UNIVERSITY OF TWENTE.

# Challenge-based Learning to Achieve Higher-order Thinking Skills

Master Thesis

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**Abstract**

Higher education institutions are seeking ways to develop students' HOTS through student-centred teaching approaches, as these skills promote active learning, align educational programs with job market demands, and equip students with the cognitive abilities necessary for future career success. This study focuses on one such teaching approach called CBL. The aim of this study is to explore what is claimed in the theory of CBL in relation to HOTS and confront that with the CBL implementation at a Dutch university. Six broad propositions were formed based on the literature review: Relevant societal problem, broad ideas, structured yet divergent, formulation of questions, co-creation and reflection and sharing. Twenty-four interviews were conducted to gather the perceptions about these six propositions from teachers and educational experts involved in implementing CBL across twenty-two courses at this university. This study revealed that the majority of the interviewees agreed with the propositions, drawing from their own first-hand experiences. The article ends by discussing the study's limitations and giving directions for future research.

## 1. Introduction

To meet the changes and challenges in the 21st century, higher education (HE) is expected to equip students with higher-order thinking skills in addition to skills such as recall and understanding which are considered as lower-order thinking skills (LOTs) (Lukitasari et al., 2018; Suparman et al., 2021; Zhou, 2015). Universities have started to adopt different educational methods that stimulate 21st-century skills such as critical thinking, analytical thinking, and creativity to prepare students to be successful in the job market. These skills are also referred to as higher-order thinking skills (HOTS) or higher-order cognitive skills. These skills differ from other foundational skills, such as basic literacy or calculation skills, which involve lower-level cognitive processes (Tikhonova, 2015). While various teaching approaches are being utilised to stimulate HOTS, more studies must be conducted on how they promote HOTS because the literature on this is currently scarce, especially in the context of HE. The outcome of such studies can benefit teachers by providing evidence-based guidance to promote the development of HOTS in students. In addition, such studies can benefit students in valuable ways that directly impact their skills and future jobs (Asok et al., 2016). The existing literature suggests that utilising 21st-century teaching methods, such as inquiry-based learning (IBL) (Madhuri et al., 2012), problem-based learning (PBL) (Hmelo & Ferrari, 1997), and project-based learning (PjBL) (Eliyasni et al., 2019), can support the attainment of HOTS. Similarly, challenge-based learning (CBL), which is also a contemporary pedagogical approach, has the potential to help achieve HOTS as it focuses on solving real-world problems by utilising and stimulating skills such as critical thinking and collaboration (Gallagher & Savage, 2020; Leijon et al., 2021; Nawawi, 2017; Nufus et al., 2018) CBL is described by Malmqvist (2015) as an educational approach where students tackle complex world challenges by making use of various skills such as analytical thinking, evaluative ability and innovativeness. In addition, CBL in relation to the achievement of HOTS is yet to be studied together, especially in a HE context. Although the existing literature mentions the potential of CBL in gaining 21st-century skills (Gallagher & Savage, 2020; Leijon et al., 2021; Nawawi, 2017; Nufus et al., 2018), how and which aspects of CBL lead to attaining HOTS are yet to be researched. Therefore, the current research aims to address this identified gap.

According to Pérez-Rodríguez et al. (2022), CBL is an active learning approach in which students have the authority over their learning process and learning goals. Despite that, teachers still need to provide guidance and facilitation to support students to take authority and engage in self-regulated learning (Doulougeri et al., 2022). In order to support students and appropriately implement CBL in HE, educators need to know about the mechanism of this pedagogical approach, its components, the conditions that support CBL and association with HOTS. By familiarising themselves with such a student-centred teaching approach (Keiler, 2018), its strengths and relation with HOTS, educators can enhance their coaching and scaffolding techniques to better guide students' learning process. Therefore, due to the potential of CBL and HOTS to support students to be equipped for 21st-century challenges, there is a need to further investigate, explore and elaborate on CBL in relation to HOTS. Hence, the main research question developed for this study is: How does CBL lead to the achievement of HOTs? Further, three sub-questions were formulated to guide the investigation:

1. According to existing literature, what is the theory of action of CBL to achieve HOTS in students of HE?
2. What are the perspectives of teachers and educational experts regarding the theory of action of CBL to achieve HOTS?
3. What is the difference between theory and the teacher's perspective? If there is a difference, how can it be explained?

## 2. Theoretical Framework

### 2. Higher-order thinking skills

To be able to build basic knowledge and understanding of a topic, students should be able to use their LOTS. On the other hand, to design elaborate solutions for complex problems, students must be able to activate their higher-level thinking processes (Ghanizadeh et al., 2020). Skills requiring students to go above memorisation and mastery of facts are referred to as critical thinking, higher-level thinking, or higher-order thinking skills (HOTS) due to their requirement of higher cognitive processing (Hendricks et al., 1994; Tsaparlis, 2020; Viktorovna & Natalia, 2015). HOTS are often interrelated and can tend to overlap with each other (Mainali, 2013; Tikhonova & Kudinova, 2015). For instance, problem-solving is considered as HOT and the underlying cognitive activity encompassed in problem-solving is analysing the situation, evaluating information, and developing creative solutions (Mainali, 2013). To better understand HOTS, how it works and what is required by an individual to possess HOTS, it is important to explore the theories associated.

Numerous theories are relevant to HOTS and support understanding the concept; some commonly discussed theories are the reflective thinking theory mentioned in Dewey's book, Vygotsky's theory of cognitive development (Moore, 2011), Bloom's taxonomy (Bloom’s Taxonomy - Centre for Instructional Technology and Training - University of Florida, 1956), and Marzano's taxonomy (Marzano & Kendall, 2007). However, this study will adopt the conceptualisation of HOTS as suggested by Bloom because the taxonomy developed has been widely recognised as a framework in education for several years (List & Sun, 2023).

## 2.1 Bloom’s Revised Taxonomy

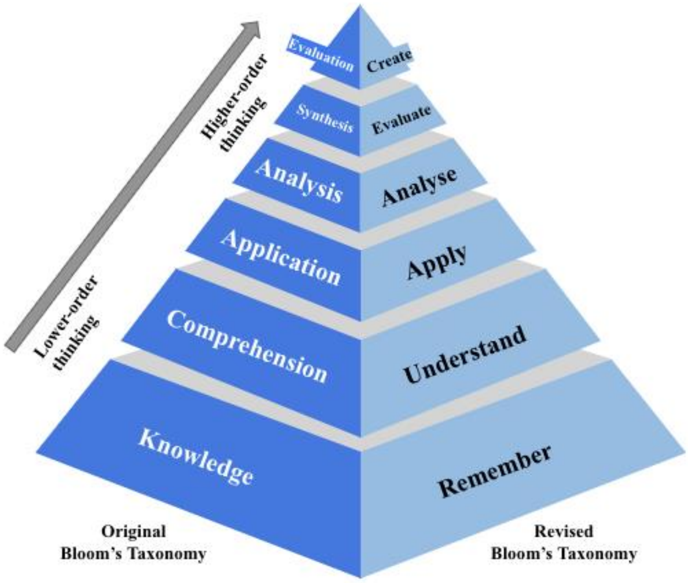
HOTS are commonly discussed and categorised using cognitive levels introduced in Bloom's Taxonomy for educational objectives (Conklin, 2012). This taxonomy classified cognition into six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. These levels are assumed to be hierarchical in terms of complexity, meaning that the lower level of knowledge is where learning begins and advances until the level of evaluation (Britto & Usman, 2015; Jensen et al., 2014). The top three levels of Bloom's taxonomy, also commonly referred to as HOTS, comprise analysis, synthesis, and evaluation (Arlianty et al., 2018; Jensen et al., 2014).

Although Bloom's taxonomy (introduced in 1956) was considered a notable contribution to the field of education, it also received some criticism from researchers and practitioners (Amer, 2017; Hyder & Bhamani, 2016; Larsen et al., 2022; Stanny, 2016; Wineburg & Schneider, 2010). A general weakness of the taxonomy discussed in the literature is that it is over 60 years old and assumes the learning process to be linear or hierarchical (Hyder & Bhamani, 2016). The taxonomy attached considerable importance on the knowledge domain compared to the cognitive process (Anderson & Krathwohl, 2001).

In a major revision to Bloom's Taxonomy, Anderson and team emphasised that the thinking levels are divided into knowledge (what) and cognitive process (how) (Hanna, 2007; Phillips et al., 2013). They highlighted that learning is dynamic in nature and thinking levels might not be hierarchical (Bümen, 2007). In addition, the revision uses active verbs to represent each thinking level, indicating that cognitive processes are complex, ergo active (Bümen, 2007). This revision changed a few other things in the original work. The term "comprehension" was changed with the term "understand", and the term "synthesis" was changed to "create" (Krau, 2011, p. 306). Furthermore, the level “evaluate” and “create” were swapped (Krau, 2011, p. 306). Figure 1 visually depicts both the original taxonomy and the revised taxonomy.

**Figure 1**

*Bloom's Taxonomy Original and Revised - side by side*




*Note.* This figure is a graphical representation of the original and revised Bloom's taxonomy as described in the book by Anderson et al. (2001, p.27-33). Anderson and Krathwohl (2001). *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives: Complete Edition.* New York: Longman https://www.jstor.org/stable/42926529

The revised Bloom's taxonomy consists of six thinking levels, described below, and each is considered to be conceptually distinguishable (Zapalska et al., 2018). The levels of analyse, evaluate, and create are considered as HOTS (Soozandehfar, 2016). Some scholars such as Booker (2007) and Marley (2014) have discussed that each level of the Bloom's taxonomy builds on the previous level. Instructors and teachers use various verbs to describe each thinking level. However, this research focuses mainly on the HOTS, and hence, the verbs commonly used for the levels of analyse, evaluate, and create are depicted in Figure 2.

- **Remember -** This is the foundational level and includes the action of recollection or retrieval of factual information stored in an individual's long-term memory. Upon achieving proficiency in this level of thinking, individuals are able to involve in higher levels. For example, recollecting dates of historical or past events.
- **Understand -** The next level is understanding, where individuals make meaning of the available information, comprehend logics and form connections.

- **Apply -** This level requires cumulating previous levels and going a step beyond, which means remembering the factual information, understanding it and then applying the interpretation to the problem at hand.
- **Analyse -** At this level, individuals are involved in activities such as distinguishing important and unimportant information, organising the available resources based on relevance and developing a perspective of their own.
- **Evaluate -** This level of thinking leads to detecting or assessing inconsistencies and framing justifications for their perspective.
- **Create -** This is a rather complex level as compared to the rest. At this level, individuals use all the previous levels of thinking and produce something new.

**Figure 2**

*Typical verbs involved in HOTS: Analysing, Evaluating and Creating*

| Analysing | Evaluating | Creating |
|---|---|---|
| Examine the details | Make decisions using given information | Design or develop a new or original work |
| categorize | appraise | assemble |
| compare | argue | compose |
| connect | choose | construct |
| contrast | convince | create |
| criticize | critique | design |
| deduce | debate | develop |
| diagram | defend | facilitate |
| differentiate | estimate | hypothesize |
| dissect | evaluate | integrate |
| estimate | grade | invent |
| experiment | judge | modify |
| infer | justify | plan |
| organize | measure | propose |
| plan | predict | revise |
| prioritize | rank | simulate |
| question | rate | speculate |
| test | reframe | support |
| | summarize | validate |
| | support | |

*Note.* Adapted from Stanny (2016) Reevaluating Bloom's Taxonomy: What Measurable Verbs Can and Cannot Say about Student Learning. *Education Sciences*, *6*(4), 37. https://doi.org/10.3390/educsci6040037 and *Bloom's Taxonomy - Center for Instructional Technology and Training - University of Florida*. https://citt.ufl.edu/resources/the-learning-process/designing-the-learning-experience/blooms-taxonomy/

Apart from Bloom's updated taxonomy, there are other related concepts that contribute to efficient thinking processes and are interconnected with HOTS. These concepts and their relation with HOTS are briefly described below.

**Metacognition:** Dawson (2016) has discussed that metacognition involves a group of abilities that are closely connected to the way we learn and think. Metacognition refers to the act of "thinking about thinking" (Dawson, 2016, p. 3) often activated to monitor if a cognitive aim has been met (Flavell, 1979; Livingston, 2003). Hence, by engaging in metacognitive activities, students can reflect on their thinking, leading to meaningful learning and further development of HOTS (Li & Yuan, 2022). Common examples of metacognitive strategies that students can use are setting goals, monitoring their progress, self-evaluation, and self-reflection (Desautel, 2009; Goupil & Kouider, 2019).

