post-test, please think about your impression as a student in the course you have just completed. How did you feel throughout the course?

Never Sometimes Often Very often

Page 2 (sense of impact measure)

	Never	Sometimes	Often	Very often
I have the power to make a difference in how things are done in my class.	○	○	○	○
I have a choice in the methods I can use to perform my work.	○	○	○	○
My participation is important to the success of the class.	○	○	○	○
I have freedom to choose among options in this class.	○	○	○	○
I can make an impact on the way things are run in my class.	○	○	○	○
Alternative approaches to learning are encouraged in my class.	○	○	○	○
I have the opportunity to contribute to the learning of others in this class.	○	○	○	○
I have the opportunity to make important decisions in this class.	○	○	○	○
I cannot influence what happens in this class.	○	○	○	○
I have the power to create a supportive learning environment in this class.	○	○	○	○
My contribution to this class makes no difference.	○	○	○	○
I can determine how tasks can be performed.	○	○	○	○
I make a difference in the learning that goes on in this class.	○	○	○	○
I have no freedom to choose in this class.	○	○	○	○
I can influence the instructor.	○	○	○	○
I feel appreciated in this class.	○	○	○	○

Page 3 (email collection)

I would like to contact you for data analysis and further data collection. Could you please share your (student) email address?

Page 4 (thank you message)

We thank you for your time spent taking this survey.
Your response has been recorded.

10.6 Appendix F: Student Interview Structure and Presented Content

Introduction (ppt):

Challenge-based Learning for Fostering Students' Sense of Impact

MSc Educational Science & Technology

Graduation Project

If you have any questions, feel free to contact me via email:
a.Imanbayeva.@student.utwente.nl

Learner empowerment and Sense of Impact (ppt)

Learner empowerment is a condition in which learning individuals *feel inspired* and *strongly motivated to act*, have *control* over the *process* and the *outcomes* of their actions (Frymier et al., 1996).

Sense of impact refers to students' perception of their *power to "make a difference in the scheme of things"* (Frymier et al., 1996, p. 184) and their *perceived ability to make choices* as they feel that their *choices have an impact* on their surroundings.

Sense of Impact Before CBL (ppt and Wooclap):

Different educational settings influence students' sense of impact. Thus, let's think about the classical education at the UT. Wooclap question:

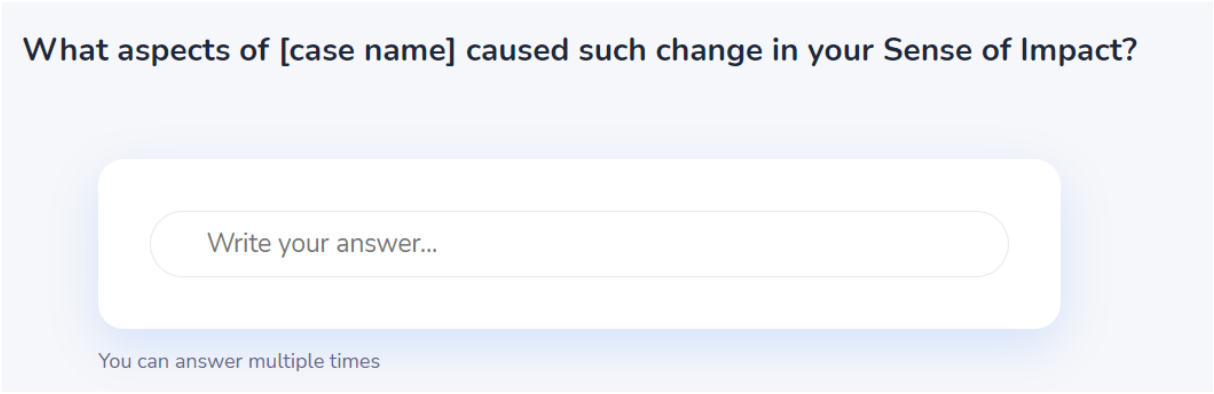
Sense Of Impact After CBL (ppt and Wooclap):

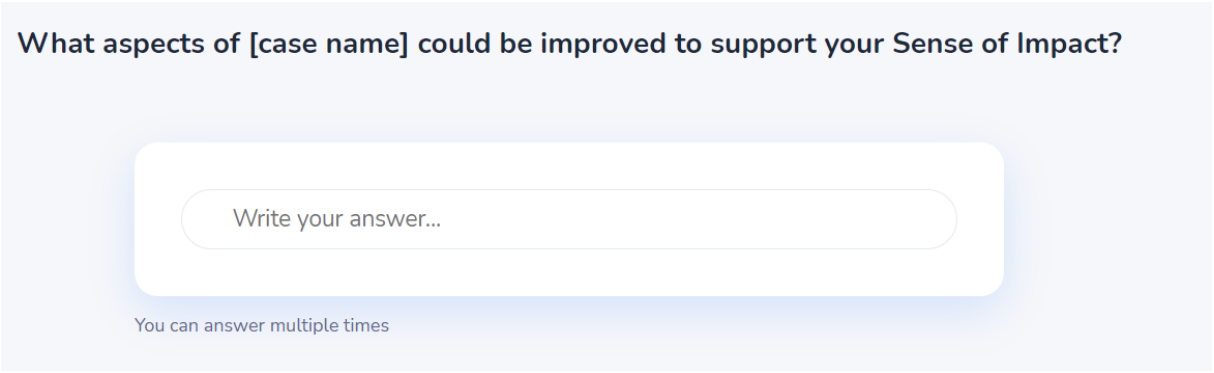
In the [case name] your Sense of Impact increased/decreased/stayed the same:

	Student 1	Student 2	Student 3	Student 4
Pre-test				
Post-test				

Note: in the group interview, the students saw the results of the students in the group; in the individual interviews, the students only saw their own results

Wooclap questions to foster discussion:





10.7 Appendix G: Evaluation Interview Questions

1. What are your first impressions concerning the case and students' sense of impact needs reports?
2. In your opinion, is it feasible to guide future CBL course design by the outlined design requirements?
3. What do you think about the feasibility of the presented design proposition?
4. Are there any other ways of complying with the outlined design requirements?
5. Do you have anything else you would like to add?

10.8 Appendix H: CBL Course Analyses Codebook

Instructions:

First, code for categories. Then, based on the quotes that you have, decide which code would fit the quotes in total.

Category	Code	Description	Quotes
Learning Rationale Why are they learning?	Mild CBL	• Interaction with the real world • Passive impact on the real world • Broad big ideas • Wicked problems • Actionable challenges • Challenges of personal choice • Solution design	
	Moderate CBL	• Interaction with the real world • ***Active impact*** on the real world • Broad big ideas • Wicked problems • Actionable challenges • Challenges of personal choice • Challenges of ***profound personal relevance*** • Solution design	
	Intense CBL	• Interaction with the real world • Active ***and immediate impact*** on the real world • Broad big ideas • Wicked problems • Actionable challenges • Challenges of personal choice • Challenges of profound personal relevance • Solution design	
Learning Objectives Towards which goal are they learning?	Mild CBL	• Reflection on existing knowledge and skills is facilitated • Students mainly work towards pre-defined narrow learning objectives	
	Moderate CBL	• Reflection on existing knowledge and skills is facilitated • A pool of ***pre-defined broad LOs*** (incl. academic and 21st-century skills) is presented • Students are independent in ***choosing LOs from the pool***	
	Intense CBL	• Reflection on existing knowledge and skills is facilitated • Students are ***independent in defining personal LOs*** • Academic knowledge and 21st-century skills are ***encouraged***	
Content Knowledge What are they learning?	Mild CBL	• Groups of students together gain inter-/trans-disciplinary knowledge (content and soft skills) • The scope of CK is mainly defined by the course • The scope of CK is partially defined by students' challenge investigation needs	
	Moderate CBL	• Groups of students together gain inter-/trans-disciplinary knowledge (content and soft skills) • The scope of CK is ***partially*** defined by the course • The scope of CK is ***partially*** defined by students' challenge investigation needs	
	Intense CBL	• Students ***independently gather disciplinary knowledge*** (content and soft skills)	

		• A group of students ***combine*** their disciplinary knowledge and ***build*** an inter-/trans-disciplinary ***knowledge base*** • The scope of CK ***is defined*** by students' challenge investigation needs	
Learning Activities How are they learning?	Mild CBL	• Students (individuals or groups) engage with a wicked problem (i.e., big idea) • They identify an actionable challenge • They deeply investigate a challenge (incl. scheduled engagement with the primary stakeholder) • They design a consciously chosen solution • They (indirectly/directly) implement the solution in the real world • They reflect on the possible effects of the solution	
	Moderate CBL	• Students (individuals or groups) engage with a wicked problem (i.e., big idea) • They identify an actionable challenge • They deeply investigate a challenge (incl. ***free engagement with the primary stakeholder***) • They design a consciously chosen solution • They (indirectly/directly) implement the solution in the real world • They ***evaluate the effects*** of the solution • A ***cycle*** of ***reflecting*** and ***documenting*** follows the process	
	Intense CBL	• ***Individual students engage*** with a wicked problem (i.e., big idea) • ***Individual students identify immediate*** actionable challenges • Students ***form a group*** based on their actionable challenge • The group deeply investigates a challenge (incl. ***free engagement with relevant stakeholders***) • The group designs a consciously chosen solution • The group ***directly*** implements the solution in the real world • The group evaluates the effects of the solution • A cycle of ***reflecting, documenting, and sharing*** with the public follows the process	
Teacher Role How is the teacher facilitating the learning?	Mild CBL	• A learning supervisor (expectation manager, process facilitator) • Field experts and professional advisers	
	Moderate CBL	• A learning supervisor (expectation manager, process facilitator) • A ***coach*** (a ***learning guide***) • Field experts and professional advisers	
	Intense CBL	• A learning supervisor (expectation manager, process facilitator) • A coach (a learning guide, ***co-researcher/co-designer/co-learner***) • Field experts and professional advisers	
Materials & Resources With what are they learning?	Mild CBL	• Teachers prepare guiding resources • Students must familiarise themselves with the guiding resources • Students are encouraged to explore additional resources • Technology can be used	

