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CHALLENGE-BASED LEARNING IN COURSES: THE IMPLEMENTATION CONTINUUM (PRACTICE)

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ABSTRACT

Given the increasing criticality and complexity of societal challenges, higher education institutions are urged to equip students with the ability to develop sustainable solutions for 'wicked' problems. Consequently, the Challenge-based Learning (CBL) framework has attracted considerable interest in higher engineering education. However, transforming existing course curricula to CBL is a challenging endeavour since it requires careful and paced execution for maintaining the quality, synergy, and flow of existing education. Therefore, this paper proposes a perspective on CBL implementation that exemplifies a gradual transition towards educational CBL innovation while reflecting on the alignment, consistency, and coherence educators aspire to when designing courses. Accordingly, we introduce a CBL implementation continuum as a conceptual model, which connects CBL elements to Van den Akker's Spider Web for curriculum design and describes a continuum of Mild, Moderate, and

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Intense CBL levels per Spider Web component. Moreover, the paper describes an online CBL implementation tool, which helps educators thoughtfully evaluate the current level of CBL in their courses and provides practical recommendations for a transition towards higher levels of CBL intensity.

1 INTRODUCTION

In this ever-changing world, humanity is confronted with inherently intricate, critical, and ever-evolving problems. Consider, for example, the issues of climate change, energy transition, pandemics, and social injustice. These so-called “wicked” problems require innovative approaches and competencies that transcend current methods of problem-solving. Consequently, higher education institutions are urged to equip students with the ability to develop sustainable solutions for wicked problems, in addition to teaching academic knowledge and soft skills.

As a result, Challenge-based Learning (CBL) has attracted substantial interest in higher education. In CBL, students, as well as teachers, field experts, and community members collaborate to actively address wicked problems relevant to their environment while acquiring deep content knowledge and advanced soft skills (Apple Inc. 2011; Nichols et al. 2016; Rodríguez-Chueca et al. 2019).

Key CBL elements are widely described in practical handbooks and scientific literature. This literature often outlines flexible learning paths, inter-/trans-disciplinarity, real-world impact, 21st-century skills, self-directed and inquiry-based learning, flexible teacher roles, stakeholder involvement, and flexible assessment as elements of CBL (Apple Inc. 2011; Nichols et al. 2016; Gallagher and Savage 2020).

Designing education, especially while embracing these CBL elements, is a wicked problem in itself. Practice shows that the transition to CBL can be difficult and requires careful execution since the rushed application of CBL in a course (re-)design can disrupt the balance of (ongoing) education.

To support teachers and educational designers in moving from established practices in higher education to the creation of fully realised CBL courses, we propose a conceptual model, the CBL Implementation Continuum, that exemplifies a gradual transition towards educational CBL innovation while reflecting on the alignment, consistency, and coherence that educators aspire to when designing courses. To create this model, first, we connected CBL elements to Van den Akker’s Curricular Spider Web components (Van den Akker 2003), reflecting the alignment, consistency, and coherence desired in a curriculum. Then, we developed a continuum of varying CBL intensity, defining Mild, Moderate, and Intense CBL levels per component of the Spider Web. In addition, we introduce an online tool that supports the implementation of CBL in course design based on the Implementation Continuum.

2 CONNECTING CBL ELEMENTS TO THE SPIDER WEB COMPONENTS

To connect CBL elements to Van den Akker's Spider Web, we started by summarising key CBL characteristics found in the relevant literature and identifying how these align with each Spider Web component. Next, to grasp how CBL implementation can vary

in course designs, we examined the implementation of CBL at the University of Twente through three cases: a bachelor-level minor (C1), a master-level extracurricular module (C2), and a master-level curricular course (C3).

As a result, we propose a Mild-Moderate-Intense Continuum per Spider Web component. At the Mild level, we guide incorporating CBL essentials into existing educational structures. The Moderate CBL level builds on this, introducing more CBL elements into the curriculum and adding depth to the CBL experience. At the Intense level, we describe a full-scale implementation of CBL, where all elements are fully integrated into the course design.

The formation of the continuum definitions of the components of *learning rationale*, *grouping*, and *assessment* are illustrated as an exemplar within this article, reflecting the underlying reasoning behind the model.

2.1 CBL Learning Rationale

In Van den Akker's Spider Web framework, the *learning rationale* describes why students learn in a curriculum. In CBL, students learn to interact and have an impact on the real world (Apple Inc. 2011; Nichols et al. 2016). They are presented with a big idea, a wicked societal problem, which needs to be broad enough for students to define and choose actionable challenges that require a solution design (Apple Inc. 2011; Nichols et al. 2016).