**Reflective thinking:** Dewey (1933) has mentioned that reflective thinking or reflection is a component of critical thinking, which is regarded as one of the HOTS. Hence, this concept is closely related to HOTS. By including opportunities that stimulate reflective thinking, students analyse their own learning processes and form opinions about past events (Rogers, 2001). It is defined as the act of thinking back on what was done during or after the task has been completed (Rogers, 2001).

**Formulating questions:** Asking questions requires students to think harder and thus activates HOTS (Watson, 2019). Gómez-Maureira et al. (2020) reported that when students ask questions, they learn more about the topic, explore different possibilities, and better solve problems. Hence, it can be said that the act of questioning is the foundation of meaningful learning (Chin, 2004) and it stimulates HOTS (Gómez-Maureira et al., 2020; Watson, 2019).

## 2.2 Teaching Higher-order thinking skills in higher education

Although HOTS are considered learnable skills, they demand more intricate cognitive processing from students and structured instruction efforts from teachers, which makes learning and teaching HOTS challenging (Ganapathy et al., 2017; Jerome et al., 2017; Miri et al., 2007; Stayanchi, 2017). Existing literature suggests that HOTS cannot be directly taught, but they can be developed gradually with the inclusion of learning activities that activate the skills of analysis, evaluation, and creativity; as a result of participation in such a sequenced education, students achieve HOTS (Afifah & Retnawati, 2019). This way, students are pushed to accomplish a goal from what they learnt earlier rather than simply retaining the information (Zain et al., 2022). Furthermore, the learning activities must be designed in a way that students are given adequate scaffolding to progress along the thinking levels and consequently achieve HOTS (Collins, 2014).

Previous literature on teaching HOTS in HE suggests that teachers can use models and taxonomies, such as Bloom's taxonomy or Webb's depth of knowledge, to sequence their instruction to create a balanced cognitive load on students (Hamzah et al., 2022; Shukla, 2016; Singelmann et al., 2020). For instance, teachers must create opportunities for students to analyse the given task before utilising their knowledge and indulging in activities such as decision-making or problem-solving. Such an arrangement of instruction and structured cognitive load supports the achievement of HOTS in students (Shukla, 2016). Along the same line, a literature review conducted by Singh et al. (2017) discusses that the first step to teaching HOTS is to explain to the students the relationship between the questions and answers and between the learning activity's process and outcome. When teachers do this, they allow the students to start thinking critically when the course begins and establish connections from previous knowledge to explore a new domain. Another study by Hugerat and Kortam (2014) discusses that undergraduate students are engaged in HOT when they are given a chance to directly experience their domain through inquiry-based learning (IBL). By participating in the process of questioning or being curious, students involve in critical individual or independent thinking and attempt to discover the answer on their own (Aditomo et al., 2013). Therefore, the current literature on teaching HOTS suggests that instruction should be sequenced and also go beyond traditional teaching approaches. The same was discussed by Chinedu et al. (2015) in their study about teaching and learning strategies for technical and vocational education.

### 2.2.1 Teaching Analytical Skills

Areesophonpichet (2013), in their study about analytical thinking in graduate students, describe that in Bloom's taxonomy, analytical skills are divided into three main parts - the ability to categorise and examine significant elements, the ability to relate concepts or elements, and the ability to understand the underlying logic between the connections. This study mentions that when students are taught analytical skills in HE, it acts as a starting point and leads to developing other HOTS, such as analytical thinking, problem-solving and creativity. In Kirman and Kala’s (2022) study about the analytical thinking of preservice teachers, they mention that the ability to be analytical is directly proportional to academic success, successful decision-making in personal and professional life, and creative thinking skills. Traditional lecture-based teaching practices may not promote the skill of being analytical in HE students (Stover & Pollock, 2014). Literature suggests that teachers can teach analytical skills by incorporating activities that stimulate students to break down or differentiate the given information, identify problems, ask questions, and organise gathered information into categories (Chinedu et al., 2015; Stover & Pollock, 2014; Zohar & Dori, 2003). Some examples of activities that support the development of analytical skills in students of HE are concept maps (Areesophonpichet, 2013), Debates (Spaska et al., 2021), guided inquiry (Wahyuni & Analita, 2017), flipped classrooms (Phurikultong & Kantathanawat, 2022) and think-pair-share activity (Kaddoura, 2013). Another study by Sudibyo et al. (2016) shows that when teachers implemented contextual or context-based learning for undergraduate students majoring in sports science, their analytical skills increased significantly. As a result of learning through context, those students were involved in exploring and interpreting information, thinking critically, and applying their prior knowledge to solve the problem, leading to the achievement of analytical skills.

### 2.2.2 Teaching Evaluation Skills

Evaluation skills, which is placed higher in the revised Bloom's taxonomy, are considered equally important as creative skills in the problem-solving process (Phillips, 2010). Teachers can teach evaluation skills by including activities that stimulate students to recognise patterns, weigh the given information and identify the main problem. Examples of activities that employ and support the development of evaluation skills are observing, detecting, testing, and critiquing (Anderson & Krathwohl, 2021; Chinedu et al., 2015). A list of similar activities that teachers can use to teach evaluation skills are mentioned in Figure 2 in the form of verbs. For example, a study by Sasannia et al. (2022) discusses the importance of teaching critical appraisal or scientific evaluation to undergraduate medical students so they can make informed decisions for their patients. In this study, teachers employed multimedia and online workshops, which resulted in an increase in students' ability to evaluate articles. In another study, Jonassen and Kim (2010) dove into the literature to find methods that support the teaching of argumentation skills. An argument involves evaluating information based on the weight of the evidence to have a stance on a topic (Jonassen & Kim, 2010). They reported that using question prompts, direction, collaborative argument, and graphical argumentation aids are some effective strategies to support the argumentation skills of college students. Therefore, the existing studies show that evaluation skills are teachable and learnable skills that are essential for students in HE.

### 2.2.3 Teaching Creative Skills

Each individual has the potential to portray creativity differently, to varying degrees, and under different conditions (Daly et al., 2014). In their study, DeHaan (2009) argue that teaching creative skills to adults is complex and requires a content-based teaching strategy to foster creativity. They discussed that, generally, the creative process involves two phases associative and analytical. The associative phase involves connecting abstract information and making intuitive decisions. The analytical phase involves assessing the cause and effect of the given information (DeHaan, 2009). Therefore, the ability to be creative involves students to engage in critical thinking and other thinking levels of Bloom's taxonomy. Hence, similar instruction strategies used to teach analytical and evaluation skills can be employed to teach creative skills (Siburian et al., 2019). For example, an active learning strategy such as inquiry-based instruction can be used to teach HOTS (DeHaan, 2009; Lu et al., 2021; Madhuri et al., 2012). Similarly, Zhou (2012) investigated other contemporary pedagogies, such as problem or project-based learning, that resulted in the development of creativity and other HOTS in engineering students. While many activities and strategies can be used to teach and stimulate creative skills in students, Al-Zahrani (2015) recommends considering the study load of the students as they might be taking multiple classes during their studies which might obstruct the development of creative skills and other HOTS.

### 2.2.4 Teaching Strategies to Operationalise HOTS

Many researchers in the field of education have investigated different strategies to teach and promote HOTS to students of HE (Ballakrishnan & Mohamad, 2020; Ganapathy et al., 2017; Pishchukhina & Watson, 2021). The table below synthesises the reviewed literature so far and outlines additional recommended teaching strategies to stimulate each HOT (analyse, evaluate and create). However, this is not an exhaustive list.

**Table 1**

*Activities to stimulate HOTS from literature*

| Teaching and Learning Activity | Study/Evidence |
|---|---|
| Open-ended questions | Vasan et al. (2018) |
| Review and Reflect | Bravo et al. (2016) |

| | |
|---|---|
| Think-pair-share | Kaddoura (2013) |
| Think Aloud | Banning (2008)<br>Pringle and Sowden (2017)<br>Pinnock et al. (2015) |
| Compare and Contrast | Rao et al. (2006) |
| Debate | Spaska et al. (2021)<br>Cariñanos-Ayala et al. (2021)<br>Nurakhir et al. (2020)<br>Cole et al. (2020) |
| Hypothesis Testing | Jong (2017) |
| Concept Maps | Areesophonpichet (2013)<br>Daley and Torre (2010) |
| Mind Maps | Hwang et al. (2012) |
| Flipped classroom | Phurikultong and Kantathanawat (2022)<br>Dehghanzadeh and Jafaraghaee (2018) |
| Brainstorming | Al-Samarraie and Hurmuzan (2018) |
| Critique previous literature | Sasannia et al. (2022)<br>Leong (2013) |
| Case Study | Popil (2011) |
| Oral Presentation | Chou (2011) |
| Project-based Learning | Zhou (2012)<br>Afifah and Retnawati (2019) |
| Problem-based Learning | Afifah and Retnawati (2019) |

| | |
|---|---|
| Inquiry-based Learning | Thaiposri and Wannapiroon (2015)<br>Madhuri et al. (2012)<br>DeHaan (2009)<br>Lu et al. (2021) |
| Challenge-based Learning | Yang et al. (2018)<br>Kalinga et al. (2018) |

## 3. Challenge-based learning (CBL)

### 3.1 CBL Background

As mentioned in Table 1 above, Afifah and Retnawati (2019) have discussed in their study that HOTS can be taught using student-centred teaching approaches such as flipped classrooms, problem-based learning, and project-based learning. These teaching approaches place students at the centre, making them work in teams to discover new knowledge, solve a relevant challenge or problem, and innovate a sustainable solution. Student-centred learning can be achieved via an experiential learning approach (Estes, 2004). The foundation of experiential learning is that students learn best when they are given a chance to actively immerse in open-ended activities (Santos et al., 2015). One such teaching approach that is said to be student-centred and involves experiential learning by solving real-world problems is CBL (Baloian et al., 2006; Colombari et al., 2021; Félix-Herrán et al., 2019; Salinas-Navarro & Garay-Rondero, 2020; Santos et al., 2015). CBL has much to offer to teachers and students. It is reported as an approach that supports the development of essential skills in today's job market while creating a meaningful and enriching learning experience (Barynienė et al., 2022). Hence, delving deeper into CBL becomes essential to fully grasp its potential in fostering these crucial skills and creating an enjoyable learning environment that empowers both teachers and students.

#### 3.1.1 What is CBL?

Apple introduced the challenge-based learning (CBL) framework in 2008 as a design proposal for the education system to prepare students for the 21st-century workplace (Ikonen et al., 2009). CBL is defined as an active teaching and learning approach where students acquire disciplinary knowledge by tackling a globally relevant challenge and participating in self-directed learning and collaborative problem-solving (Johnson & Brown, 2010; Nichols & Cator, 2008). CBL is reported as an approach that engages students, teachers, and external stakeholders in addressing real-world problems. External stakeholders involved in CBL are people relevant to the challenge, like members of the organisation or institution or field experts (Herzog et al., 2022). Literature reports that CBL arises from various other teaching approaches, such as problem-based, double-loop, project-based, and inquiry learning (Blevis, 2010; Johnson & Adams, 2011; Martin et al., 2007; O'Mahony et al., 2012). After Apple's initial documentation of the CBL framework, another significant study conducted in 2011 by Johnson and Adams discussed that CBL is an effective teaching approach to acquiring 21st-century skills in students at all educational levels (Johnson & Adams, 2011). Their study reported that CBL motivates students by giving them a big relevant challenge broad enough to find unique ideas and solutions. In addition, they also claimed that teachers of every educational level found CBL to be a suitable approach to teaching course content, considering their restricted time.

### 3.1.2 Why CBL?

CBL seemingly offers many advantages for teachers and students (Membrillo-Hernández et al., 2019). A substantial benefit of CBL claimed in the literature is that it was designed to enhance abstract thinking, collaboration, and teamwork among students, all of which are essential 21st-century skills demanded by the present job market (Johnson & Adams, 2011; Membrillo-Hernández et al., 2019; Nawawi, 2017). These skills could be fostered when students participate in activities embedded in CBL, such as being faced with a big idea, using technology to explore, and working in groups. Another claimed benefit of CBL for teachers and students is that CBL increases motivation and engagement (Johnson et al., 2009). When students are provided with a real-world problem that might have multiple solutions, they become curious, start caring about it, and are inspired to do well to develop their unique solution. Therefore, students are involved in a learning experience that is both enriching and meaningful. Additionally, for teachers, CBL is meant to create an environment where they are no longer an instructor but take on the role of co-researcher, mentor and designer (Baloian et al., 2006; Membrillo-Hernández et al., 2019). As a result of this change in the role, they have ceased being the only source of information for students and can provide personalised guidance to students. Therefore, CBL seems to provide a rewarding experience for teachers by allowing them to play an active role in student learning, engage deeply in the topic, and innovate solutions with students.