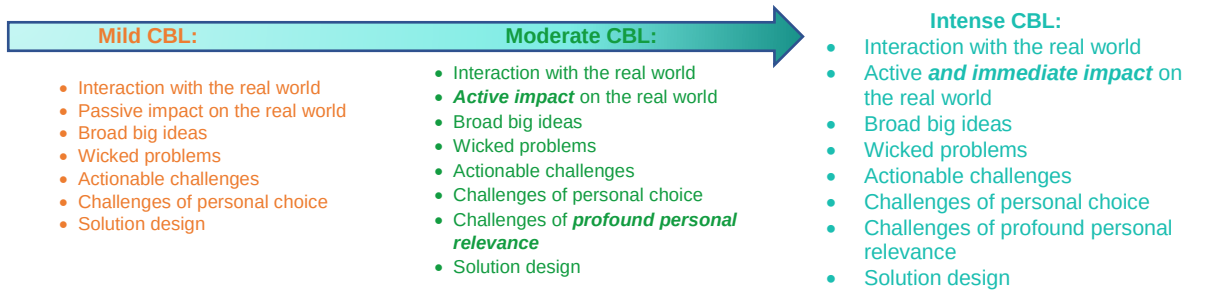
	Moderate CBL	• Teachers prepare guiding resources • Students ***can choose to*** familiarise themselves with the guiding resources • Students are encouraged to explore additional resources • ***Open access to technology***	
	Intense CBL	• Teachers prepare guiding resources • Students can choose to familiarise themselves with the guiding resources • Students are encouraged to explore additional resources • Open access to ***state-of-the-art technology***	
Grouping With whom are they learning?	Mild CBL	• Students form a group of co-learners • Inter-/trans-disciplinary collaboration is fostered	
	Moderate CBL	• Students form a ***multidisciplinary group*** of co-learners • Inter-/trans-disciplinary collaboration is fostered	
	Intense CBL	• A multidisciplinary group of ***co-learners*** consists of: - ***students*** from different disciplines - ***coaches*** (teachers) from various disciplines - ***stakeholders*** • Inter-/trans-disciplinary collaboration is fostered	
Location & Time Where are they learning?	Mild CBL	• Fixed learning in the real world • Fixed T&L for the offered learning activities • Flexible T&L for self-regulated learning and groupwork • A collaborative virtual and/or physical workspace is accessible by schedule	
	Moderate CBL	• ***Semi-fixed*** learning in the real world • ***Semi-fixed*** T&L for the offered ***learning activities*** • Flexible T&L for self-regulated learning and groupwork • A collaborative virtual and/or physical workspace is accessible by schedule	
	Intense CBL	• ***Flexible*** learning in the real world • ***Flexible*** T&L for the offered ***learning activities*** • Flexible T&L for self-regulated learning and group work • A collaborative virtual and/or physical workspace is ***constantly accessible***	
Assessment How is their learning assessed?	Mild CBL	• The learning product and process are assessed • Teacher- and/or stakeholder-defined criteria include: - the incorporation of the acquired content and skills into a solution design - the feasibility of the solution • Critical reflection on the process/progress is assessed • Teachers and/or stakeholders conduct the assessment	
	Moderate CBL	• The learning product and process are assessed • Teacher- and/or stakeholder-defined criteria include: - the incorporation of the acquired content and skills into a solution design - ***creativity*** and ***innovativeness*** of the design	

		- the feasibility of the solution • Critical reflection on ***process successes and failures*** is assessed • Students ***can contribute*** to the assessment • Teachers and/or stakeholders conduct the assessment	
	Intense CBL	• The learning process is assessed • The ***student and teacher-defined criteria*** include: - students' ***personal progress*** - students' ***decision making*** - **the reflection** on the creativity and innovativeness of the design - **the reflection** on the feasibility of the solution • Critical reflection on process successes and failures is assessed • ***Students and teachers choose the assessment procedure*** • Students and teachers ***co-assess the process***	

10.9 Appendix I: CBL Course Design of NTBD

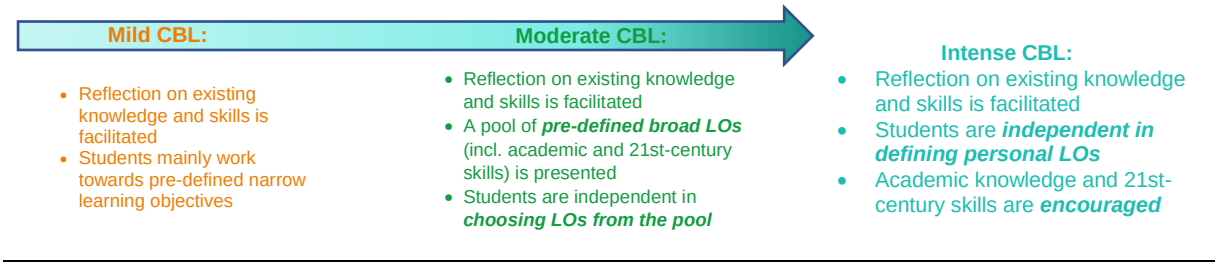
New Technology Business Development (NTBD) is a CBL-designed minor that UT bachelor students can choose to follow in their third year of studies. Students usually select their minor based on the information (e.g., the subject area, the educational features) presented in promotional materials and a marketing event. This context analysis describes the educational aspects employed in the minor and how they fit into the CBL approach based on the Mild-Moderate-Intense (MMI) CBL Continuums model created to support the data analysis within the graduation project.

Learning Rationale



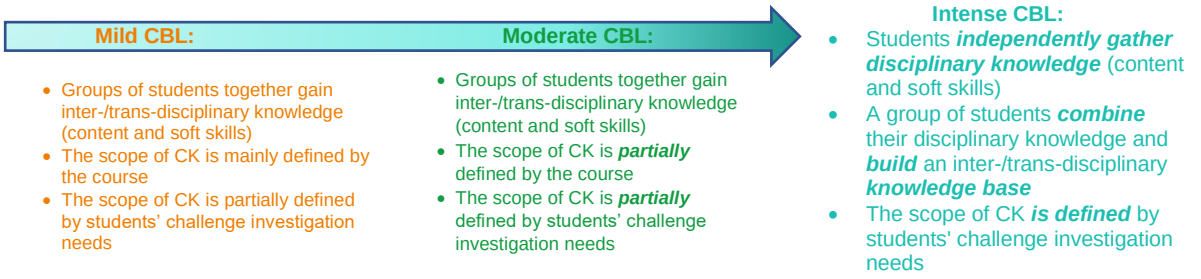
The learning rationale of NTBD seems to align with the moderate CBL level definition presented above. The course documents highlight that by following the minor, the students were expected to engage and interact with the real world. It was revealed that students had an indirect but active impact on the real world as they were in direct contact with the challenge providers. The students were presented with a pool of big ideas and thus were seemingly facilitated to define challenges of personal choice and relevance. In addition, the expectation to design solutions for actionable wicked challenges was posed to the students.

Learning Objectives (LOs)



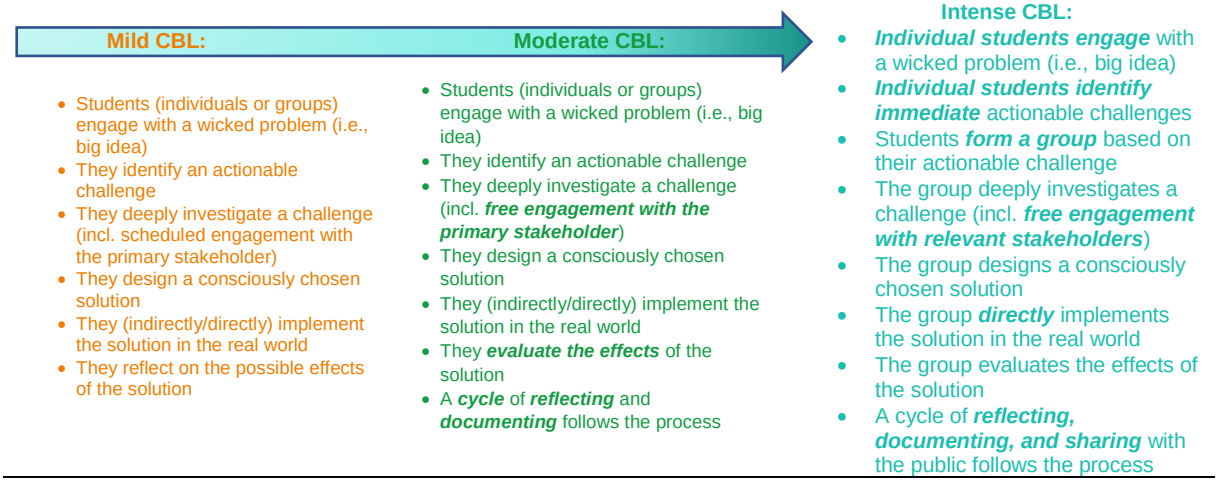
The learning objectives of the minor seem to fall between mild and moderate CBL level descriptions. The pre-defined objectives of the minor were broad (e.g., explore, analyse, integrate), which seem to allow students to be flexible in approaching the challenge and gaining knowledge/skills. Moreover, 21st-century skills development was a part of the learning objectives. However, according to the course documents, students were not expected to define personal learning objectives based on the presented pool. Notably, reflection on existing knowledge and skills was facilitated via a content-focused assessment. The teacher also mentioned that he observed it happening naturally when the students had to investigate the challenge and work on the content-focused assessment.

Content Knowledge (CK)



The content knowledge of the NTBD minor seems to align with the intense CBL level definition. According to the minor documents, the students were "in the driver seat of the learning process". Notably, the course schedule showed that although subject area-specific sessions were offered in the minor, a considerable amount of time was allocated for the students to gather disciplinary knowledge necessary for the challenge and share it with their team. It seems like the students were required to combine all the disciplinary knowledge and build an inter-disciplinary knowledge base to approach the challenge since they were encouraged to "explore each other's professional worlds".

Learning Activities



The minor's learning activities seem to be almost of the moderate CBL level. The learning activities descriptions of the minor hint that students could engage with the big ideas as they worked with their "own challenge". The students were expected to do an in-depth investigation of the challenge-relevant topics. Moreover, the students had constant contact with the challenge provider, allowing for free engagement. The students were expected to engage with a design thinking cycle which seems to scaffold student reflection, documentation, and a conscious design of a solution for the challenge. The teacher also shared that some students got to implement and evaluate their solutions in the real world, while others were able to test the feasibility of their solutions based on the peer responses during presentations.

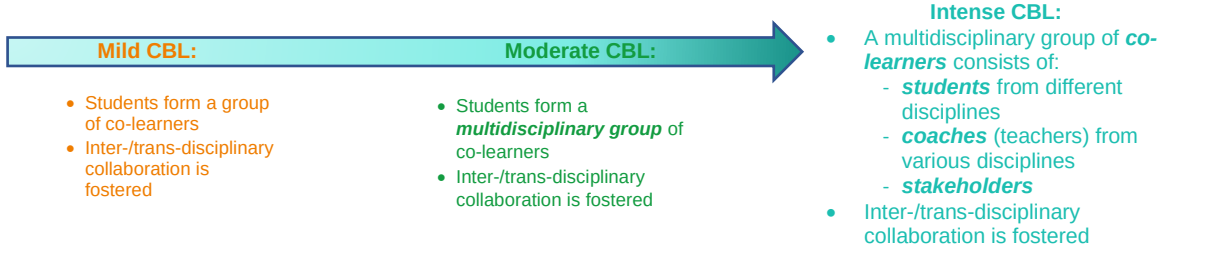
Teacher Role

The teacher role of NTBD adheres to the intense CBL level. The minor had teachers of different functions. Firstly, the minor supervisor managed students' expectations and facilitated the learning process. Secondly, the teachers had the role of field experts and professional advisers who conducted educational meetings for students to get insights into the subject area. Lastly, each team had a coach – a teacher who was expected to be a part of the student team, thus, acting as a co-learner, co-designer, and co-researcher. One teacher could take on multiple roles within the minor.