To incorporate CBL into their course, teachers can start by introducing a big idea that encompasses a wicked societal problem. The big idea should empower students to define their own actionable challenges and design solutions while engaging with real-world communities and stakeholders. In the meantime, real-world impact within a curriculum can manifest in various ways. In Mild CBL courses, student impact is limited to providing recommendations for a challenge solution, while the implementation and evaluation of the solutions are left to others. In such a way, Mild CBL courses allow students to have a passive impact on the real world.

To elevate the implementation of CBL to a Moderate level, teachers can guide students in prototyping solutions and fostering a more active impact on the real world. Additionally, the literature emphasises the value of guiding students to personally connect with the big idea, as it increases the perceived sense of meaning (Apple Inc. 2011; Nichols et al. 2016). Thus, in Moderate CBL courses, teachers scaffold students in defining challenges that have personal relevance to them.

Lastly, a full-scale CBL experience empowers students to leverage their learning process for societal contribution and witness their influence on real-world communities. As a result, students are required to design and implement solutions that have an immediate impact on the chosen challenge and evaluate the effects of their solutions in real life (Apple Inc. 2011; Nichols et al. 2016).

In summary, the Mild CBL level, within the learning rationale, is characterised by interaction with the real world, passive impact, broad big ideas, wicked problems, actionable challenges of personal choice, and solution designs. The Moderate CBL

level introduces the characteristics of active impact on the real world and challenges of profound personal relevance. Lastly, Intense CBL courses, in addition to the Mild and Moderate level descriptions, provide students with opportunities to have an immediate impact on the real world. See Figure 1 for a visual overview.

Applying these CBL levels to the learning rationale of the aforementioned cases, C2 and C3 were categorised as Mild CBL, while C1 was Moderate CBL. In both C2 and C3, students chose actionable challenges from a broad big idea presented by field stakeholders, but the big idea was confined to a specific case, limiting personal exploration. The solution design resulted in an advice report, creating a passive impact. Conversely, C1 offered a pool of big ideas for students to select from, facilitating the choice of a personally relevant challenge. C1 also enabled students to design prototype solutions and evaluate their effectiveness with primary stakeholders, creating a more active impact. If teachers of C1 would want to promote their CBL implementation to the Intense CBL level, they would scaffold the students in applying their solution designs in real-world settings and evaluate their effectiveness with a broader range of stakeholders.

2.2 CBL Grouping

The Spider Web's *grouping* component depicts with whom students are learning. When applied to CBL, literature accentuates the significance of fostering inter- or trans-disciplinary collaboration within a group for a deeper understanding of the big idea (Observatory of Educational Innovation 2015; Nichols et al. 2016; Gallagher and Savage 2020; Dieck-Assad et al. 2021). Consequently, Mild CBL level courses can start by enabling students of the same discipline to work together while looking at the challenge from diverse perspectives to ensure a rich and critical exchange of ideas.

To take CBL a step further, teachers can facilitate forming groups of students from various disciplines to foster a multidisciplinary perspective on the challenge (Nichols et al. 2016; Gallagher and Savage 2020; Dieck-Assad et al. 2021).

Finally, Intense CBL groups consist of students, *and* coaches (i.e., teachers), *and* stakeholders. In such a way, coaches and stakeholders enrich their team's understanding of the big idea and the real-world context while students provide original perspectives on the addressed topics. Ultimately, the group members become active co-learners, co-researchers, and co-designers (Baloian et al. 2006; Nichols et al. 2016; Chanin et al. 2018).

Accordingly, regarding the grouping component, Mild CBL courses enable students within the same discipline to collaborate and explore the chosen challenge from diverse perspectives. Moderate CBL courses encourage the formation of groups with students from various disciplines to foster a multidisciplinary perspective. The Intense CBL level requires forming groups of students, coaches, and stakeholders who actively collaborate as co-learners, co-researchers, and co-designers.

The three analysed cases were characterised by different levels of CBL on the grouping component. C3 had a Mild level of CBL, with students from the same discipline encouraged to collaborate interdisciplinarily. The students were expected to

explore their challenges from diverse perspectives and leverage their personal experiences during the investigation. C2 was considered to have a Moderate-to-Intense level of CBL, as students formed multidisciplinary groups and were required to collaborate transdisciplinary, with occasional participation from primary stakeholders and teachers during team reflections. C1 had an Intense level of CBL, with multidisciplinary groups and active participation from the team coach and primary stakeholders throughout the process.