### 3.1.3 Effectiveness of CBL in HE

CBL is reported to be a valuable teaching approach in HE because it enhances student learning and engagement (Membrillo-Hernández et al., 2019). In the realm of HE, CBL is gaining popularity, and many researchers are beginning to further explore this teaching approach and its effectiveness. Roselli and Brophy (2006) analysed the effectiveness of challenge-based instruction (CBI) compared to the traditional taxonomy-based teaching approach in a biomedical engineering course at Vanderbilt University. Their study revealed that when students were involved in CBI, they better understood complex concepts than students involved in the traditional teaching approach because they were engaged in active learning and immersed in the challenge's context. In another study, Rodríguez-Chueca et al. (2020) assessed the implementation of CBL in HE STEM courses in Spain. This study reported that students rated their learning experience higher when they could apply their learning to a real-world challenge that helped them develop skills such as group work, planning and creativity. A study by Membrillo-Hernández et al. (2019) reported that engagement and student achievement were directly linked, and students' commitment increased when they were involved in the CBL teaching approach. Although most of the research on CBL in HE were conducted in the context of STEM disciplines (Gallagher & Savage, 2020), some studies also explored the effectiveness of CBL in non-STEM disciplines. For instance, a study by Pérez-Sánchez et al. (2020) with students from a management course at a Colombian university discussed that students are likely to develop critical thinking and creativity during the stage of proposing and implementing solutions. Likewise, in another non-STEM study by Cruger (2018) with students of a communications course, it was reported that when teachers use the CBL approach, students self-reported higher confidence and a better understanding of course concepts, giving them a chance to practice critical thinking. Therefore, the results of various studies discussed here suggest that CBL is seemingly an effective approach in HE as it could aid meaningful learning, shift the teacher's role to be more active, create practice opportunities for critical thinking and creativity, and support comprehension of complex concepts for students.

### 3.1.4 Shortcomings of CBL

While CBL has received much appreciation from educators and students in HE, it also has some shortcomings (Conde et al., 2017; Vilalta-Perdomo et al., 2020). For instance, Bombaerts (2020) discussed that CBL requires a heavy time dedication from both teachers as well as students. In a similar vein, Hernandez et al. (2020) stated that CBL requires many reflection points throughout the process and requires teachers to invest a lot of time and effort. Vilalta-Perdomo et al. (2020) in their study collected students' insights on the shortcomings of CBL. The students in this study reported differences in terms of efforts from members of their group and wished for the CBL course to be longer than the current set-up. The same was discussed by Conde et al. (2017). Another problem with CBL in HE could be that teachers might have difficulties adapting their existing course to CBL due to their willingness and lack of knowledge about this pedagogy (Bombaerts, 2020). Further, large class sizes could also cause a hindrance in applying the CBL approach to a course, which is typically the case in STEM courses (Martin et al., 2007).

### 3.2 CBL Theory of Action

Theory of action was first mentioned in the work of Argyris and Schon (1994) to understand the theories used within organisations. Later, many researchers drew upon this concept of theory of action to clarify the espoused theories and compare the underlying assumptions of how a particular program operates versus what actually happens in reality in their respective fields (Cobb & Jackson, 2011; Malen et al., 2002). Therefore, embracing a broad view of the concept of theory of action, the upcoming sections uncover the implicit logic of the CBL components, process, and conditions. The theory of action of CBL in this study also explores the relation of CBL with HOTS in the context of HE. The outcomes of the literature review of the theory of action of CBL and its relation with HOTS have been synthesized into a set of propositions, which are presented in section 3.3.2.

#### 3.2.1 Process and Components of CBL

The Challenge Institute, formed to spread and extend the CBL framework created by Apple, described that learners go through three main phases in a CBL environment: engage, investigate and act (Challenge Based Learning, 2022; Nichols & Cator, 2008).

- In the 'engage' phase, learners are presented with a broad idea or theme that they need to define by posing appropriate questions.
- Then comes the 'investigate' phase, where learners attempt to better understand the challenge through interviews, surveys, etc.

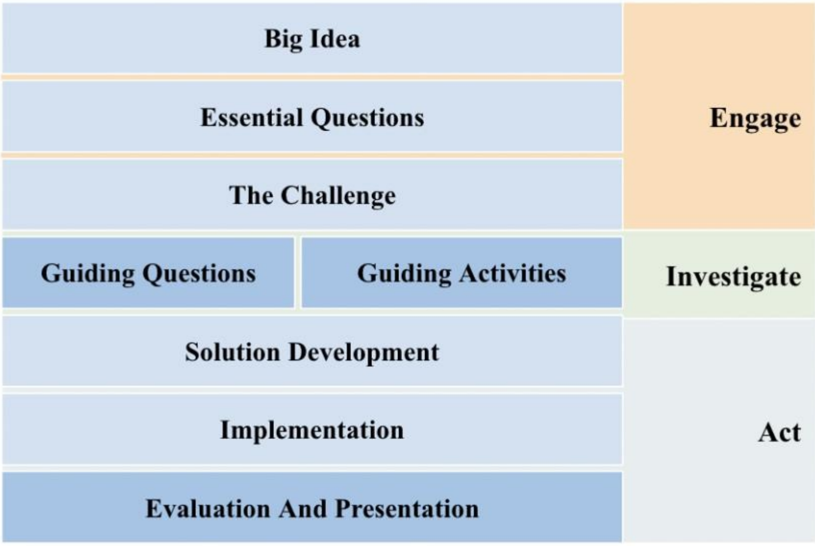
- Finally, innovative solutions are designed by sharing knowledge and collaboration in the 'act' phase.

In general, the CBL process consist of eight components and are described below based on studies done by Castro and Zermeño (2020), Gallagher and Savage (2020), Johnson et al. (2009), López-Guajardo et al. (2023), and Santos et al. (2015). Figure 2 shows the CBL components and its corresponding phase in the CBL process.

1. **Big Idea:** A big idea refers to a broad concept that has the potential to be explored in many ways. For example, sustainability or innovation.
2. **Essential Questions:** CBL is designed in a way that when a big idea is presented, it immediately leads to the creation of essential questions that either reflects the need of society or the interests of the learners. For example: If the big idea is sustainability, then learners involved in the discipline of business may have a different set of essential questions than learners from the discipline of engineering.
3. **The Challenge:** The essential questions then lead to the formulation of a concrete challenge that the learners will work towards and solve.
4. **Guiding Questions:** This refers to the questions that learners will develop to indicate the gap of knowledge that needs to be filled in order to solve the challenge and guide their own learning process.
5. **Guiding Activities:** These activities support gaining the knowledge required to address the guiding questions. Examples of guiding activities are: interviews, simulations, lectures, reading literature, observations etc.
6. **Solution Development:** One or multiple solutions (based on the complexity of the challenge) is concretely developed, defined, and proposed by the learners.
7. **Implementation:** This refers to the part where learners execute their ideas and solutions to an authentic situation.
8. **Evaluation and Presentation:** After implementing the solution, the learners check the results, evaluate, and refine their solutions. After the solution has been refined and finalised, they showcase their work in the form of presentation or videos or written document.

**Figure 2**

*Challenge-based Learning Phases and Components*




*Note.* Adaptation from Apple Inc. (2011). *Challenge Based Learning: A Classroom Guide.* Cupertino, CA. and a study by Nichols and Cator (2008). Challenge-based learner user guide. *Redwood City, CA: Digital Promise*, 24-36.

### 3.2.2 Designing CBL

Teachers or educators must thoroughly understand the CBL process and its components because the steps employed in CBL, such as starting with a big idea and then progressing to guiding questions and beyond, are commonly used as a design framework for CBL courses (Da Silva-Ovando et al., 2022; De Stefani & Han, 2022; Gabriel, 2014; Kasch et al., 2022). Therefore, by being well-versed in CBL, educators can effectively utilize the iterative approach of CBL to design or redesign their courses. Literature suggests that a restricted number of frameworks are suitable for designing a CBL course. For instance, Marin et al. (2013) used the design thinking methodology to design the CBL course for the English language in their study. They found that the design thinking methodology shared an identical focus with CBL in terms of problem-solving and innovation (Marin et al., 2013). Kasch et al. (2022) have suggested some design recommendations for an online CBL course. They recommended that educators take into consideration the psychological space between students, teachers, and experts in a CBL course to maintain engagement. They also recommended using an online community of inquiry to nurture collaboration, a sense of community, and student engagement (Kasch et al., 2022). In addition, Chapel et al. (2021) used constructive alignment and Van Den Akker's (2004) curriculum spider web to design the CBL courses in their university. Therefore, the abovementioned design considerations and frameworks can be used by educators to design effective CBL courses to ensure engagement, structure, and innovation.

### 3.2.4 Conditions of CBL

Several conditions need to be considered to ensure that CBL is implemented effectively and promotes deep learning. Caratozzolo and Membrillo-Hernández (2020) and Martinez et al. (2020) have discussed certain conditions from the viewpoints of students and teachers' perspectives. It was discussed that students need to understand their obligations to actively participate both cognitively and socially. The students must empathise with their peers and ensure participation from everyone in the group. Students should ask questions, think critically, draw on previous knowledge and practice self-directed learning. Moreover, from a teacher's or course's perspective, there must be points of reflection, opportunities for critical analysis and synthesis. After every phase of CBL, debriefing is recommended, which facilitates and shows how the decision-making process was completed. Teachers are recommended to create a safe environment for students to face risks, failure and success freely (Martinez et al., 2020). The CBL course needs to be designed to promote informal learning opportunities for all participants. Additionally, the teacher should provide enough scaffolding for each task so students can smoothly transition between CBL phases and activities (Martinez et al., 2020).

## 3.3 Claims from literature about CBL in relation to HOTS

A literature review was performed to synthesise the findings from theory about CBL in relation to HOTS. The overview of results can be found in Appendix A.

### 3.3.1 Teaching HOTS in higher education using CBL

Other contemporary teaching approaches, such as PBL, PBjl and IBL, have been shown to develop HOTS in students (Eliyasni et al., 2019; Ersoy & Başer, 2014; Madhuri et al., 2012). Since CBL is a similar active teaching and learning approach and shares commonalities with the mentioned teaching approaches, it is assumed that CBL can stimulate HOTS (Nawawi, 2017; Putri et al., 2020). However, the aspects or components of CBL that lead to achieving HOTS should be examined more. Therefore, the section below synthesises what is claimed in the literature from the last ten years around CBL and how it leads to HOTS.

Certain studies indirectly discussed how HOTS are achieved throughout the CBL process. Yang et al. (2018) designed a nursing course using the CBL approach for bachelor students. They reported that students' perceived curiosity, creative consciousness, and innovation increased after implementing the CBL course. This was evident from the mean scores of the self-perception questionnaire and the fact that students preferred positive words conveying that they felt less stressed in ambiguous situations, more open to change, thought of unconventional solutions, identified problems, and had newer perspectives. The study discusses the aspects of CBL that could lead to increased curiosity, creativity, and innovation. In the study, the teacher regularly conveyed the true meaning of creativity and innovation to students, which gave students more context and prompted them to try unexplored problem-solving strategies. This act of the teacher conveying information is an example of a "guiding activity" within the process of CBL. Furthermore, the CBL approach included "real-world" problems, which may have contributed towards motivating students to be more involved, innovative, think critically about possible solutions, and be more open to risks (Yang et al., 2018). In another study by Vilalta-Perdomo et al. (2022), CBL was used in an operations management course. The students in this course were given a reflection assignment where they reported that "real-life situations" made their experience of the CBL course exciting and unique. They were creative because they felt they made a real impact on society. They sensed a personal connection with the challenge, and the connection of the challenge with their own community made them feel like they should not jump to conclusions but practice critical thinking and eventually come to a solution. Membrillo-Hernández et al. (2018) supported the same and discussed that the primary motive for using CBL in education is not to resolve the challenge completely. Instead, it should be used to gradually develop HOTS in students by taking them through the engage, investigate, and act phases to be ready for professional endeavours. Students often undergo a negative experience in their first CBL course (Santos et al., 2015). From their second CBL course, they usually start to understand the purpose of CBL and experience a shift in mindset about fast problem-solving. CBL design prompts students to broaden their thinking and consider every possible perspective and aspect. This happens at various phases of CBL, such as the big idea phase, after the challenge has been defined and after the information is gathered (Santos et al., 2015).