Materials & Resources

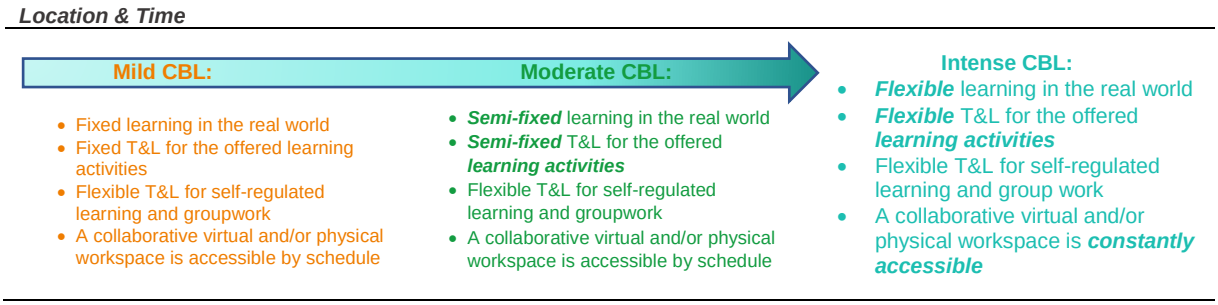
NTBD's materials and resources seem to be of the moderate CBL level. The students were offered various guiding resources (e.g., literature, lectures, workshops, educational videos) and suggested exploring other resources. The use of the guiding resources was optional. In addition, the minor's documents often emphasise the importance of using modern technology when approaching the challenges. However, as the minor teacher mentioned, UT students always have access to state-of-the-art technology via various facilities (e.g., BMS Lab, Design Lab). However, it was uncertain whether the students were aware of the access. Therefore, the minor did not necessitate or highlight the available technological facilities.

Grouping

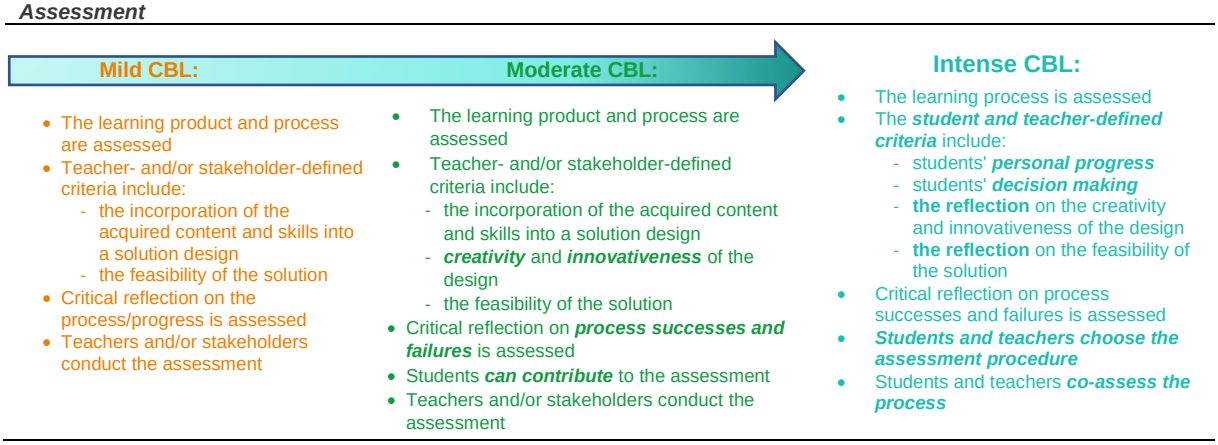


NTBD grouping seems to be better defined by the intense CBL level. Students became a part of a multidisciplinary group and were required to collaborate when approaching the

challenge. It seems like each team's coach and the challenge provider were also an active part of the team as they regularly met throughout the process. Due to the requirement of approaching the challenges from the perspectives of multiple disciplines, interdisciplinary collaboration seemingly was fostered.



The location and time of the minor are in line with the moderate CBL level. There were scheduled learning activities. However, they were optional for students to attend. The students were expected to engage with the real world weekly but could contact the stakeholders whenever they saw fit. The self-regulated learning and group work were flexible in NTBD. Moreover, "free timeslots" were available in the minor's timetable to provide students with access to physical and virtual environments.



The assessment within NTBD falls in between moderate and intense CBL levels. There were two significant assessments within the minor: content-focused and process-focused. The content-focused assessment seemingly allowed students to show which knowledge they have successfully acquired and how they can practically apply it. The learning product was not formally assessed. In the process-focus assessment, the students apparently got the chance to reflect on their learning experiences (i.e., team interactions, stakeholder interactions, engagement, investigation, and implementation) within the minor, justify their choices, evaluate their progress, and critically reflect on the process successes and failures. Such an approach to assessment suggests that students could contribute to evaluating their work. However, the assessment was still conducted by the teachers.

Table 1 summarises the educational features that were seemingly applied in the NTBD design.

Table 1

NTBD: CBL Course Design Features
(the level of the features coded by colour: mild, moderate, intense, was not defined by the model)

Curricular Component	CBL Level	Educational features
Learning Rationale	Moderate	• Interaction with the real world • Active impact on the real world • Broad big ideas • Wicked problems • Actionable challenges • Challenges of personal choice • Challenges of profound personal relevance • Solution design
Learning Aims and Objectives	Mild ∿ (between) Moderate	• Reflection on existing knowledge and skills was somewhat facilitated via a content-focused assessment • A pool of pre-defined broad LOs (incl. academic and 21st-century skills) was presented • Students mainly worked towards the pre-defined LOs
Content Knowledge	Intense	As was instructed by the minor's design: • Students independently gathered disciplinary knowledge (content and soft skills) • A group of students combined their disciplinary knowledge and built an inter-/trans-disciplinary knowledge base • The scope of CK was defined by students' challenge investigation needs
Learning Activities	∿ (almost) Moderate	• Groups engaged with a wicked problem (i.e., big idea) • They identified an actionable challenge • They deeply investigated the challenge (incl. free engagement with the primary stakeholder) • They designed a consciously chosen solution • A cycle of reflecting and documenting followed the process • Some students directly implemented the solution in the real world, and some did so indirectly • Only some of the students were able to actively evaluate the effects of the solution
Teacher Role	Intense	**Teachers worked in teams consisting of:** • A learning supervisor (expectation manager, process facilitator) • A coach (a learning guide, co-researcher/co-designer/co-learner) • Field experts and professional advisers
Materials and Resources	∿ Moderate	• Teachers prepared guiding resources • Students could choose to familiarise themselves with the guiding resources • Students were encouraged to explore additional resources • The use of technology was encouraged (but students were not actively made aware of the open access)
Grouping	Intense	• A multidisciplinary group of co-learners consists of: - students from different disciplines - coaches (teachers) from various disciplines - stakeholders • Inter-/trans-disciplinary collaboration is fostered
Location and Time	Moderate	• Semi-fixed learning in the real world • Semi-fixed T&L for the offered learning activities • Flexible T&L for self-regulated learning and groupwork • A collaborative virtual and/or physical workspace was accessible by schedule
Assessment	Moderate ∿ Intense	• The learning process was assessed • Critical reflection on process successes and failures was assessed • Students could contribute to the assessment • Teachers conducted the assessment • Content-focused assessment was present

10.10 Appendix J: NTBD Students' Sense of Impact Needs

The data analysis of the NTBD self-reflection reports resulted in two networks. The first network exhibits NTBD's educational design features that, according to the students, positively influenced their sense of impact (Figure 1). In contrast, the second one outlines the educational features of the minor that negatively affected their sense of impact perception (Figure 2).

Figure 1

Educational design features that positively influenced NTBD students' sense of impact

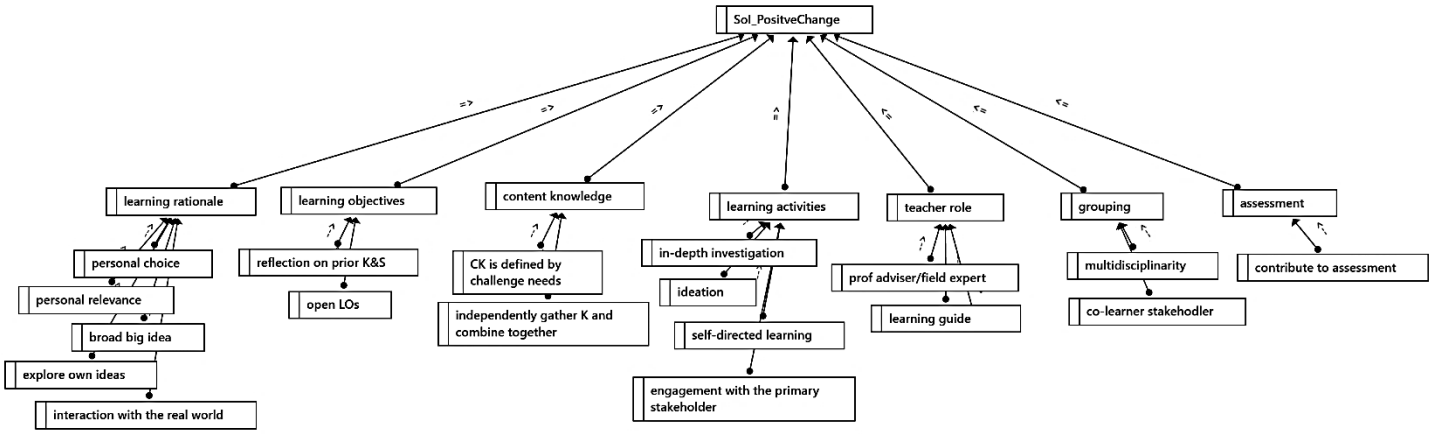
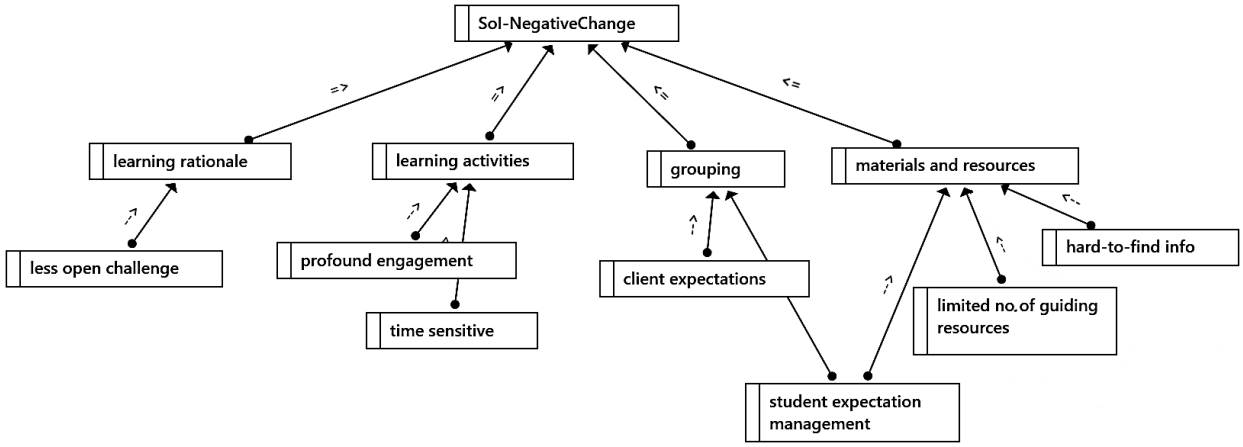


Figure 2

Educational design features that negatively influenced NTBD students' sense of impact



Learning Rationale. As the figures show, the educational features defined by NTBD's learning rationale were mainly perceived to influence the students' sense of impact positively. Students discussed that interacting with the real world made them feel a stronger sense of impact. Moreover, they reported that having broad big ideas made them feel their impact on the learning path. The students could decide in which direction they wanted to go. In addition, the ability to work with challenges of personal choice and relevance was frequently mentioned when students described positive changes in

their sense of impact. However, some students mentioned that the big ideas they chose were less broad as the challenge providers already knew in which direction they wanted the idea to go. This negatively affected the students feeling of impact. Interestingly, students highlighted that by designing solutions, they were fostered to explore their ideas, which positively influenced their sense of impact.