### 3.3.2 Propositions from literature about CBL in relation to HOTS

Through literature review, a set of propositions were derived that require further exploration. These propositions were formulated based on the researcher's analysis, synthesis, and interpretation of the literature from the last ten years around CBL and HOTS.

#### 3.3.2.1 Proposition 1: Relevant Societal Problem

CBL has been reported as an approach that increases deep learning in students when the course content is aligned with real-world situations (Cheung et al., 2011; Lake, 2021). A systematic literature review revealed that having a real-world connection seemingly makes students motivated towards the challenge. In other words, when challenges presented are relevant to students' lives and they make a personal connection to the challenge, they are more likely to proactively engage with it (Cheung et al., 2011; Vilalta-Perdomo et al., 2022). When motivation and personal interest increases, students tend to proactively apply HOTS in each phase of CBL and consequently achieve it. When relevant societal problems or real-world challenges are presented in CBL, it seemed to inspire students to think in a more creative way, adapt their learning methods, maintain their enthusiasm, and be more open to taking risks (Yang et al., 2018). Therefore, it has been claimed in substantial amount of studies that CBL fosters students' motivation by presenting them with real-world issues, encouraging them to ponder social phenomena, engage in intense and intricate thinking, and venture into uncharted territories with unique and unconventional ideas (Cheung et al., 2011; Johnson et al., 2009; Vilalta-Perdomo et al., 2022; Yang et al., 2018).

Proposition 1A: If the course addresses a relevant societal problem, then students are more likely to be motivated.

Proposition 1B: If students are more motivated, then they are more likely to proactively apply HOTS during the course.

Proposition 1C: If the course addresses a relevant societal problem, then students are motivated and proactively apply HOTS during the course.

#### 3.3.2.2 Proposition 2: Presence of broad ideas

Literature reports that for students to be motivated and proactively practice their critical thinking abilities, the big ideas in CBL must be complex and multifaceted. The students must be made aware that multiple solutions possible for a challenge. This promotes creativity among students, and they proceed to solve the challenge with autonomy. For instance, a study by Ardiansyah et al. (2021) posed big or broad ideas to the students to increase motivation, trigger learning and creative ideation. In another study done by Detoni et al. (2019), it was reported that students attributed their motivation towards the course to their connection with the broad idea.

Proposition 2A: If the course presents broad ideas that have multiple possible solutions, then students are more likely to be motivated.

Proposition 2B: If students are more motivated, then they are more likely to explore different possibilities for the presented broad idea.

Proposition 2C: If the course presents broad ideas that have multiple possible solutions, then students are motivated to explore different possibilities and are more likely to apply HOTS.

#### 3.3.2.2 Proposition 3: Structured yet divergent nature

While CBL has an iterative and structured process that stops learners from jumping to solutions, certain steps of this process stimulate lateral or divergent thinking giving learners the chance to explore the topic in-depth with free-flowing ideas or questions (Jensen et al., 2018; Lin & Chen, 2017; Santos et al., 2015; Susilawati et al., 2018). In such steps, students open up their thinking and explore possibilities by using their analytical and evaluation skills. Hence, it can be said that CBL seems to have a balance of structure and divergence that could give students opportunities to practice and achieve HOTS.

Proposition 3A: If the course includes a structured problem-solving process, then students are more likely to have a restricted time frame to explore the problem.

Proposition 3B: If the course includes opportunities for students to engage in divergent or free-flow thinking, then students are more likely to explore the problem in depth.

Proposition 3C: If the course follows a structured process, then students are more likely to apply HOTS to explore the problem in depth within a restricted time frame.

#### 3.3.2.3 Proposition 4: Formulation of questions

For the most part, in CBL, students are involved in active learning (Yang et al., 2018). However, in certain phases of CBL, this type of learning could be heightened (Ardiansyah et al., 2021), and students have the possibility to utilise their HOTS more. For example, in the phase of formulating essential questions, guiding questions, and solution development, students are prompted to look at their chosen challenge from various lenses, consider all aspects and make decisions (Nichols & Cator, 2008). Hence, in these phases, students organise the facts, understand the logic, identify the gaps, select the activities required to gain meta-knowledge, evaluate their choices and make informed-decisions.

Proposition 4A: If the course includes opportunities that stimulate formulation of questions before investigation, during investigation and before solution development, then students are more likely to approach the problem from different perspectives.

Proposition 4B: If the students approach the problem with different perspectives, then students are more likely to gain more knowledge.

Proposition 4C: If the course provides students with opportunities to formulate questions at multiple stages, then they approach the problem from different perspectives by applying HOTS and as a result, gain more knowledge.

#### 3.3.2.4 Proposition 5: Co-creation

CBL allegedly creates opportunities for teachers, students, and stakeholders to collaborate, analyse, synthesise, evaluate, create solutions, and come up with new insights towards the identified shared societal challenge (Christersson et al., 2022, p. 8). They share ideas, listen to each other's perspectives, gain knowledge from each other, and build upon each other's knowledge to reach to a solution. For instance, in the study by Detoni et al. (2019) reported that students felt that collaboration helped them in better solving the problem at hand. Hence, the aspect of co-creation in CBL has the potential to lead to the development of HOTS in students.

Proposition 5A: If the course includes the element of collaboration, then the students, teachers and stakeholders are more likely to share and build upon each other's ideas.

Proposition 5B: If the students, teachers, and stakeholders share and build upon each other's ideas, then unique insights are generated.

Proposition 5C: If teachers, students, and stakeholders collaborate in the problem-solving process, then they co-create a unique solution by applying HOTS.

#### 3.3.2.5 Proposition 6: Reflection and Sharing

Reflecting during the CBL process requires students to be involved in metacognition. When they reflect in a CBL environment, they analyse their own choices, choices they made as a team, engage in self-assessment, and self-regulation (Doulougeri et al., 2022). In terms of content, they reflect on what knowledge was acquired so far and how this can be applied in other disciplines in the future (Van Den Beemt et al., 2023). These metacognitive activities involved in reflection could lead to the development of HOTS. In addition, when learners share their reflections with their team or with teachers, they also tend to engage in HOTS, such as critical thinking and evaluation.

Proposition 6A: If a course includes opportunities to reflect, then students engage in metacognition.

Proposition 6B: If a course includes opportunities to share reflections with other students or teacher, then the students apply HOTS to communicate their thoughts and ideas clearly.

Proposition 6C: If a course includes reflection and sharing, then students tend to apply HOTS when reflecting and sharing their reflections.

## 4. Method

### 4.1 Research Question

The main guiding question of this research is: How does CBL lead to the achievement of HOTS? By performing an in-depth investigation of how CBL leads to HOTS by reviewing literature and gathering empirical evidence from the context of a university in the Netherlands, this research refines and elaborates on the theory of CBL. To answer the main question, three sub-questions were formulated to guide the investigation:

1. According to existing literature, what is the theory of action of CBL to achieve HOTS in students of HE?
2. What are the perspectives of teachers and educational experts regarding the theory of action of CBL to achieve HOTS?
3. What is the difference between theory and the teacher's perspective? If there is a difference, how can it be explained?

### 4.3 Research Context

The research context was a university in the Netherlands that implemented CBL courses in their educational programs. The university's educational vision is to increase the incorporation of CBL. Therefore, the university continues to expand its efforts to use CBL as a teaching method. This means that more knowledge is being generated every day around teaching CBL to students in HE at this university.

### 4.2 Research Design

This study uses a qualitative research design. A literature review was conducted to identify relevant literature about HOTS and CBL. The findings from the literature review formed a basis to derive general themes or propositions that are later used to compare and contrast with empirical evidence collected via interviews in order to refine the CBL theory. This approach is referred to as theory elaboration. The theory elaboration research approach is valuable as it allows for a deeper understanding of complex phenomena (Ketokivi & Choi, 2014). The process of theory elaboration includes specifying concepts, their mechanisms, and relations to further explain the empirical observations (Fisher & Aguinis, 2017). The theory elaboration approach involves utilising already existing theories and strives to improve them to provide precise explanations of empirical observations (Fisher & Aguinis, 2017). Thus, using the theory elaboration approach, this study aims to expand on prior knowledge of CBL and generate new insights about CBL in relation to HOTS, consequently refining the CBL theory.

Data was consequently collected using semi-structured interviews with the teachers and educational experts of a university in the Netherlands. The interviews aimed to capture the perspectives of teachers and experts about the propositions that emerged from theory. These semi-structured interviews methodologically contributed as the empirical evidence which is required to elaborate on existing theories of CBL concerning HOTS. The semi-structured interviews and the interview guide were designed using a framework developed by Kallio et al. (2016).

### 4.5 Data Collection

This study collected qualitative data through semi-structured interviews with teachers and CBL experts. These interviews methodologically contributed to the study as the empirical evidence which was required to elaborate on existing theories of CBL relating to HOTS. The purpose of the semi-structured interviews was to collect the perceptions of teachers and educational experts on the propositions that emerged from literature about CBL, and HOTS based on their first-hand experience with implementing CBL in a university setting.

#### 4.5.1 Interviewees

Within the Dutch university under study, teachers of twenty-two courses using the CBL approach were asked to participate. These courses are supported by five educational experts who guide and assist more than twenty teachers involved in these courses. Hence, this research used purposive sampling as the interviewees chosen had closely experienced CBL and possessed the necessary knowledge related to this research. The educational experts and teachers who were interviewed for this research were from diverse faculties, including behavioural science, engineering, computer science, mathematics, geo-information science, and science and technology. They were involved in delivering CBL courses both for undergraduate and graduate students.

### 4.5.2 Ethical Consideration and Informed Consent

The university's ethics committee approved this study and the data collection process. Interviewees were informed about the purpose of the study and their right to withdraw at any time. Participation in this interview was voluntary. Informed consent was obtained from all interviewees during the interviews verbally. Their anonymity and confidentiality were ensured.

### 4.5.3 Instrumentation

The interview setup and questions that were used to prompt the interviewee to share their perceptions can be found in Appendix B. The researcher prepared a PowerPoint presentation to showcase the propositions and questions during an online interview. This presentation helped to maintain the structure of the interview. A physical copy of this presentation was provided in the case of in-person interviews.

## 4.6 Data Analysis

The interviews were audio-recorded and transcribed verbatim for analysis. The current study used thematic analysis as a method to analyse and interpret the collected data. Thematic analysis is a helpful technique to organise extensive qualitative data into clear categories (Braun & Clarke, 2006; Nowell et al., 2017; Vaismoradi et al., 2013). The first step to thematically analyse the collected data involved transcribing the semi-structured interviews. During this step, the researcher familiarised themselves with responses from the interviewees and get a clearer picture. The second step involved applying preliminary codes to the data using the Atlas.ti software program. This was done to highlight and label the significant findings based on the propositions. The third step was to identify patterns and themes and making connections from the data. The themes or patterns were revisited in the fourth step to ensure that data was thoroughly analysed. Finally, the themes or patterns were defined and documented.

In addition to thematic analysis, this study employed the pattern-matching (PM) strategy. Using the pattern-matching strategy, one can effectively observe, analyse, compare, and contrast the theoretical assumptions with reality to gain a better and newer understanding of the concept or phenomenon (Bouncken et al., 2021; Sinkovics, 2018; Trochim, 1989). "Expected patterns" emerging from theory and "observed patterns" emerging from empirical observations are typical information types in the PM process (Vargas-Bianchi, 2020, p. 2). For this study, the knowledge gained from the literature was used to develop theoretical propositions which served as a base for data collection. Once the empirical data was collected, the expected and observed patterns were compared. With this comparison or matching process, there are three possible results: a complete match, a partial match, or no match at all (Cassell et al., 2018; Trochim, 1989). A match between the patterns indicates that there are empirical indications to support the assumptions from the theory. If the PM process results in a mismatch or partial match, then inferences need to be made to provide a plausible explanation of the outcome i.e, answering why the assumptions from the theory did not match with perceptions of reality.

Abductive reasoning is an effective method for elucidating unanticipated results (Mirza et al., 2014). Abductive reasoning was used in this study to analyse and explain the most likely cause of the match, mismatch, or partial match between theoretical and empirical data. Mantere and Ketokivi (2013) recommend abductive reasoning as a suitable strategy because it has the capability to turn unexpected results into plausible explanations and identify connections that may not be apparent immediately. Abductive reasoning allows creativity and the generation of new ideas, which might lead to novel insights and discoveries based on the observed information (Mantere & Ketokivi, 2013). Furthermore, by making educated predictions with the outcome at hand, i.e., match, mismatch or partial match of the patterns, a more refined understanding of the concept is achieved (Ketokivi & Choi, 2014).