Learning Aims and Objectives. Here, the NTBD students only reported the positive effects of the minor's learning objectives on their sense of impact. The students described that by reflecting on their existing knowledge and skills, they felt the value of their experiences and perceived to have a higher impact on their surroundings (e.g., peers, teachers, stakeholders) and the learning outcomes. They also expressed that the openness of the learning objectives gave them freedom in defining their learning path, which, consequently, strengthened their feeling of impact.

Content Knowledge. Similarly, content knowledge was mentioned by NTBD students only along with the positive sense of impact changes. The students often depicted how the freedom to define what they are learning according to the investigation needs of their challenge made them feel like they were in control of their learning and had a more substantial impact on the learning process. In addition, the ability to independently gather the knowledge of the own disciplines and subsequently combine it with the knowledge of the other groupmates was reported to positively influence the students' perception of impact. Students also reported that as they were "defending" the value of the gathered information to the groupmates, recognising its added value to the group's knowledge base, and combining all the gathered information to build interdisciplinary solutions, their sense of impact was stronger.

Learning Activities. NTBD students reported both positive and negative sense of impact changes when describing the minor's learning activities. In-depth investigation and self-directed learning were frequently mentioned by the students and depicted as educational features that positively affected their sense of impact. As the students investigated the different instances of the challenge in their own learning pace, they felt the importance of their choices and their control over the learning. Moreover, open engagement with the stakeholders reportedly fostered the students' perception of impact beyond the classroom. Interestingly, the students highlighted that when following the design cycle, they truly enjoyed the ideation phase, where they could present, share, and discuss different ideas when approaching the solution design. According to the students, such an activity positively affected their sense of impact. On the other hand, engaging with the big idea and coming to the challenge had a negative impact on the students' sense of impact. The students expressed that the engage phase of the learning process was too time-consuming, resulting in less time to design solutions and have a noticeable impact on the real world. The teacher also reported that some students could not implement and evaluate their solutions in the context analysis. However, eliminating the engage phase would directly influence the learning rationale features (i.e., challenges of personal choice and relevance) that students described as agents scaffolding a stronger sense of impact.

Teacher Role. Overall, the NTBD students highlighted that having the teacher give advice and not narrate the choices made throughout the experience increased the sense of impact. The students felt ownership of the learning process and outcomes. In addition, the students enjoyed having a learning guide as a part of the team as he/she was someone they could rely on in difficult situations. Interestingly, the students described that mainly they did not view their coaches as learning peers; according to the

students, if the coach were to actively contribute to the team's learning process, he/she would take over the course of action due to having more advanced expertise.

Grouping. Regarding grouping, NTBD students mentioned the positive influence of the group's multidisciplinarity and stakeholders' co-learner role on their sense of impact. Students elaborated that multidisciplinary teams allowed them to expand their knowledge and skills by gaining insight from different or conflicting perspectives. Such a gain strengthened the students' perception of having the ability to make a difference as their competence increased. However, some students expressed frustrations with having multidisciplinary teams as they did not expect the workload of multidisciplinary collaboration. In addition, the students often explained that challenge providers or their representatives were part of the team and the learning process. This positively affected the students' sense of impact because, as reported, they witnessed their influence on a real-world stakeholder as they were free to ask questions and felt reinforced to explore their ideas. On the other hand, some students also mentioned grouping, specifically stakeholder relations, when describing an adverse change in the sense of impact levels. These students shared that their stakeholders were acting more like clients who had specific outcomes in mind; thus, they were hindered from exploring what influence they could have on the real world. This again emphasises the importance of stakeholders co-learning with the student teams for the students' sense of impact.

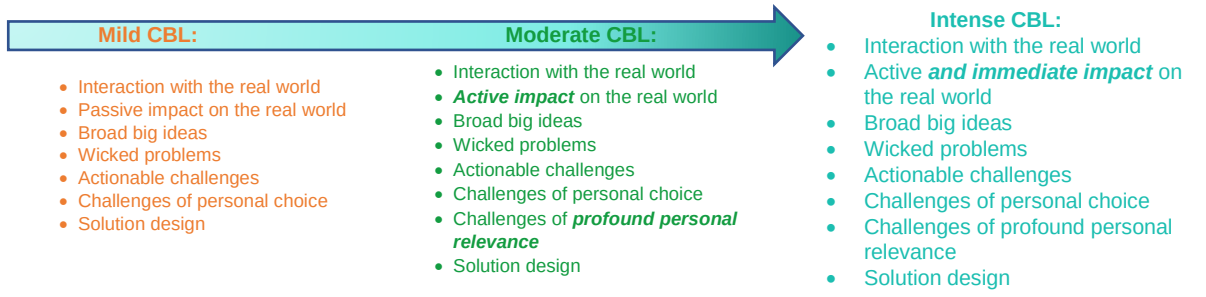
Materials and Resources. NTBD students expressed that the materials and resources offered in the minor negatively affected their sense of impact. As the students explained, they felt like the information offered in the minor (i.e., the guiding resources) that was supposed to help the challenge investigation was quite hard to find. Moreover, the students described that the guiding resources were relatively narrow or "off the topic"; consequently, the students did not see the meaning of what was offered in the guiding resources. Having trouble navigating the offered resources and not recognising their value made the students feel like they did not have control over what they were learning. It must be mentioned that it seems as if some NTBD students did not realise that the guiding resources were optional and that they were required to look for information outside of what was offered.

Assessment. Although the assessment was not often mentioned, the students indicated that the open assessment criteria of the minor allowed them to adjust the evaluated deliverables according to the challenge's needs. Students described this approach to assessment as "a new challenge" that fostered a stronger sense of impact.

10.11 Appendix K: CBL Course Design of LSC

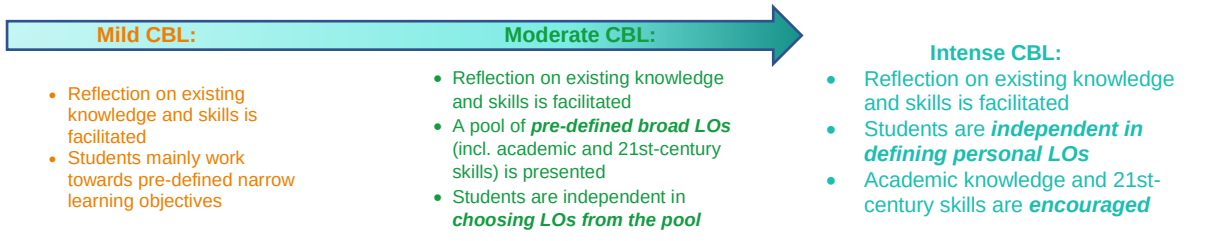
Leading Systematic Change (LSC) is an extracurricular "challenge package" (a part of UT's Transdisciplinary Master Insert programme, where students thrive on developing their transdisciplinary competencies). Students followed two CBL-designed modules within the LSC package: Change Making and Systems Thinking, while working with one challenge provider. Notably, most students were familiar with the CBL approach and its design features from their prior education. The following case analysis describes how the educational aspects employed in the challenge package fit into the CBL approach based on the Mild-Moderate-Intense (MMI) CBL Continuums model created to support the data analysis within the graduation project.

Learning Rationale



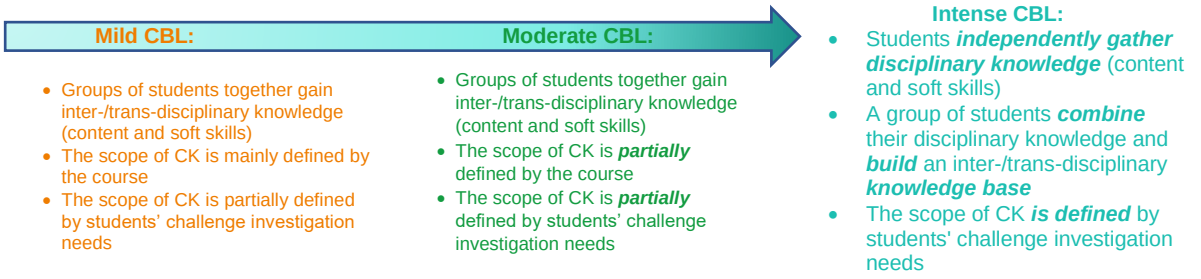
LSC's learning rationale seems to align with the mild CBL level presented above. According to the course documents, the students were learning to "analyse and change complex systems" while investigating a presented big idea and providing advice (i.e., a solution) to the challenge provider. The topics of the modules and the big idea were somewhat open and could prompt the students to conduct an in-depth investigation and find wicked actionable challenges. However, the big idea seems to bind the students to one specific community (i.e., the Green Hub), which might have hindered the students' ability to explore the personal relevance of the big idea. Moreover, even though the solution is not pre-defined and is open for students to explore (i.e., make an impactful decision), the advice format of the solution might have hindered students' ability to actively affect the real world.

Learning Objectives (LOs)



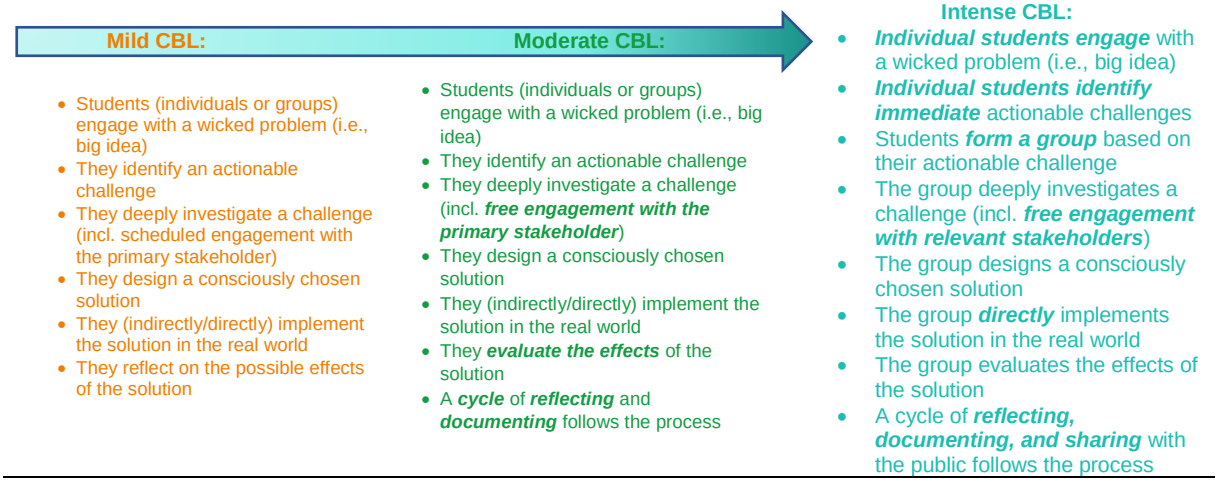
The LSC modules' learning objectives seem to fall between mild and moderate CBL levels. For example, the course documents suggest that in one of the modules, the students were encouraged to reflect on prior knowledge, skills, behaviours, and perspectives throughout their learning path by creating a development plan. Furthermore, the learning objectives of that module were broad (e.g., show perspectives, evaluate a process, reflect, analyse), which might have allowed students flexibility when thriving towards narrow. In contrast, another part of the package required students to meet relatively narrow learning objectives (e.g., understand, recognise), towards which they were expected to thrive.

Content Knowledge (CK)



The moderate CBL level could define the content knowledge of the LSC package. The course documents exhibit that an interdisciplinary group of students could partially decide what content knowledge to acquire based on what they deemed necessary for understanding the challenge and building solutions. Seemingly, the students were guided towards building a transdisciplinary knowledge base by broader topics within which the group could make the necessary decision. Nonetheless, the courses defined some of the content knowledge that students were required to gain.

Learning Activities

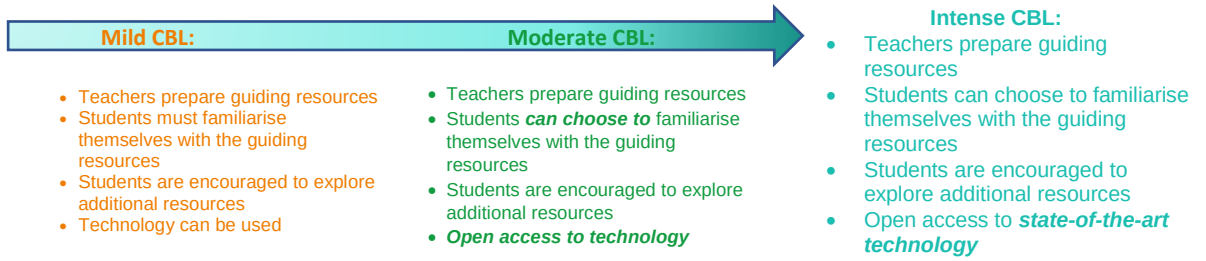


The LSC modules' learning activities seem to be between mild and moderate CBL levels. Within the modules, the guiding activities described in the course documents (e.g., reflective workshops, field visits, facilitated debates, feedback sessions, tutorials, lectures, stakeholder interviews) could scaffold the students to strongly engage with the presented big idea and deeply investigate their challenge. Moreover, the students had complete freedom in deciding when and how they wanted to engage with the challenge providers. It can be predicted that the outcomes of the guiding activities motivated the students to design a consciously chosen solution. The students presented the solution to the teachers and the challenge provider. As the solution was advice, it seems the students did not get to implement or evaluate their solutions directly. In the modules, students cyclically reflected on their learning process. A few scaffolded reflection moments were offered to the students.

Teacher Role

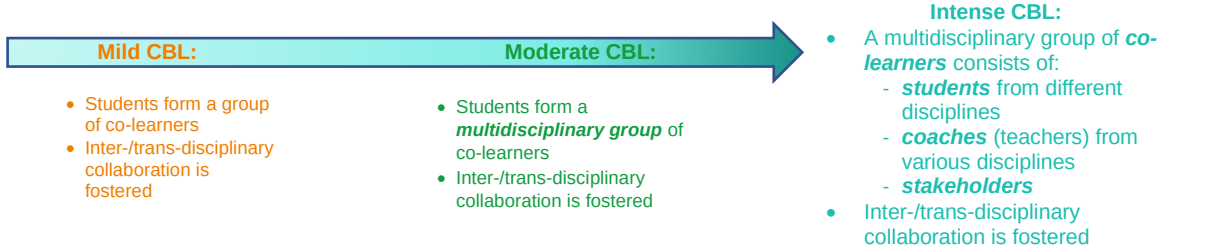
The LSC modules' teacher role seems to align with the moderate CBL level. The module teachers primarily acted as course coordinators who managed student and stakeholder expectations and facilitated the course process (i.e., scheduling, syllabus, assessment, etc.). Notably, the primary teachers investigated the challenge independently from students to better guide students' learning and provide advice, so they were seemingly acting as co-researchers and co-learners. Moreover, the teachers reported that by being a coach, they tried to guide the student team by being in close contact with them. Several additional teachers acted as professional advisers and field experts who provided information in the form of a lecture. Therefore, it seems like in LSC, the primary teachers of the modules acted as learning supervisors (expectation managers, process facilitators), learning guiding coaches; and several teachers were available as field experts and professional advisers.

Materials & Resources

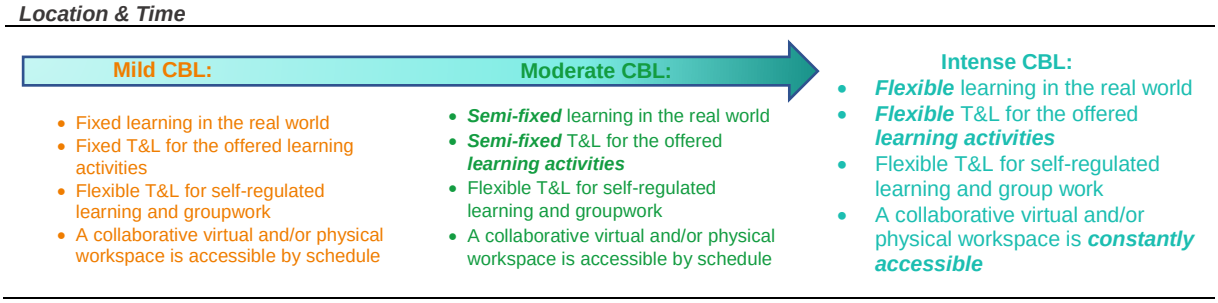


LSC's materials and resources seem close to the moderate CBL level. The students were offered various guiding resources (e.g., lectures, workshops, materials) and were encouraged to explore other resources. However, the modules had one compulsory reading list. In addition, one of the modules encouraged the use of and provided access to course-relevant technology.

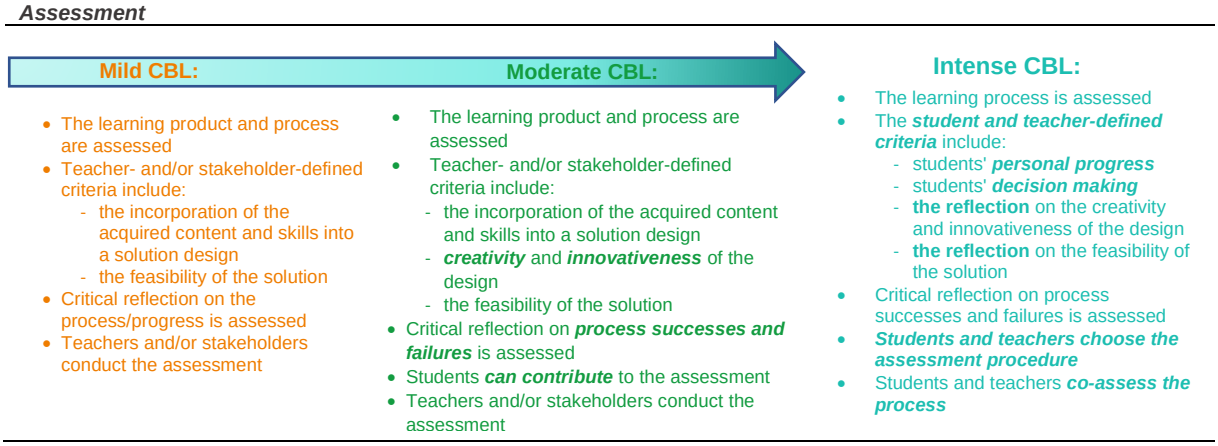
Grouping



LSC's grouping seems to be between the moderate and intense CBL levels. Students became a part of a multidisciplinary group and were required to collaborate in a trans-disciplinary manner. The primary teachers and the stakeholder occasionally learned alongside the students during group reflections but were not a part of the group.



The challenge package's location and time seem to fall between moderate and intense CBL levels. The students were seemingly flexible concerning learning in the real world. The students could choose whether they wanted to attend the scheduled learning activities. Self-regulated learning and group work could happen whenever and wherever students would decide. The students had the option to collaborate in a creativity-prompting flexible physical workspace (i.e., the university's Design Lab) accessible by schedule.



The assessment within LSC seems to align with the mild CBL level. The primary teachers assessed the learning product and the process. The assessment criteria mainly focused on incorporating the knowledge and skills gained within the modules and the feasibility of the solution. The ability to critically reflect and identify strengths or weaknesses was also assessed.

Table 1 summarises the educational features that were seemingly applied in the design of LSC courses.

Table 1

LSC: CBL Course Design Features
(the level of the features coded by colour: mild, moderate, intense, was not defined by the model)

Curricular Component	CBL Level	Educational features
Learning Rationale	Mild	• Interaction with the real world • Passive impact on the real world • Broad big ideas • Wicked problems • Actionable challenges • Challenges of personal choice • Solution design

Learning Aims and Objectives	Mild ∿ Moderate	• Reflection on existing knowledge and skills was somewhat facilitated via a content-focused assessment • In one course, students worked towards broad LOs • In one course, students worked towards narrow LOs
Content Knowledge	Moderate	• Groups of students together gained inter-/trans-disciplinary knowledge (content and soft skills) • The scope of CK was partially defined by the course • The scope of CK was partially defined by students' challenge investigation needs
Learning Activities	Mild ∿ Moderate	• Groups engaged with a wicked problem (i.e., big idea) • They identified an actionable challenge • They deeply investigated the challenge (incl. free engagement with the primary stakeholder) • They designed a consciously chosen solution • A cycle of reflecting and documenting followed the process • Students indirectly implemented the solution in the real world • Students reflected on the possible effects of the solution
Teacher Role	Intense	**Teachers worked in teams consisting of:** • A learning supervisor (expectation manager, process facilitator) • A coach (a learning guide, co-researcher/ co-learner) • Field experts and professional advisers
Materials and Resources	∿ Moderate	• Teachers prepared guiding resources • Students could choose to familiarise themselves with the guiding resources (except for one compulsory reading list) • Students were encouraged to explore additional resources • Open access to technology was given
Grouping	Moderate ∿ Intense	• A multidisciplinary group of co-learners consists of: - students from different disciplines - sometimes coaches - sometimes stakeholders • Inter-/trans-disciplinary collaboration is fostered
Location and Time	Moderate ∿ Intense	• Flexible learning in the real world • Semi-fixed T&L for the offered learning activities • Flexible T&L for self-regulated learning and group work • A collaborative physical workspace was accessible by schedule
Assessment	Mild	• The learning product and process were assessed • Teacher-defined criteria included: - the incorporation of the acquired content and skills into a solution design - the feasibility of the solution • Critical reflection on the progress was assessed • Teachers conducted the assessment

10.12 Appendix L: LSC Students' Sense of Impact Needs

To gain a general understanding of the sense of impact (SoI) changes in the LSC's students, the mean results of the pre-test and post-test surveys for each student were compared based on the descriptive analyses of the survey results. Table 1 presents the revealed differences.