### 4.7 Reliability and validity

This study used a consistent interviewing and data collection approach to increase reliability. The interview questions were aligned with the research questions of this study to ensure content validity as suggested by Brod et al. (2009). A pilot interview was conducted first to ensure the questions are clear and relevant as recommended by Majid et al. (2017) and

Malmqvist et al. (2019) in their independent studies about qualitative research. Based on this pilot interview, questions and propositions were revised for clarity. Member checking process was followed where participants could review their responses to ensure that the collected data accurately reflect their views and experiences (Nowell et al., 2017). Further, 10% of the data was coded by a second coder to ensure reliability as recommended by O'Connor and Joffe (2020). The codes were compared, and the inter-rater agreement score was 87% after two discussions.

## 5. Results

This section will include results of the thematic analysis of the semi-structured interviews and pattern matching process.

### 5.1 Teachers' and Experts' perceptions of CBL and HOTS

#### 5.1.1 Relevant societal problem

This theme included the propositions 1A, 1B and 1C. According to the findings, a majority (58%) of the interviewees expressed agreement with proposition 1A, which states that when a course tackles a relevant societal problem, it enhances student motivation. For instance, interviewee L who agreed to 1A mentioned *"... whenever it's something that is relevant and currently existing in the real world, students really feel like they can change the world. They enjoy it way more as compared to some scenario that we (teachers) came up with."*. However, an interviewee who partially agreed to 1A mentioned that they generally agree but have reservations because *"... it depends on the engagement of students"*. In addition, there was a higher level of disagreement (25%) for proposition 1B when compared to propositions 1A and 1C. The proposition for 1B stated that students who are more motivated will actively apply HOTS during the course. An interviewee that disagreed mentioned *"I don't think more students are able to take other people's perspectives or synthesize or integrate different disciplinary views".* In addition, when compared to 1A and 1B, proposition 1C received the most partial agreement (54%). This proposition states that if a course tackles a relevant societal problem, students are more likely to be motivated and proactively apply HOTS during the course. An interviewee that partially agreed to 1C stated that *"The first part is definitely true ... but the proactive application of HOTS depends on the scaffolding part".*

### 5.1.2 Presence of broad ideas

The propositions 2A, 2B and 2C were included under this theme. According to the results, compared to 2B and 2C, proposition 2A received the highest disagreement of 33%, with only 17% of respondents agreeing with the statement. One respondent expressed, *"... plenty of students who are confronted with multiple possible solutions actually will struggle with it, and it can be demotivating for them. So, there's a certain category of students who do well at CBL".* Additionally, 58% of the interviewees agreed with 2B's that stated that motivated students will explore different possibilities for the broad idea presented. An interviewee mentioned *" ... if they find the topic interesting, students are more inclined or more motivated indeed to look into all sorts of sources."*

### 5.1.3 Structured yet divergent nature

3A, 3B and 3C were the sub-proposition under this theme. Based on the collected data, 67% of interviewees agreed with proposition 3A, which states that if the course includes a structured problem-solving process, then students have a restricted time frame to explore the problem. An interviewee who agreed with this proposition conveyed that *"CBL is good to set some kind of boundaries ... otherwise they will keep discussing things for the whole course of 10 weeks".* Further, the proposition 3B received the highest level of disagreement (21%) with 46% of the interviewees partially agreeing to the statement that if the course includes opportunities for students to engage in divergent or free-flow thinking, then students explore the problem in depth. Table 2 contains selected quotes from the interviewees who disagreed and partially agreed with proposition 3B.

### 5.1.4 Formulation of questions

From the propositions under this theme (4A, 4B, and 4C), 88% of the respondents agreed with 4A, which states that if the course includes opportunities that stimulate the formulation of questions at multiple stages, then the students approach the problem from different perspectives. One interviewee emphasized, "*... at first students formulate questions from one or two perspectives, ... , but maybe during the investigation, they ask questions again and they get excited ... and that's why I like CBL so much because you ask questions, ask more questions and then as as a coach, you stimulate them to ask even more questions.*". In addition, it was found that proposition 4A had no partial agreement (0%), meaning that everyone fully agreed and there was very little disagreement (12%). Furthermore, 17% of the interviewees disagreed with proposition 4C, which received the highest level of disagreement compared to propositions 4A and 4B. Proposition 4C stated that when students are allowed to formulate questions at multiple stages of problem-solving, they explore different perspectives, apply HOTS, and acquire enhanced knowledge. For instance, interviewee B mentioned *"it does not happen automatically ... the teacher has to get them there and think about how to coach the students so they can ask questions, include other perspectives and use HOTS".*

**5.1.5 Co-creation**

The theme was divided into the the propositions 5A, 5B and 5C. Evident from the findings presented in Table 2, under this theme of "co-creation" the proposition 5C received the highest level of agreement of 63% when compared to 5A and 5B. This proposition stated that if teachers, students, and stakeholders collaborate in the problem-solving process, then they co-create a unique solution by applying HOTS. In the words of interviewee E *"... in terms of the skills of synthesis and evaluation and coming to such a unique but also value added solution after collaborating would require the application of higher order skills"*. Moreover, the proposition 5A received the highest disagreement (21%) when compared to 5B and 5C. This proposition stated that if the course includes the element of collaboration, then the students, teachers and stakeholders share and build upon each other's ideas. Interviewee F who disagreed with this proposition mentioned that they have mostly observed collaboration between the student and the tutor but not with the stakeholder. Additionally, it's noteworthy that both propositions 5A and 5B received the same level of agreement (54%), with 38% partially agreeing with 5B. Keywords of these propositions and select quotes are presented in Table 2.

**5.1.6 Reflection and Sharing**

The propositions 6A, 6B and 6C were formulated under this theme. From the collected data, it is apparent that 75% of the interviewees agreed with proposition 6C. This proposition suggests that when a course incorporates reflection and sharing, students are more likely to apply HOTS. In agreement with this proposition an interviewee mentioned *"Students reflect and share also in problem-based learning ... but it is included in CBL to do that in all stages. so sharing and reflection and documenting happens throughout all steps"*. Further, it is evident from the results that the proposition 6A received the highest disagreement (8%) in this theme. The essence of this proposition is that if a course includes opportunities to reflect, then students engage in metacognition. Interviewee X who disagreed with this proposition stated that *"They do not reflect automatically. Because reflection is a skill in itself that students have to learn. And if students have the opportunity to reflect doesn't mean that everybody, does it. So, it's not only about having the opportunity, it's the obligation to reflect ... but the teachers have to support students on how to reflect"*.

### 5.2 Overall Findings

Table 2 summarises the findings from the interviews. The percentages indicate the proportion of teachers who expressed each type of response. Since this study collected data from ~24 interviewees, only a subset of verbatim responses are included in the table. The results shows that the interviewees had varying opinions.

In general, the findings show that teachers and experts resonated with the propositions based on their experience implementing CBL in HE. Out of the eighteen propositions, the one that received the highest agreement was 4A (88%) which belonged to the theme of "formulation of questions". Another key finding was that proposition 1C which belonged to the theme of "relevant societal problem" received the highest degree of partial agreement from the interviewees (54%). Moreover, the proposition 2A under the theme of "broad ideas" received the most disagreement (33%) from the interviewees.

**Table 2**

*Pattern matching and percentage for each type of response given by interviewees*

| Proposition (Theoretical Pattern) | Sub - propositions | Keywords | Agreemen t % | Partial Agreement % | Disagreement % | Empirical Pattern | Evidence |
|---|---|---|---|---|---|---|---|
| Formulation of questions | 4A | formulation of questions, before investigation, during investigation and before solution development, different perspectives of problem | **88%** | 0% | 12% | When students are given chances to formulate questions at various stages throughout the course, they not only approach the problem from diverse perspectives but also apply HOTS such as critical thinking, analysis, evaluation, synthesis, and creativity. | "... formulation of questions is at the heart of CBL ... but I definitely think that the formulation of questions during or throughout the whole process is stimulating the students to approach the problem from different perspectives."<br><br>"It is also our experience and also students agree on that ... it really helps them to go think in different directions by setting up those questions in the in the |

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| | | | | | | | early engage phase. They get a broader view ... and might end up with solutions that they never thought of before. ... they go really out of the box and come up with very creative solutions ...” |
| Reflection and sharing | 6C | reflection and sharing, application of HOTS | **75%** | 25% | 0% | The CBL courses implemented varying degrees of reflection and sharing. Nevertheless, when these elements are integrated into the course, the utilization of HOTS such as meta-cognition, critical thinking, analysis, evaluation, and | "In my class, I often ask students to reflect towards the end of the course"<br><br>“I would agree with this because evaluation is nothing else than reflection”<br><br>“It's all about higher order thinking in reflection and sharing. You have to apply higher-order teaching to be able to achieve this. That |

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| | | | | | | synthesis becomes apparent. | should be the approach to get them at a higher order thinking.” |
| Structured yet divergent nature | 3A | structured problem solving process, limited time-frame, exploration of the problem | **67%** | 21% | 12% | Due to the inherent structure of courses, students often find themselves operating within a limited time frame. This constraint arises not only from the nature of structured CBL process but also from the relatively short duration of courses at the university, typically spanning one quartile lasting around 8 weeks. | “... Because you have those three phases, the exploration phase in in CBL gets less time than if you have a project based or an other type of type of approach ... in the first engage phase, they are learning a lot. They are exploring the problem ... really data digging for example or detailed literature reading is often restricted.”<br><br>“... it depends on the structure ... If you look at the educational practice, |

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| | | | | | | | you only have an X amount of ECS in an X amount of time frame. So 9 of 10 times the structure just simply ends at the end of the last phase, or sometimes also in between somewhere, depending on how they want to set up a which elements of CBL the course wants to use.” |
| Formulation of questions | 4B | different perspectives of problem, gain more knowledge | **67%** | 29% | 4% | When students explore a problem from different perspectives, their knowledge expands beyond the problem itself, deepening their understanding and providing insights into wider context. CBL | “... they obtain different new knowledges because of the kind of discussion that they had with their team or with their stakeholder ... I assume that they gain more knowledge, certainly about the context.”<br><br>“... they have to probe into |

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| | | | | | | approach fosters interdisciplinary connections and collaborative learning, broadening students' collective knowledge through shared experiences and diverse insights. | solution, probe into getting the challenge right. They look for literature or secondary data sources, reports ... so students especially learn more. Maybe you can nuance this proposition with contextual knowledge. So what's going on surrounding the challenge and what are the possible solutions or multiple solutions combined together, which of course is very good source of knowledge creation.” |
| Co-creation | 5C | collaborate, co-create, unique solutions, application of HOTS | **63%** | 25% | 12% | The current CBL implementation exhibits that there is collaboration, however, there is an unequal | "... often stakeholders are involved only at the beginning of the course"<br><br>“... there is a lot of HOTS |

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| | | | | | | distribution of collaboration among students, teachers, and stakeholders, with stakeholders being the least involved. Students and teachers have a higher degree of collaboration in the problem-solving process. | present at these student discussions.”<br><br>“... when students collaborate with various stakeholders, they always would need to evaluate, to reflect, and develop”<br><br>“I think in CBL the whole structure and the whole process makes that this co-creation is embedded, so it's not a isolated thing.” |
| Reflection and Sharing | 6B | share reflections, communicate thoughts, application of HOTS | **63%** | 33% | 4% | The inclusion of sharing opportunities in a CBL course obliges students to engage in HOTS when sharing their thoughts with either the teacher or their peers. | "if scaffolded properly, because I often see courses where students handing reflection reports where they report what happened and that is not reflection ... so you need to assist or |

While some students excel and demonstrate intended HOTS such as analysis, evaluation and meta-cognition, others merely recount events without engaging in deep reflection, remaining at a lower level.

guide students in this reflection process"

“If it is well guided by the teacher or by the coach. We call them coach in the challenge-based learning. Yes, they are more forced to ... to articulate their ideas clearly and also different ideas and also make some pros and cons.”