Table 1

The sense of impact level changes among LSC students

	Student 1	Student 2	Student 3	Student 4
Pre-test SoI	M=2.00 SD=.52	M=1.63 SD=.62	M=2.06 SD=.77	M=2.31 SD=1.08
Post-test SoI	M=2.81 SD=.40	M=2.44 SD=.63	M=2.94 SD=.57	M=2.69 SD=.79
Mean difference	.81	.81	.88	.38

The survey results showed that there was an overall increase in the sense of impact levels among the LSC students. In the group interview, all six students who followed the LSC courses were asked to explain why they thought there was an increase and why some students perceived little sense of impact change. The group discussion resulted in two coding networks describing educational features that supported the increase in the sense of impact levels of LSC students (Figure 1) and features that hindered the increase (Figure 2).

Figure 1

Educational design features that positively influenced LSC students' sense of impact

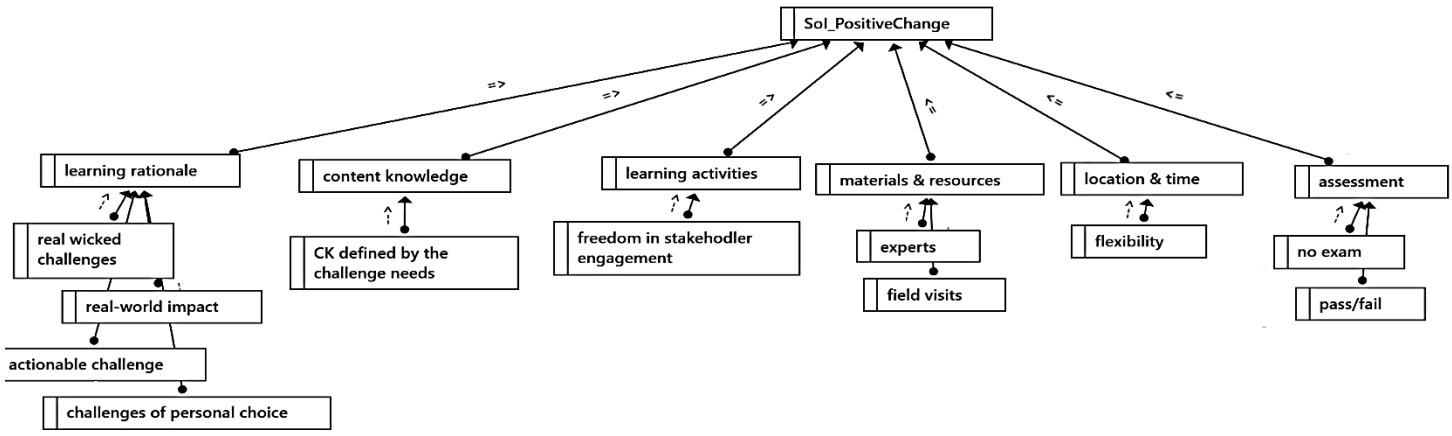
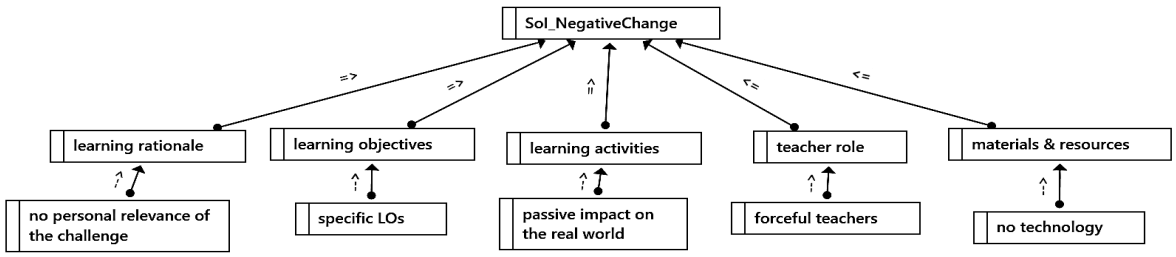


Figure 2

Educational design features that negatively influenced LSC students' sense of impact



Learning Rationale. LSC students described how educational features defined by the course design's learning rationale supported the increase in their sense of impact levels. They explained that working to influence a real case and real people made them feel like they had an impact on the world. Moreover, the "wickedness" of their challenge supported the indicated increase as by recognising the complexity and realness of the issue, the students felt the value of their ideas, the work, and the choices for forming new ways of understanding and solving wicked problems. In addition, the students mentioned that working within a local context allowed them to see more actionable solutions. This, consequently, helped their sense of impact increase because they were made aware of how their actions could affect their immediate environment. Furthermore, forming challenges of personal choice was described as an influencing factor in the sense of impact increase as it gave the students control of the CBL experience. When it came to factors of the LSC course design that hindered the sense of impact increase, students mentioned that they could not closely relate to their challenge as the big idea was relatively narrow. Such a narrow focus decreased the students' perceived control over the learning process.

Learning Aims and Objectives. The students expressed that a few learning objectives were narrow, but they were not related to their challenge. Thus, this required the students to do corresponding assignments instead of investing more time into the challenge. This weakened the students' perception of impact on the learning process as they could not choose whether they needed/wanted to work towards these objectives.

Content Knowledge. Here, the LSC students described that the freedom to define the knowledge to be acquired within the courses gave them a stronger feeling of impact on the learning process as they were "in control of" what they were learning

Learning Activities. Open engagement with the stakeholders reportedly fostered the students' perception of impact. The students enjoyed visiting the challenge provider's workplace, asking questions, and gaining a more in-depth understanding of the challenge. In such a way, the students were "becoming experts on the challenge" and felt that their choices in solution design could make a crucial difference. However, the students also mentioned that forming an advice report instead of creating actual solutions decreased their sense of impact. The students explained that they did not know what was going to happen with their advice, "it might just end up in someone's desk drawer".

Teacher Role. LSC students did not mention teachers so often when talking about the sense of impact changes. The students felt like they knew more about the challenge and were informed enough to not adhere to some advice given by teachers. However, they described that some of the teachers would express strong opinions on how the solutions must be designed and would at times try to "force certain choices" into the solution design. This weakened their feeling of control over the learning and the learning outcomes as the students

sometimes would “find it hard to defend their choices” and would feel like they “had to please the teachers”.

Materials and Resources. Doing field work and “having access to different field experts/teachers” were mentioned as factors supporting the increase in the LSC students’ sense of impact levels. The students felt the importance of their learning as they first-hand witnessed how the experience can be used in the real world. The freedom of contacting people of strong academic and professional backgrounds made the students feel a stronger sense of impact. Not being able to use technology within the scope of the challenge to some extent negatively influenced the sense of impact levels. This was because some students could not explore their personal interests in state-of-the-art technology.

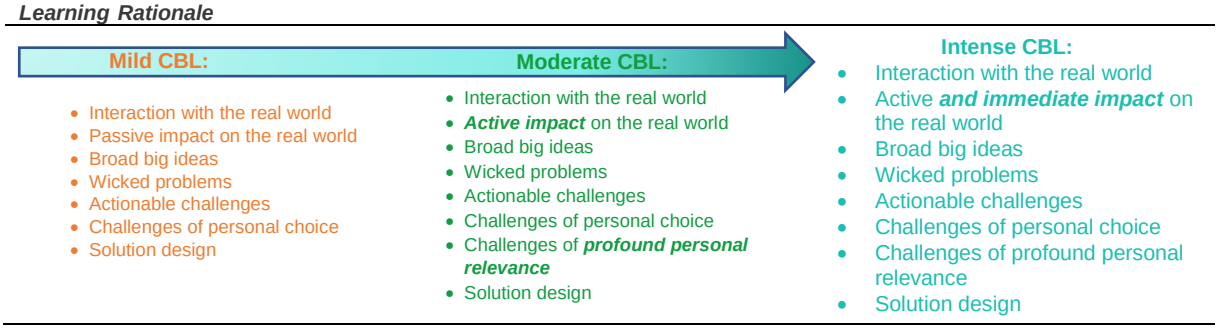
Location and Time. LSC students also described that they had some freedom when following the modules. This increased the students’ feeling of control over the learning as they felt like the progress, process, and outcomes of learning were mainly affected by their own choices.

Assessment. Interestingly, LSC students mentioned that not having an exam and being evaluated on a pass/fail bases allowed them to be more determined in making their own choices. Reportedly, this cancelled out the negative effect of the teachers’ forcefulness described earlier. The students shared that they felt more comfortable going “against the teachers’ advice when it was necessary for the challenge” because it would not have too big an effect on the final assessment result. Strikingly, most students who followed the LSC challenge package had prior experience with CBL. The students mentioned that this experience “certainly helped” maintain their perceived sense of impact and be firm in decision-making.

10.13 Appendix M: CBL Course Design of SEiC

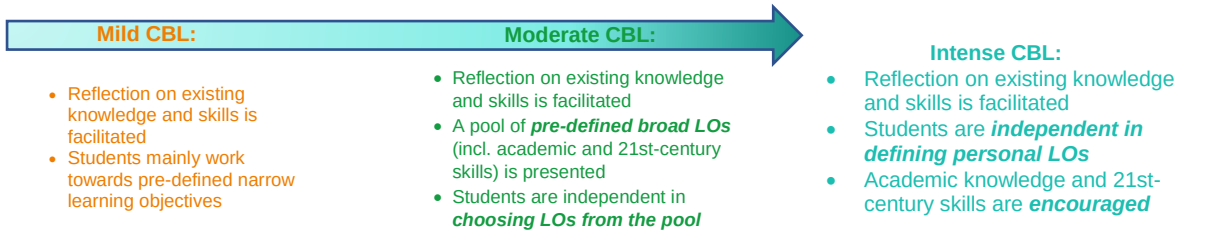
Systems Engineering in Construction (SEiC) is a curricular course offered to master level students. The course was designed to be partially CBL. In the first part of the course, students focused on gaining course topic-relevant knowledge. The SEiC one part of the course employed a CBL design, where groups of students worked with one challenge provider. This context analysis describes the educational aspects of the course's CBL part and how they fit into the CBL approach based on the Mild-Moderate-Intense (MMI) CBL Continuums model created to support the data analysis within the graduation project.

Learning Rationale



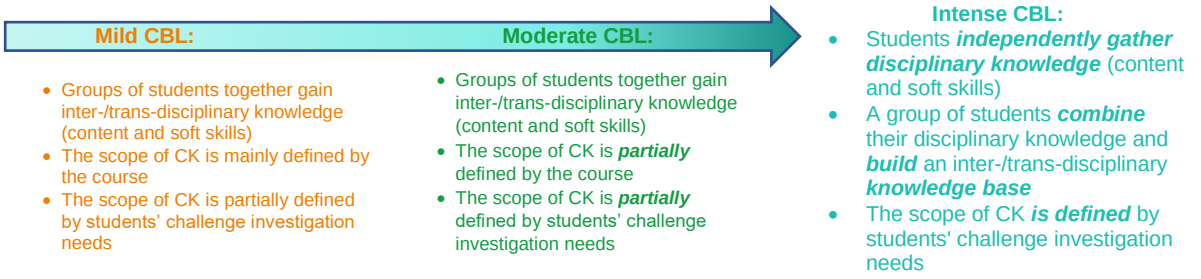
The learning rationale of SEiC seems to align with the mild CBL level description presented above. The course documents highlight that within the SEiC one part of the course, the students were encouraged to interact with a real-world situation (i.e., the Floriade case) and, by "submitting a proposal", passively impacted the situation. Moreover, the course seems to have encouraged the students to "determine" their actionable wicked challenge strictly within the scope of the offered case. Although the students might have found personal relevance within the case's scope, the challenge definition was bound solely to the case. The students were also expected to design a sustainable solution.

Learning Objectives (LOs)



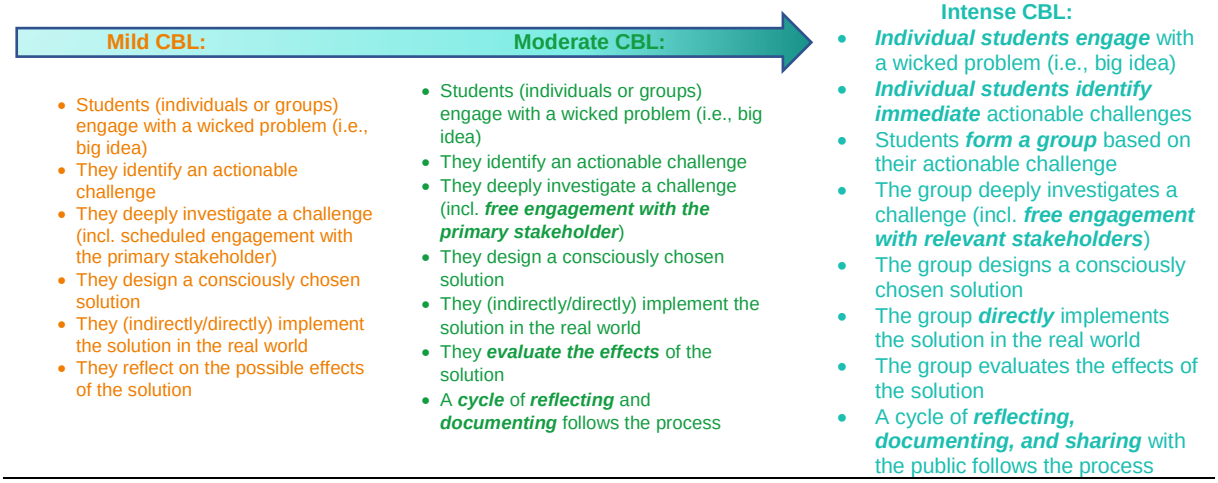
The SEiC's CBL's learning objectives seem to fall in between mild and moderate CBL levels. It seems like while working on the challenge, the students were required to reflect on their prior knowledge and skills relevant to the course topic. The pre-defined objectives of the CBL part of the course were broad (e.g., incorporate principles, design an object, present findings), which seem to allow students to be flexible in approaching the challenge and gaining additional knowledge/skills. Moreover, 21st-century skills development was presented to the students as an additional part of the learning objectives. However, the students were not encouraged or required to identify personal learning objectives.

Content Knowledge (CK)



The content knowledge of the CBL part of SEiC seems to fall close to the intense level of CBL. The course documents hint that mainly a group of students together gained relevant knowledge and skills. However, it can also be seen that the students had the freedom to gather knowledge independently; seemingly, the decision of whether to approach the challenge investigation as a group or individually was left to the students. In addition, it seems like the scope of the CK was solely defined by the students and their challenge investigation needs.

Learning Activities

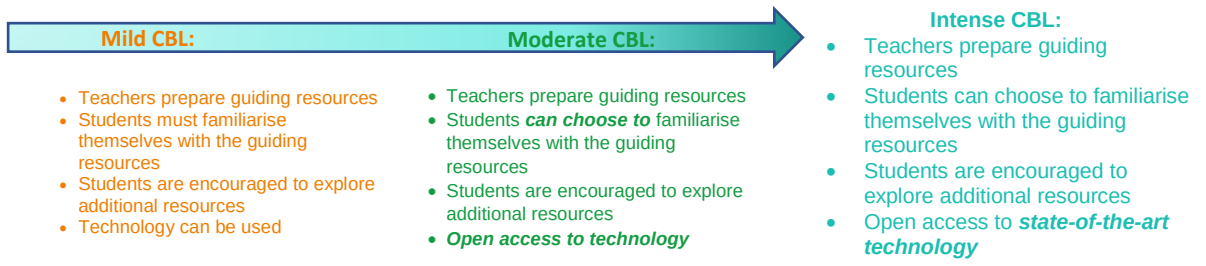


The learning activities of the CBL part of SEiC seem to align with the mild CBL level. The learning activities descriptions of the minor hint that students could engage with a presented big idea as each group had the freedom to choose their design's direction. The students were advised to investigate and do a "background study" of the challenge-relevant topics. However, the students were "not allowed to contact any other (actual) stakeholders" and got the chance to contact the challenge providers only during "scheduled moments". Since the students were required "to perform at least one design iteration", it seems like the students were encouraged to design a consciously chosen solution, indirectly implement it in the real world by presenting it to a stakeholder who can directly implement the design and were required to evaluate the possible effects of the solution. Notably, the students got to "submit a proposal for a design competition", which seems to have allowed students to go beyond the mild level and share their solutions with the public.

Teacher Role

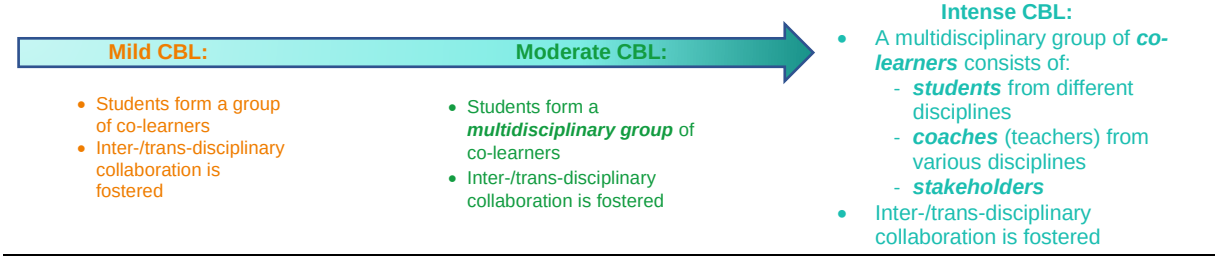
The teacher role of SEiC 's CBL part seems to be aligned with the moderate CBL level. The teacher acted as learning supervisors who managed the expectations and facilitated the process. Seemingly, the teacher also played the role of a learning guide as they were "available to assist [the students] in the design process during the scheduled project hours". Lastly, the students were advised to "consult" with the teacher throughout the course, allowing the teacher to also act as professional advisers and field experts.

Materials & Resources



Materials and resources offered in the CBL part of the SEiC course seem to mainly fall under the moderate CBL level description. The teachers provided guiding resources (e.g., course materials, project guide, assessment form) and let the students decide whether they wanted to use those. Additionally, the students were "expected to collect and interpret information from a variety of sources", thus, encouraged to go beyond the course-offered materials. Notably, it does not seem like technology use was promoted in the course as no extra access to technology was provided; thus, students could choose to (but were not obligated to) use technology.

Grouping



The grouping within the CBL part of SEiC seems aligned with the mild CBL level. Seemingly, since the course students came from the same master's programme, they formed groups of co-learners, there was no specific requirement to form multidisciplinary groups.

However, each student's bachelor level, choice topics, and personal and professional experiences likely allowed the teams to form a multidisciplinary group. Moreover, the wicked nature of the big idea seemingly fostered interdisciplinary collaboration. Seemingly, the course teacher and the stakeholder were there to advise the students but were not a part of the group. The stakeholders mainly were playing the role of "a client".

Location & Time

Mild CBL:

- Fixed learning in the real world
- Fixed T&L for the offered learning activities
- Flexible T&L for self-regulated learning and groupwork
- A collaborative virtual and/or physical workspace is accessible by schedule

Moderate CBL:

- ***Semi-fixed*** learning in the real world
- ***Semi-fixed*** T&L for the offered ***learning activities***
- Flexible T&L for self-regulated learning and groupwork
- A collaborative virtual and/or physical workspace is accessible by schedule

Intense CBL:

- ***Flexible*** learning in the real world
- ***Flexible*** T&L for the offered ***learning activities***
- Flexible T&L for self-regulated learning and group work
- A collaborative virtual and/or physical workspace is ***constantly accessible***

The location and time of the course's CBL part seem to be of the mild CBL level. The students could only engage with the real-world stakeholders during fixed teacher-defined timeslots. Moreover, the students attended some scheduled learning activities. It seems that to investigate the challenge, the students flexibly self-regulated their learning and group work. In addition, the students could collaborate in a collaborative physical workspace assessable by schedule.

Assessment

Mild CBL:

- The learning product and process are assessed
- Teacher- and/or stakeholder-defined criteria include:
  - the incorporation of the acquired content and skills into a solution design
  - the feasibility of the solution
- Critical reflection on the process/progress is assessed
- Teachers and/or stakeholders conduct the assessment

Moderate CBL:

- The learning product and process are assessed
- Teacher- and/or stakeholder-defined criteria include:
  - the incorporation of the acquired content and skills into a solution design
  - ***creativity*** and ***innovativeness*** of the design
  - the feasibility of the solution
- Critical reflection on ***process successes and failures*** is assessed
- Students ***can contribute*** to the assessment
- Teachers and/or stakeholders conduct the assessment

Intense CBL:

- The learning process is assessed
- The ***student and teacher-defined criteria*** include:
  - students' ***personal progress***
  - students' ***decision making***
  - **the reflection** on the creativity and innovativeness of the design
  - **the reflection** on the feasibility of the solution
- Critical reflection on process successes and failures is assessed
- ***Students and teachers choose the assessment procedure***
- Students and teachers ***co-assess the process***

The assessment of SEiC 's CBL part seems to fall between mild and moderate CBL levels. The course documents state that a "design report that presents both the design process and the design outcomes" was assessed. The teacher-defined assessment criteria suggest that mainly the incorporation of the acquired content and skills into the solution design and the feasibility of the solution were evaluated. The teacher shared that creativity and innovativeness of the design were encouraged and somewhat assessed. The design process descriptions potentially might have allowed the students to present their critical reflection on the process for evaluation. Teachers conducted the assessment, and the primary stakeholder could contribute to it.

Table 1 summarises the educational features that were seemingly applied in the CBL design of SEiC course.