“If you ask them to reflect, for example, at the end of the class, ‘what have you learned?’. They learn to think, they learn to listen to the others ... they all have their own formulation of their reflections. Hardly

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| | | | | | | | anyone is repeating what somebody else has said, so there is definitely an higher order of thinking there in communicating.” |
| Relevant Societal Problem | 1A | relevant societal problem, motivation | **58%** | 33% | 9% | Incorporating relevant societal problems into a CBL course tends to inspire student motivation, although it was observed that not all students respond equally to this approach. | "I would disagree ... Maybe there's a type of students who are interested ... But in general, I would not say that relevant societal problems would attract more students or they are more motivated to join."<br><br>“I would agree. Yes, there are of course conditions. And I would say yes, if it's relevant and societal relevant, then students might say, okay, now this makes sense.” |

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| Presence of broad ideas | 2B | motivation, exploration of different possibilities, broad idea | **58%** | 25% | 17% | Motivated students actively explore different possibilities for the given broad idea. Ne e t eless s v r h , ome students may lack self-initiated exploration and require scaffolding or guidance from their teacher. | “But I do see the tendency of better motivation when problems that are addressed are more relevant, not necessarily societal.” "It really dependent on the students. Some are very motivated. But sometimes, they are just having that blind spot s mew e i l o h re ... so it s a l again on that scaffolding of the teachers" “ ee i e ... ind d, f th re are multiple possible solutions, that helps to be motivated, because if there's only one solution then it's not really CBL, then it's mathematics. |

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| | | | | | | | Students are motivated when there is not just one solution” <br><br> “I would agree because they they are engaging with other students in the discussion.” <br><br> “They probably read more and they look for different combinations of the literature.” |
| Structured yet divergent nature | 3C | structured problem solving process, limited time-frame, exploration of the problem, application of HOTS | **54%** | 29% | 17% | The CBL course offers a helpful framework enabling students to explore the problems thoroughly and within a limited time frame. However, the CBL structure, especially if it | "If you really want to keep it challenge based, then you need a certain level of structuring ... otherwise it turns very quickly into project-based learning ... skipping the in-depth exploration" |

is implemented in an 8-week course, might prompt the students to skip the in-depth exploration phase or be stuck in it for long. This impacts their critical thinking skills.

“... giving students specific time frames like this is the end of engage phase makes sure that they have the time to really engage with their problem as much as they can until the time frame ... it does enable students to apply HOTS early on in the process, because I think if we give them too much time and no structure at all, they would maybe longer be stuck on the lower thinking levels.“

“I think in that sense, CBL is unique in the process and in the structure. But also unique in the combination,

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| | | | | | | | so that's about the process, the structure, the timing and the learning aspect.” |
| Formulation of questions | 4C | formulation of questions, before investigation, during investigation and before solution development, different perspectives of problem different perspectives of problem, gain more knowledge, application of HOTS | **54%** | 29% | 17% | The formulation of questions at multiple steps of the CBL process helped students look at the problem from different perspectives. The students tend to apply HOTS such as critical analysis, synthesis of information and make connections when questions are formulated to go beyond surface-level understanding of the problem and integrate | “Definitely through questions and throughout multiple steps. They realize that the problem is not that one sided as the initially might have thought about it ... definitely the questions and helping them in the questions brings them to approach the problem for multiple perspective, especially if your student group is multidisciplinary ... they are having a communication going on and even sharing all kinds of information and gain more knowledge.” |

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| | | | | | | knowledge from multiple disciplines. | "... Stimulating this questioning aspect which is a part of the CBL framework, really enables students to look at the problem from different perspectives and enables them to learn from each other." |
| Co-creation | 5A | collaboration, build upon ideas | **54%** | 25% | 21% | Incorporating collaborative elements into the course creates an environment where students, teachers, and stakeholders actively share and expand upon each other's ideas. This synergistic atmosphere fosters collective learning and innovation | "I think CBL gives good opportunities indeed for collaboration and for building upon each other's ideas"<br><br>"In other approaches there's a different level.<br>For example, the stakeholder is the problem owner or the teacher is the |

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| | | | | | | | teacher and not co-learner. But in CBL there are all on the same level. So everybody learns from each other. It's more open.” |
| Co-creation | 5B | build upon ideas, unique insights | **54%** | 38% | 8% | In CBL, students, teachers, and stakeholders collaborate and contribute to one a t e ea i no h r's id s, but t only sometimes leads to newer insights. Several factors influence this, such as whether the c s ece sitate our e n s s innovative solutions, the equality of collaboration, and the st e ts e e ud n ' xtrov rt d nature. | "... unique insights might be not generated ..." e t a l “ ... ev ryone on he t b e has their usually has their own unique perspective because they're their own unique individual. And if students openly share their knowledge and ideas and are also open to others, t at act all T e h 's u y good. h y also need to be open to each other's perspectives.” “ eac t e a ... h of h m h ve |

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| | | | | | | | different experience. Each of them have different perspective also within the student team ... CBL helps students and teachers and the stakeholders to learn from each other.” |
| Presence of broad ideas | 2C | broad ideas, multiple possible solutions, motivation, exploration of different possibilities, application of HOTS | **50%** | 46% | 4% | When a course introduces broad ideas with multiple potential solutions, students become motivated to explore various possibilities and are more inclined to employ HOTS. The success of implementing HOTS for students depends on the level of support and guidance provided to them. Teachers/experts | ".. I think this applies for master level students ... probably third year bachelor's students might be able to deal with that ... but they are not fully prepared in terms of HOTS before they reach masters course"<br><br>“I agree because I think in order to be able to have to develop these different solutions and different possibilities students need |

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| | | | | | | have believed that previous education systems may not have properly prepared students to apply HOTS. | to elaborate, they need to evaluate and synthesize”<br><br>“Yes, I mean the the engage phase is always also difficult.<br>Also to that, there is uncertainty. But once they find their broad idea, it definitely motivates them.” |
| Reflection and Sharing | 6A | reflection, metacognition | **50%** | 42% | 8% | Reflective exercises in a CBL course stimulate students' HOTS, such as metacognitive abilities. However, some students may encounter difficulties in reaching the appropriate level of metacognition. | "We need to assist or guide students in this reflection process. They do not get to it themselves and so when you would say 'opportunities to reflect' if it is in the form of scaffolds? Then I would agree."<br><br>“I would agree if a student are stimulated to reflect, |

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| | | | | | | | they are more aware of their own learning paths."<br><br>"I think in pretty much all of the iterations I saw that"<br><br>"I mean reflection gives them the opportunity to also be clear, be transparent in terms of what and how their thoughts came about." |
| Relevant Societal Problem | 1B | motivation, proactive application of HOTS | **38%** | 37% | 25% | The motivation of students only sometimes led to the proactive application of HOTS. Students typically require additional time to acquire and master these cognitive abilities fully. In addition, they | "... automatically they do not apply higher order thinking skills because ... we give them the authentic problem and we see that they're motivating there or enjoying it, but because they were taught in in the system, which does not really foster higher order |

also require guidance from their teachers.

thinking skills, they're used to working on the, let's say, the lower thinking skills ... so it doesn't mean that it's automatically there.”

“Applying higher order thinking skills, it requires you some time. Time for the student to understand it's not sufficient for me to go with the standard approach. ... problems which require assessing, competing interests at societal level, of course it's the highest order in terms of the evaluation, the these types of problems usually require the student to develop their thinking way into a more integrative

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| | | | | | | | fashion. That usually requires time.” |
| Structured yet divergent nature | 3B | Divergent thinking, exploration of problem in depth | 33% | **46%** | 21% | The CBL structure allows students to explore and analyze a given problem extensively. However, instances of CBL implementation have shown that students may need help initiating their work as they find all aspects equally intriguing, resulting in many unfocused ideas. Hence, support from teachers is required to provide scaffolding and maintain direction. | "it might be too difficult for the students to grasp what they are required to do ... so in general, it's important to help the students, and if you don't have those scaffolding methods in place, then it might not be effective at all and they might just get lost in the process"<br><br>“... not all students do that, even if the opportunities are there, I think some students explore the problem in depth, usually good students.”<br><br>“Just providing the |

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| | | | | | | | opportunity doesn't motivate students necessarily to explore a problem in depth ... some students actually get demotivated if there's too much open-endedness” |
| Relevant Societal Problem | 1C | relevant societal problem, motivation, and application of HOTS | 25% | **54%** | 21% | The aspect of relevant societal problems in the course tends to increase students' motivation levels. However, the proactive use of HOTS requires guidance from teachers or coaches. While students may engage in deeper thinking, attaining university-level HOTS requires support from teachers. | “... if the course addresses a societal problem relevant to the students, then the student is more motivated and then the proactive application of the whole then again depends on the scaffolding part. So they might more deeply think about things but to really achieve a university level of critical thinking that may require some guidance and assistance from teachers to |

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| | | | | | | | really take hold.” |
| | | | | | | | “Some students are not able to proactively apply HOTS and then of course, I would say it comes a little bit on me or my colleagues and supervisors. But we are also products of old school education.” |
| Presence of broad ideas | 2A | broad ideas, multiple possible solutions, motivation | 17% | **50%** | 33% | Students' exposure to a broad idea stimulated motivation, but not automatically. Students struggled with the open-endedness of the broad idea and needed the active involvement of the teacher in assuming | “I agree but ... the biggest thing is the role of the teacher here. If the role of the teacher is helping them, finding multiple solutions and that any solution they find is good ... Good coaching is crucial for students to be motivated. If the teacher is not giving |

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| the role of a coach or guide. | them directions or boundaries, then the students are lost and then they are not motivated.”<br><br>"... sometimes students might not like such an open ended problem"<br><br>“... some students are really complaining that it's too broad and then they get less motivated. So it's gives them a motivation that they can go and find their own way or their own challenge, but it can also be too broad.” |

## 6. Conclusion and Discussion

This study aimed to explore the claims regarding CBL in relation to HOTS by confronting the literature with the perceptions of reality. The study specifically focused on a Dutch university, providing valuable insights to enrich and expand the CBL theory. The main research question that this study aimed to answer was: How does CBL lead to the achievement of HOTS? In order to address this primary question, this study was guided by the formulation of three sub-questions: 1) According to existing literature, what is the theory of action of CBL to achieve HOTS in students of HE? 2) What are the perspectives of teachers and educational experts regarding the theory of action of CBL to achieve HOTS? 3) What is the difference between theory and the teacher's perspective? If there is a difference, how can it be explained? To answer these questions, a literature review was performed, and interviews were conducted with teachers and experts at a Dutch university. In this section, the findings from the literature review and interviews are discussed.

### 6.1 According to existing literature, what is the theory of action of CBL to achieve HOTS in students of HE?

To answer this question, a literature review was conducted. Details of this literature review can be found in Appendix A. Many studies indirectly analysed and discussed how HOTS are achieved through the CBL approach in HE. In summary, according to literature, CBL is claimed to have the potential to lead to HOTS in HE students. CBL aspects such as relevant societal problems (Cheung et al., 2011; Lake, 2021; Vilalta-Perdomo et al., 2022), broad ideas (Ardiansyah et al., 2021; Detoni et al., 2019), structure of CBL (Jensen et al., 2018; Lin & Chen, 2017; Santos et al., 2015; Susilawati et al., 2018), formulation of questions (Yang et al., 2018), co-creation (Christersson et al., 2022; Detoni et al., 2019), and reflection and sharing (Bombaerts et al., 2022; Van Den Beemt et al., 2023) are claimed to contribute to the development of HOTS such as analysis, evaluation and creation in students through CBL. Therefore, six sets of propositions were formed with three sub-propositions each around these aspects of CBL (section 3.3.2). These propositions were later used in this study to confront teachers and experts for their perceptions based on their experience in practice.

### 6.2 What are the perspectives of teachers and educational experts regarding the theory of action of CBL to achieve HOTS?

This study's findings indicated that most interviewees agreed with the presented propositions and found them relevant to implementing CBL at their university. Thus, the collected data provides evidence that the theory claimed about CBL in relation to HOTS is generally consistent with the perceptions of teachers and educational experts in real-world implementation. The most agreed propositions belonged to the following themes: "formulation of questions (keywords: formulation of questions, before investigation, during investigation and before solution development, different perspectives of problem)," "reflection and sharing (keywords: reflection and sharing, application of HOTS)," "structured yet divergent (keywords: structured problem solving process, limited time-frame, exploration of the problem)," and "co-creation (keywords: collaborate, co-create, unique solutions, application of HOTS)." As a result, these propositions emerged as the top five agreed-upon statements. According to the interviewees, formulating questions during the phases of CBL, including essential questions, guiding questions, and activities, served as a scaffold for students to delve into the challenge at a deeper level. A significant portion of interviewees agreed that using the CBL framework effectively stimulates HOTS, such as analysis, organization, inference, and making connections. This shared perception is consistent with the literature review on teaching analytical skills, which underscores the necessity for teachers to engage students in a multitude of activities to foster analytical skills. Moreover, the perspectives shared by the interviewees suggest that CBL effectively fulfils this requirement without requiring multiple activities or many efforts from teachers to explicitly further stimulate HOTS in students. Furthermore, teachers and experts largely agreed that reflection and sharing encouraged students to think critically and evaluate both their own learning progress and group process. For example, an interviewee stated that when reflection and sharing are integrated into the course, students become cognizant of their learning paths and showcase an increased inclination to improve their contributions within the group. This self-assessment and improvement stem from being involved in the process of reflection and sharing in multiple stages in CBL. This is in line with what Doulougeri et al. (2022) discussed in their study. In addition, the majority of interviewees, amounting to 67%, expressed agreement with the initial sub-proposition of "structured yet divergent." They supported their perceptions by mentioning that CBL effectively provides students with a framework for investigating the given challenge while also allowing them to engage in divergent thinking, where they explore the open-ended challenge, think creatively, and devise innovative solutions. This supports the analysis done by Lin and Chen (2017) in their study about training undergraduate students on innovative thinking using CBL. Finally, a majority (63%) of the interviewees agreed with the third sub-proposition of "co-creation." One notable recurring reason for their agreement was the inclusion of all three key actors, namely students, teachers, and stakeholders, who were relied upon to engage in co-creation. This finding highlights the importance of involving these parties in the co-creation process in CBL, which was also recommended by Christersson et al. (2022) in their study.