Table 1

SEiC: CBL Course Design Features
(the level of the features coded by colour: mild, moderate, intense, was not defined by the model)

Curricular Component	CBL Level	Educational features
Learning Rationale	Mild	• Interaction with the real world • Passive impact on the real world • Broad big ideas • Wicked problems • Actionable challenges • Challenges of personal choice • Solution design
Learning Aims and Objectives	Moderate	• Reflection on existing knowledge and skills is facilitated • Pre-defined broad LOs (incl. academic and 21st-century skills) were presented • Students were able to explore on personal LOs
Content Knowledge	∿ Intense	• Groups of students were expected to gain interdisciplinary knowledge (content and soft skills) • Students could independently gather the knowledge and combine it together • The scope of CK was defined by students' challenge investigation needs
Learning Activities	Mild	• Groups engaged with a wicked problem (i.e., big idea) • They identified an actionable challenge • They deeply investigated the challenge (incl. scheduled engagement with the primary stakeholder) • They designed a consciously chosen solution • They indirectly implemented the solution in the real world • They reflected on the possible effects of the solution • They submitted the proposal for a design competition = sharing
Teacher Role	Moderate	**A pair of teachers that took on multiple roles:** • A learning supervisor (expectation manager, process facilitator) • A coach (a learning guide) • Field experts and professional advisers
Materials and Resources	Moderate	• Teachers prepared guiding resources • Students could choose to familiarise themselves with the guiding resources • Students were encouraged to explore additional resources • Technology was not promoted
Grouping	Mild	• Students formed a group of co-learners • Inter-/trans-disciplinary collaboration was fostered • Stakeholder = "client"
Location and Time	Mild	• Fixed learning in the real world • Fixed T&L for the offered learning activities • Flexible T&L for self-regulated learning and groupwork • A collaborative physical workspace was accessible by schedule
Assessment	Mild ∿ Moderate	• The learning product and process were assessed • Teacher-defined criteria included: – the incorporation of the acquired content and skills into a solution design – the feasibility of the solution – creativity and innovativeness of the design were encouraged and somewhat assessed • Critical reflection on the process was somewhat assessed • Teachers conducted the assessment, and the primary stakeholder could contribute to it

10.14 Appendix N: SEiC Students' Sense of Impact Needs

To get an overview of the sense of impact (SoI) changes in the SEiC students, the mean results of the pre-test and post-test surveys for each student were compared. Table 1 presents the revealed differences.

Table 1

The sense of impact level changes among the SEiC students

	S1	S2	S3	**S4**	**S5**	S6	S7	**S8**	S9	S10	S11
Pre-test SoI	M=3.31 SD=.48	M=2.50 SD=1.27	M=2.69 SD=.48	**M=2.50 SD=.50**	**M=2.56 SD=.73**	M=2.38 SD=.89	M=2.44 SD=.81	**M=2.06 SD=.93**	M=1.88 SD=.96	M=1.81 SD=.66	M=1.88 SD=.62
Post-test SoI	M=2.56 SD=1.21	M=2.19 SD=.40	M=2.75 SD=.45	**M=2.63 SD=.73**	**M=2.88 SD=.62**	M=2.88 SD=.72	M=2.94 SD=.68	**M=2.69 SD=.95**	M=2.56 SD=.81	M=2.88 SD=.72	M=3.06 SD=.44
Mean difference	-.75	-.31	.06	**.13**	**.31**	.50	.50	**.63**	.69	1.06	1.19

The survey results showed that students of the SEiC course experienced the sense of impact changes differently. For some students, the change was rather negative; for some, it was moderate, and for some, it was pretty positive. To understand the results, interview discussions were conducted. Unfortunately, due to the lack of responses, it was only possible to interview students 4, 5, and 8. Thus, the insights on the moderate changes in the sense of impact levels were explored in depth.

As a result, three coding networks were created summarising educational features that had positive (Figure 1), neutral (Figure 2), and negative (Figure 3) influences on the SEiC students' perceived sense of impact levels.

Figure 1

Educational design features that positively influenced SEiC students' sense of impact

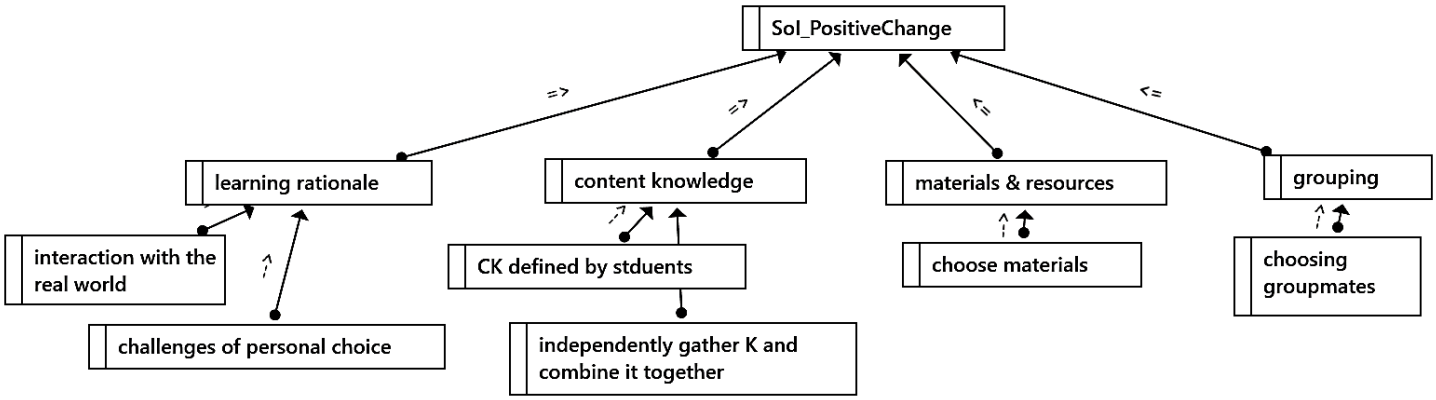


Figure 2

Educational design features that maintained SEiC students' sense of impact levels

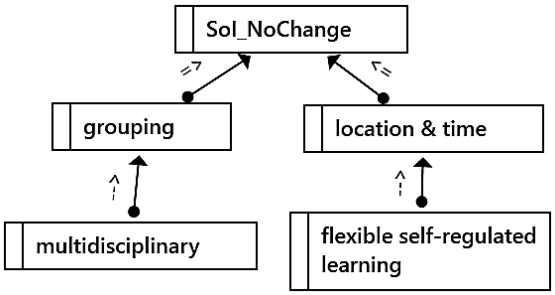
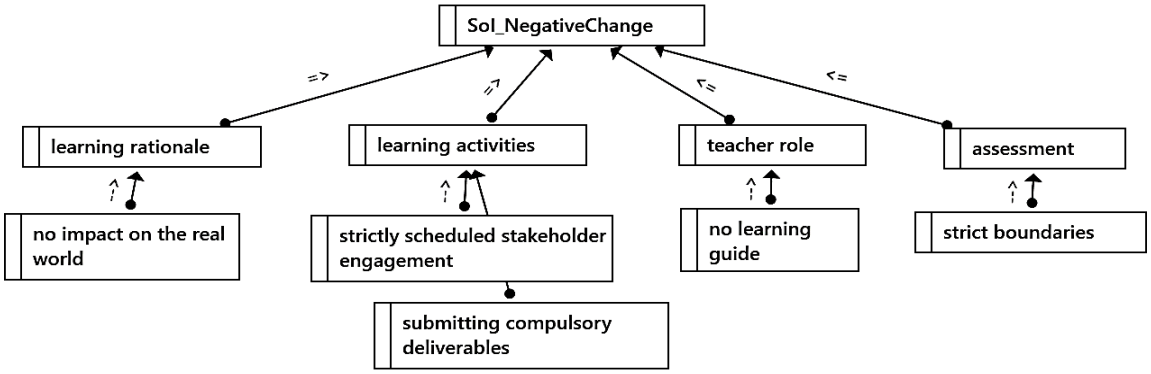


Figure 3

Educational design features that negatively influenced SEiC students' sense of impact



Learning Rationale. Defining the focus within the presented problem, reportedly, was the main factor that created a stronger sense of impact among SEiC. As a result, the students could feel the impact of their choices on their learning path. Moreover, the interviews revealed that SEiC students appreciated interacting with a real company. It was elaborated that the students could strongly perceive their impact by having such contact. However, the students did not feel like they had any impact outside the classroom environment. It was explained that although the challenge provider was supposed to use the students' solution designs as an inspiration for implementing a design in the field, a feeling that the stakeholders already had their own idea of what the end design will look like was predominant. For this reason, the students' sense of impact was weakened.

Content Knowledge. How content knowledge was approached by SEiC's course design fostered students' sense of impact. Firstly, the students felt control over the learning process as they could define the content to be acquired. Secondly, the ability to independently gather the knowledge and combine it with the knowledge of the groupmates was mentioned as a factor that positively affected the sense of impact levels. The students described that they could choose which information to prioritise and look for by doing independent research. Then, when the students saw how the gathered information could be combined to form innovative ideas, they perceived a more substantial impact on the learning progress and its outcomes.

Learning Activities. Specific features of SEiC's learning activities were reported to negatively influence the students' sense of impact. A significant factor was the limited access to the relevant stakeholders. As the students were strictly prohibited from contacting any real stakeholders during the investigation and only had a couple of scheduled contact moments with the challenge providers, they felt they did not have control over the learning process. The students compared that in courses they followed before, they still had scheduled stakeholder meetings, but these were offered more frequently, which gave some feeling of impact. In addition, having compulsory deliverables in the CBL experiences hindered the students' sense of impact as they felt like "the deadlines were sometimes in control" of the process.

Teacher Role. The students mentioned that the teacher tried to be as distant as possible and would usually give vague responses to their questions. Such an approach negatively affected students' sense of impact as they perceived little influence on the teacher's behaviour. Although the students realised that the teachers were trying to provide freedom and encourage independent learning, they felt they did not have a guide to rely on in difficult situations.

Grouping. It was described that being able to select own groupmates created a stronger sense of impact because the students felt the responsibility for their choices and needed to be comfortable with the consequences. In addition, the students described that having groups of students from the same field but different intradisciplinary tracks and prior experiences is also perceived as multidisciplinarity. Such a mild multidisciplinary approach to learning was reported to have a neutral effect on the sense of impact levels as the students experienced such multidisciplinarity in most educational settings offered at the UT. However, the students mentioned that having a disciplinary group would have probably decreased the sense of impact levels since every group member would have similar expertise.

Materials and Resources. The students greatly enjoyed feeling encouraged to explore many materials and resources within the learning process. In addition, they expressed that choosing their materials positively affected the sense of impact levels.

Location and Time. Flexibility in self-regulated learning and group work was mentioned as a neutral factor in the sense of impact changes throughout the SEiC's CBL experiences. This was due to such flexibility, reportedly almost always offered in higher education. Yet, according to the students, self-regulating the learning process and group work strengthens the perception of impact.

Assessment. Lastly, the students shared that they would have liked to discuss the learning process with the teacher as a part of the assessment process as the boundary conditions of the final deliverable (e.g., page number limit) did not allow the students to deeply describe and defend their progress. In addition, having rather strict practical requirements of the assessment somewhat "pulled the feeling of control" from the students.

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