### 6.3 What is the difference between theory and the teacher's perspective? If there is a difference, how can it be explained?

Some interviewees had different opinions and did not agree with certain propositions for various reasons. Based on the findings, it is evident that the interviewees expressed minimal consensus on propositions under "co-creation (keywords: reflection, metacognition)", "structured yet divergent (keywords: Divergent thinking, exploration of problem in depth)", "relevant societal problem (keywords: relevant societal problem, motivation, and application of HOTS)", and "broad ideas (keywords: broad ideas, multiple possible solutions, motivation)", making them the top five least agreed-upon statements. Remarkably, each proposition received agreement levels below 20% from the interviewees. This indicates that there is a difference between certain theoretical aspects of CBL and the perspectives of reality. A dominant reason for disagreement emerging for many propositions appeared to be the interviewees' belief that the CBL framework might not be suitable for learners from different backgrounds and educational settings. Specifically, teachers and educational experts must consider various aspects of the learners, such as their characteristics, level of extroversion, professionalism, required scaffolding, and motivation. Therefore, it was discovered that solely implementing the CBL framework may not suffice, and additional efforts from the teacher are required in the form of scaffolding to effectively stimulate HOTS in students with varying backgrounds. The aspects of scaffolding, motivation and interaction was also mentioned as influencing factors for HOTS among HE students by Lu et al. (2021) and Aouaf et al. (2023).

In summary, this study revealed that implementing the CBL framework does not automatically result in HOTS among HE students, as claimed in the literature. The empirical patterns presented in Table 2 show how CBL fairs in practice in relation to HOTS. All empirical patterns are listed in the table, but select patterns are further discussed below. These show evidence that contradicts the assumptions of the theory, indicating the difference between theory and perceptions of reality.

**Relevant Societal Problem (keywords: motivation, proactive application of HOTS):** From the perceptions of the interviewees, it was revealed that when a relevant societal problem is addressed in the course, the motivation of students only sometimes led to the proactive application of HOTS. Certain students require additional time to acquire and master these cognitive abilities fully. In addition, it was perceived that students also require guidance from their teachers. To scaffold this aspect of CBL (relevant societal problem) and to increase the student's motivation as well as proactive application of HOTS, teachers can incorporate specific activities recommended in the literature review discussed in earlier chapters (Banning, 2008; Ganapathy et al., 2017; Kaddoura, 2013). These activities include think-pair-share or think-aloud exercises, which can serve as effective scaffolding techniques to foster motivation and the application of HOTS.

**Presence of broad ideas (keywords: broad ideas, multiple possible solutions, motivation):** According to the interviewees' perspectives, it was uncovered that students' exposure to a broad idea stimulated motivation, as claimed by the theory. However, it did not happen automatically. It was observed by the interviewees that students struggled with the open-endedness of the broad idea and needed the active involvement of the teacher in assuming the role of a coach or guide. In order to scaffold this aspect of CBL (broad ideas), teachers can make use of scaffolding techniques that help students break down the bigger problem into smaller focus such as creating mind maps or concept maps (Areesophonpichet, 2013; Hwang et al., 2012).

**Co-creation (keywords: collaborate, co-create, unique solutions, application of HOTS):** The CBL theory assumes that there will be equal collaboration from teachers, students, and stakeholders to co-create. However, in practice, it is seen that there there is an unequal distribution of collaboration among students, teachers, and stakeholders, with stakeholders being the least involved. Students and teachers have a higher degree of collaboration in the problem-solving process of CBL. This aspect of CBL can be scaffolded by setting some ground rules for collaboration, inviting the stakeholders as guest speakers (Yeh, 2012), holding regular check-ins with all the three parties, and arrange a panel discussion or Q&A session.

**Reflection and sharing (keywords: reflection and sharing, application of HOTS):** From the perceptions of the interviewees, it became evident that the CBL courses at this university implemented varying degrees of reflection and sharing. Meaning in certain courses, students engaged in reflective activities and shared their experiences either towards the end of the course or at multiple points throughout the course. Nevertheless, the theory was consistent with perceptions of practice. It was perceived that when the elements of reflection and sharing are integrated into a course, the utilization of HOTS, such as meta-cognition, critical thinking, analysis, evaluation, and synthesis becomes apparent in students. This aspect can be scaffolded by utilising a checklist or rubric to stimulate reflection. Teachers can also consider conducting a presentation round (Chou, 2011) with all the students with clear instructions to scaffold the sharing aspect. In case the class size is large, the think-pair-share activity could be used.

## 7. Implications for practice

The findings of this study have implications for teachers and educationalists in helping them make informed decisions about implementing or scaling CBL in their educational programmes. By showcasing the positive link between CBL and HOTS through the high rate of agreement from the interviews, the study encourages educators to adopt the CBL framework to empower learners and help them develop their HOTS. If teachers already use CBL in their courses, they can review the findings and evaluate their teaching methods to determine if any adjustments or additional aspects of CBL are necessary to better support students in achieving HOTS. Teachers and educational experts can utilize the findings of this study along with Imanbayeva's (2022) CBL continuum model to design their CBL courses. This approach will allow them to target specific HOTS without necessarily implementing the complete CBL framework intensively at once. Moreover, by exploring the literature review findings presented in Table 1, educators, educational experts, and researchers can devise scaffolding techniques that help students develop HOTS in both CBL settings and other learning contexts.

## 8. Limitations and Future Research

The empirical evidence gathered in this study relied upon the perceptions expressed by teachers and educational experts. These perceptions can be subjective. Thus, there is a need for further empirical testing of these propositions in future research. For instance, a study can use a quasi-experimental approach or a pretest-posttest design with two groups of students: one with CBL as intervention and the other with another similar teaching approach. At the end of the course, the analytical skills or any other HOTS of both groups can be assessed to determine the impact of CBL. Additionally, another limitation recorded from the perception of some interviewees was that the propositions lacked precise phrasing, thereby influencing their level of agreement. This aspect can be a focal point for future research by using different wording. Additionally, several interviewees expressed that they had partially incorporated CBL into their courses to align with their specific course goals. This resulted in conflicting viewpoints on multiple aspects. Therefore, future research could focus on courses that implement CBL uniformly. Finally, this study collected perceptions from teachers and educational experts from one Dutch university. Therefore, the findings cannot be generalised to other educational contexts. Therefore, future research can replicate this study in different contexts that use CBL.

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**Appendix A**

## Rapid literature review process

**Steps**

1. Developing a Focused Research Question
2. Creating inclusion and exclusion criteria
3. Formulating relevant search terms and keywords
4. Identifying relevant search databases
5. Conducting systematic research
6. Study selection through screening (check which is relevant and discard)
7. Data extraction, charting and synthesis (Code, map, appraise quality, synthesis)
8. Interpretation and reporting results (findings)

### Developing a focused research question

This research explores the existing theories around CBL and HOTs to learn about the theory of action of CBL, including the mechanisms and conditions needed to achieve HOTs. Hence, based on the aim of this study, the research question developed for this rapid literature review is: *According to existing literature, what is the theory of action of CBL to achieve HOTs in students?*

### Creating inclusion and exclusion criteria

| **Inclusion Criteria** | **Exclusion Criteria** |
|---|---|
| English | Languages other than English |
| Published between 2009-2022 (last 14 years) | Published prior to 2009 and after 2022 |
| All types of original literature that can be accessed online with their unique DOI or URL (peer-reviewed or non-peer reviewed) | Gray Literature and articles that cannot be accessed online |
| Educational context | |

| Global Sources | |
|---|---|

**Search Strategy**

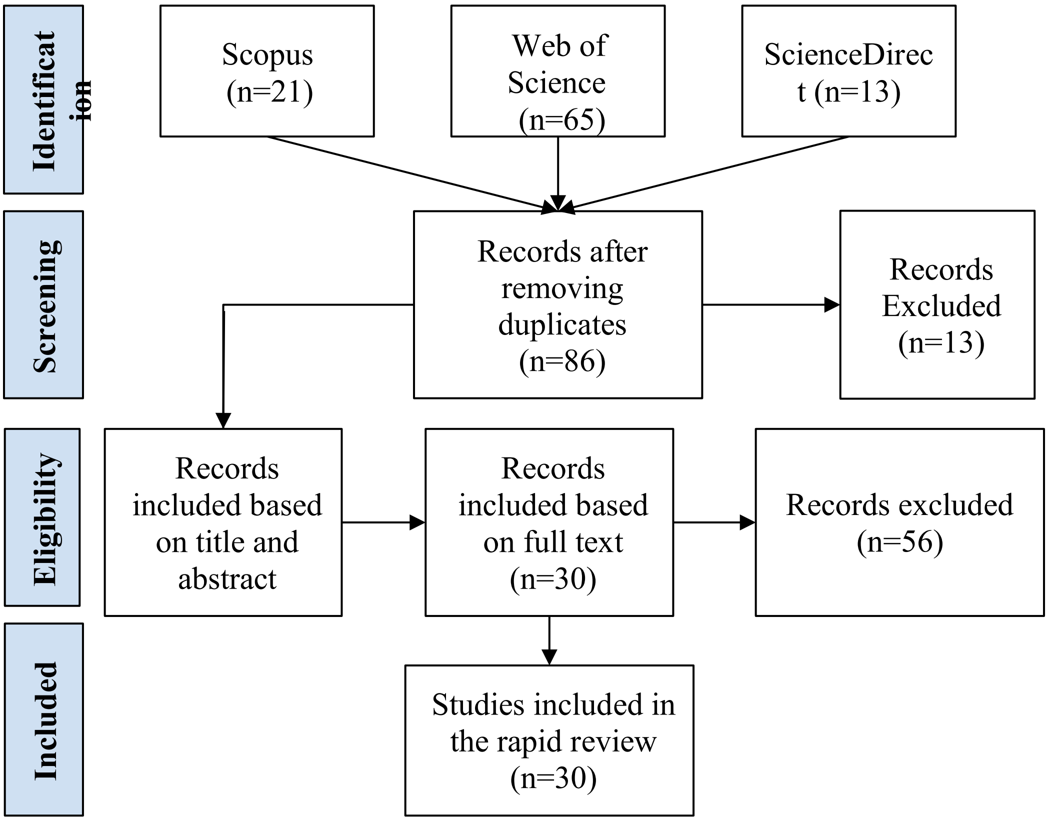
The databases used to search for relevant literature in this rapid literature review process were: Scopus, Web of Science, and Science Direct. The search was limited to the last ten years. In other words, the literature published from 2012 until 2022 were included in this search. For each part of the research question search terms or keywords were chosen:

1. Higher-order thinking skills were used as keywords (“Higher-order” AND “Thinking” AND “Skills”).
2. The acronym was also used to perform a search for relevant articles (“HOTS”). The skills considered as HOTs were added to the search for relevant literature (“Analyse” OR “Evaluate” OR “Create” OR “Analysis” OR “Analysing” AND “Skills” OR “Evaluating” AND “Skills” OR “Creating” AND “Skills” OR “Innovating” AND “Skills”)
3. Challenge-based learning as a keyword was used with and without hyphens (“Challenge-based AND “Learning, “Challenge” AND “based” AND “Learning”) along with the acronym (“CBL”). In addition, the keywords “Phases”, “Mechanism” and “Conditions” were also included in the search string. CBL was searched in the context of education where possible, with a combination of words that seemed relevant (“Challenge-based” AND “Learning” OR “Teaching” OR “Instruction” OR “Method” OR “Approach” AND “Education” OR “Higher” AND “Education”)
4. To find specific HOTS-related literature specific keywords were used such as (“Analysis” AND “Evaluation” OR “assessment” AND “Creative” OR “Innovation” OR “Critical thinking” AND “Problem-solving” AND “Decision making”)

**Conducting the Search and selecting studies through screening**

The rapid literature review was conducted across multiple electronic databases to identify relevant studies using the abovementioned search strategy. The initial search resulted in numerous potentially relevant articles, which were screened using a two-phase process to check which studies are relevant and which can be discarded. In the first phase, the titles and abstracts of the resulting literature were screened to determine their relevance to the research question and topic of CBL and HOTs. In the second phase, the entire contents of the selected literature were reviewed to assess their relevance for inclusion in the review. The two-phase screening process helped ensure that only the most relevant studies were selected for inclusion, enhancing the quality of the rapid literature review.

**Data extraction, charting and synthesis (Code, map, appraise quality, synthesis)**



**Appendix B**

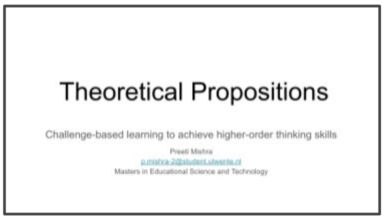
## Semi-structured qualitative interview guide

The following semi-structured interview guide was created using the framework developed by Kallio et al. (2016). The semi-structured interviews aimed to capture the perspectives of teachers and educational experts that are closely involved with CBL implementations at the university about the patterns that emerged from the theory about CBL leading to HOTs in university students.

**Main topics:** Challenge-based learning and higher-order thinking skills in higher education
**Interview Duration:** 40-45 mins
**Interview Setting:** Online (MS Teams) or Face-to-face (university Campus)
**Materials required:**

1. Laptop to do the meeting online and record the audio
2. Internet connection
3. Printed interview guide
4. Pen and paper

**Step 1: Welcome, introduction and consent (5 minutes)**

<table>
<tr><th>SLIDE</th><th>DO</th><th>SAY</th></tr>
<tr><td>
</td><td>Present the slide or handout to the participant</td><td>Hello, I have prepared a presentation of the theoretical propositions and questions for reference purposes</td></tr>
</table>

| | | |
|---|---|---|
| Theoretical Propositions<br>Challenge-based learning to achieve higher-order thinking skills<br>Preeti Mishra<br>p.mishra-2@student.utwente.nl<br>Masters in Educational Science and Technology | | *Thank you for agreeing to participate in my research about CBL leading to HOTs in HE.* |
| Consent: Audio Recording | Obtain verbal consent to record the audio | *Could you please provide your verbal consent to begin the audio recording?* |
| | | *Thank you for your consent.* |
| Consent: Audio Recording | Press the record button | *You should have received a pop-up that the audio recording and transcription has started.* |
| Informed Consent: Participation | Obtain informed consent verbally from the interviewee to participate in this research | *I would like to inform you that your responses will be used as data for this research.*<br><br>*Can you provide your verbal consent to participate in this research?* |
| Informed Consent: Participation | | *Thank you for your consent.* |
| Purpose of the Interview | Explain the purpose of the interview | *This interview aims to gain insights into your perspectives of Challenge-* |

| | | |
|---|---|---|
| | | *based learning to achieve higher-order thinking skills.* |
|  | Explain HOTS and present the pyramid of marzano | *HOTS are are skills that require individuals to analyze, evaluate, and create new ideas and concepts, rather than just recalling or memorizing information.*<br><br>*Some examples are presented on the screen.* |
| Main Interview | Inform expectations | *Several patterns emerged from literature about CBL leading to HOTs. Today you will be presented with six broad propositions and their subdivisions.*<br><br>*I will ask you about your thoughts and whether you confirm, disconfirm or partially confirm them based on your experiences here at UT.*<br><br>*In addition, this research also aims to identify the uniqueness of CBL in relation to HOTS. Hence, please share your thoughts with me and provide specific* |

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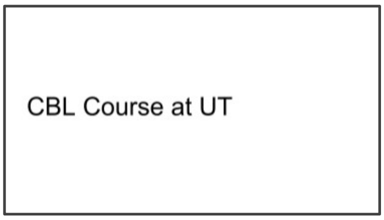
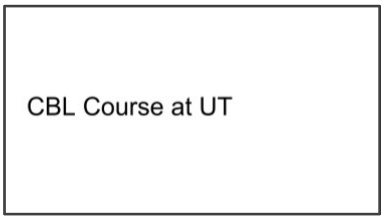
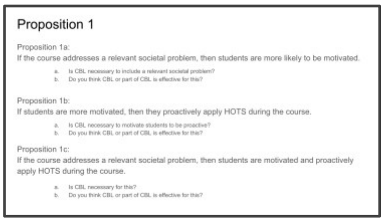
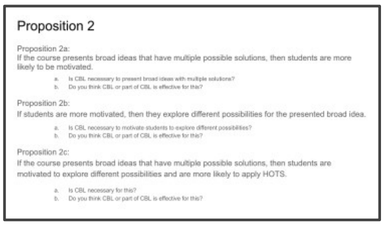
| | | *examples to support your answer.* |

**Step 2: Background and main questions (30-35 minutes)**

| SLIDE | DO | SAY |
|---|---|---|
|  | Confirm the background of the interviewee | *To confirm, you were involved as an instructor/expert in the course "course name (minor/master)" which used CBL here at the university?* |
|  | Go through each sub-proposition and discuss the questions | *Thank you for confirming* |
|  | Go through each sub-proposition and discuss the questions | *We will now look into the propositions that emerged from theory.*<br><br>*Here is the first broad proposition.*<br><br>*Proposition 1a:*<br>*If the course addresses a relevant societal problem, then students are more likely to be motivated.* |

| | | |
|---|---|---|
| | | 1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary to include a relevant societal problem, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 1b:*<br>*If students are more motivated, then they proactively apply HOTS during the course.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?* |

| | | |
|---|---|---|
| | | 3. *In your opinion, is CBL necessary to motivate students to be proactive, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 1c:*<br>*If the course addresses a relevant societal problem, then students are motivated and proactively apply HOTS during the course.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for this, or are there also other ways??* |

| | | |
|---|---|---|
| | | 4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?* |
|  | Next Slide | *Moving to the second proposition.*<br><br>*Proposition 2a:*<br>*If the course presents broad ideas that have multiple possible solutions, then students are more likely to be motivated.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary to present broad ideas with multiple solutions, or are there also other* |

| | | |
|---|---|---|
| | | *ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 2b:*<br>*If students are more motivated, then they explore different possibilities for the presented broad idea.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary to motivate students to explore different possibilities, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than* |

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| | | *other teaching approaches? Could you explain why?*<br><br>*Proposition 2c:*<br>*If the course presents broad ideas that have multiple possible solutions, then students are motivated to explore different possibilities and are more likely to apply HOTS.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for this, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?* |

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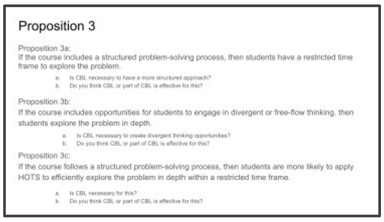
<td>
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<td>Moving to the third broad proposition.<br><br>Proposition 3a:<br>If the course includes a structured problem-solving process, then students have a restricted time frame to explore the problem.<br><br>1. What do you think of this proposition?<br>2. Do you agree with the proposition, disagree, or partly agree?<br>3. In your opinion, is CBL necessary to approach the problem in a structured way, or are there also other ways?<br>4. In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could</td>
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| | | *you explain why?*<br><br>*Proposition 3b:*<br>*If the course includes opportunities for students to engage in divergent or free-flow thinking, then students explore the problem in depth.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary to create divergent thinking opportunities, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?* |

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| | | *Proposition 3c:*<br>*If the course follows a structured problem-solving process, then students are more likely to apply HOTS to efficiently explore the problem in depth within a restricted time frame.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for this, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?* |

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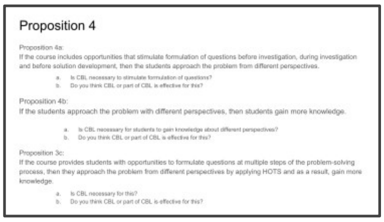

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Here is the fourth proposition.<br><br>
Proposition 4a:<br>
If the course includes opportunities that stimulate formulation of questions before investigation, during investigation and before solution development, then the students approach the problem from different perspectives.<br><br>
1. What do you think of this proposition?<br>
2. Do you agree with the proposition, disagree, or partly agree?<br>
3. In your opinion, is CBL necessary to stimulate formulation of questions, or are there also other ways?<br>
4. In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?
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| | | *Proposition 4b:*<br>*If the students approach the problem with different perspectives, then students gain more knowledge.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for students to gain knowledge about different perspectives, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 4c:* |

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| | | *If the course provides students with opportunities to formulate questions at multiple steps of the problem-solving process, then they approach the problem from different perspectives by applying HOTS and as a result, gain more knowledge.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for this, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?* |

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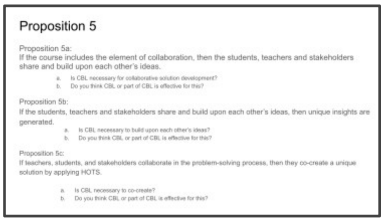
|  | Next Slide | *Proposition 5a:*<br>*If the course includes the element of collaboration, then the students, teachers and stakeholders share and build upon each other's ideas.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for collaborative solution development, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 5b:*<br>*If the students, teachers and* |

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| | | *stakeholders share and build upon each other's ideas, then unique insights are generated.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary to build upon each other's ideas, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 5c:*<br>*If teachers, students, and stakeholders collaborate in the problem-solving process, then they co-create a unique solution by applying HOTS.* |

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<td>1. What do you think of this proposition?<br>2. Do you agree with the proposition, disagree, or partly agree?<br>3. In your opinion, is CBL necessary to co-create, or are there also other ways?<br>4. In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?</td>
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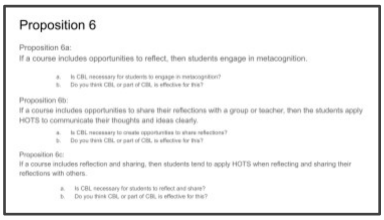
<td>
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<td>Proposition 6a:<br>If a course includes opportunities to reflect, then students engage in metacognition.<br><br>1. What do you think of this proposition?<br>2. Do you agree with the proposition,</td>
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| | | *disagree, or partly agree?*<br>3. *In your opinion, is CBL necessary for students to engage in metacognition, or are there also other ways?*<br>4. *In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 6b:*<br>*If a course includes opportunities to share their reflections with a group or teacher, then the students apply HOTS to communicate their thoughts and ideas clearly.*<br><br>1. *What do you think of this proposition?*<br>2. *Do you agree with the proposition, disagree, or partly agree?* |

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| | | *3. In your opinion, is CBL necessary to create opportunities to share reflections, or are there also other ways?*<br>*4. In general, do you think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?*<br><br>*Proposition 6c:*<br>*If a course includes reflection and sharing, then students tend to apply HOTS when reflecting and sharing their reflections with others.*<br><br>*1. What do you think of this proposition?*<br>*2. Do you agree with the proposition, disagree, or partly agree?*<br>*3. Is CBL necessary for students to reflect and share, or are there other ways?*<br>*4. In general, do you* |

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| | | *think that (these parts of) CBL is more effective than other teaching approaches? Could you explain why?* |

**Step 3: Probing Questions (If required)**

1. In case the interviewee provides a short or unclear response, probing questions will be used. The interviewee will be asked to clarify, expand or rephrase their responses.
    a. Examples of questions:
        i. Can you provide an example to illustrate your point?
        ii. Can you clarify what you mean by term/phrase?

**Step 4: Closing (5 minutes)**

| SLIDE | DO | SAY |
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| Additional Questions? | Next Slide | *Do you have anything else to add about the subject of CBL and HOTS that wasn't covered in my propositions?* |
| Closing | | *Thank you for your perspectives and responses. Your time and participation are appreciated.* |

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| | | *This interview will be anonymised and transcribed. Once the collected data is ready, I will share it with you via email for member checking to ensure accuracy in the first week of June. You can respond to the email in case you observe any inaccuracies. Your participation in this member-checking process is entirely voluntary, and if you choose to participate, your feedback will be invaluable in ensuring the accuracy and credibility of the findings.* |
| Closing | Stop the audio recording and transcription | |