2.3 CBL Assessment

In CBL, assessment focuses on the learning process rather than the final product (Nichols et al. 2016). Mild CBL level courses can start by assessing both the learning process and the challenge solution. The assessment of the learning process can be restricted to an overall reflection on the progress made throughout the CBL experience. As for the learning product, CBL assessment usually draws attention to the feasibility of the solution design (Apple Inc. 2011; Nichols et al. 2016; Yang et al. 2018; Gallagher and Savage, 2020). Hence, similarly to the common assessment of projects, teachers and/or stakeholders of Mild CBL courses define assessment criteria focusing on utilising course content into solution designs and their feasibility.

Moderate CBL courses build on this by emphasising creativity and innovativeness of the solution design within the assessment criteria (Yang et al. 2018; Gallagher and Savage, 2020). Moreover, Moderate CBL courses incorporate critical reflections on the successes and failures of the learning process, as these are valuable for a CBL experience (Apple Inc. 2011; Nichols et al. 2016; Yang et al. 2018). Lastly, the literature introduces the role of a student as a co-assessor of the learning process (Nichols et al. 2016; Cruger 2017). Therefore, Moderate CBL courses allow student contribution to the assessment. Practically, it often manifests in students critically evaluating their progress.

Intense CBL courses take the evaluation of the learning process to the next level. Students and teachers become co-assessors of the learning process, choosing the assessment procedures and criteria (Nichols et al. 2016; Cruger 2017). They define the assessment criteria, which usually includes the assessment of students' achievement of personal learning objectives, decision-making, reflection on the successes and failures of the learning process as well as reflection on the solution design's creativity, innovation, and feasibility (Nichols et al. 2016; Yang et al. 2018).

Thus, Mild CBL courses assess both the learning process and the challenge solution, focusing on the effective utilisation of course content and solution feasibility. Moderate CBL courses incorporate creativity, innovation, and critical reflections on the learning process, allowing student contribution to the assessment. Intense CBL courses involve students and teachers as co-assessors, defining assessment criteria that encompass personal learning objectives, decision-making, reflection on the learning process, and evaluation of the solution design's creativity, innovation, and feasibility.

Accordingly, C2 was aligned with the Mild CBL level descriptors. C2 teachers evaluated both the learning product and the process, focusing on how students applied

their knowledge and skills to their solution designs, the feasibility of the solution, and their overall reflection on the learning experience. C3 had a Mild-to-Moderate level of CBL, guiding students to reflect on process successes and failures as part of the assessment. C1 had Moderate CBL level elements, assessing the creativity and innovativeness of students' solution designs and prioritising reflections on the learning process. Assessment criteria in C1 focused on students' ability to justify their choices, evaluate their progress, and critically reflect on process successes and failures. Bringing the curricular design to the Intense CBL level in C1 would involve students defining the assessment procedures and criteria alongside teachers and stakeholders.

2.4 CBL Implementation Continuum

Accordingly, Figure 1 presents the CBL Implementation Continuum in full:

Fig. 1. The CBL Implementation Continuum

3 FACILITATING CBL IMPLEMENTATION WITH AN ONLINE TOOL

An online interactive tool has been developed to guide teachers in using the CBL Implementation Continuum when (re-)designing courses. The tool combines the continuum with an evidence-based database of practical advice on how to transition to higher levels of CBL intensity. The advice database was collected from CBL practices and experiences at the University of Twente and knowledge on CBL implementation available in the literature. The tool first asks users to indicate the

current CBL level of their course and the desired one for each curricular component. Based on the users' input, the tool visually presents the gap between current and desired levels of CBL in the form of a spider web. Then, based on the presented gap, the tool compiles an advice report on how the users can bridge the gap between the current and the desired levels of CBL intensity. The tool is also designed to gather user feedback for regularly updating and continuously improving the offered advice and the level descriptors.

4 CONCLUSIONS AND FURTHER WORK

The CBL Implementation Continuum offers a practical approach for integrating CBL into higher education and suggests that courses can gradually evolve towards CBL innovation. Such a perspective can foster an increase in CBL acceptance in higher education. It prompts teachers to capitalise on what they are already doing in their courses and add new CBL elements to their curriculum step by step.

Notably, we present the CBL Implementation Continuum as a heuristic prototype. Intense CBL level descriptors were derived from literature, which details elements common to CBL, while Moderate and Mild level descriptors were heuristically deduced from CBL practice at the University of Twente. Moreover, the presented model does not consider the CBL-compass of Van den Beemt et al. (2023), as their work was published after the continuums were defined. Thus, we endorse further developments of the model and the level descriptors as new knowledge on CBL emerges.

In addition, as Van den Akker (2006) noted, while the emphasis of curriculum design on specific Spider Web components may vary, alignment is crucial for maintaining coherence. Teachers using the CBL Implementation Continuum should be aware that strengthening the intensity of one component while neglecting another could jeopardise constructive alignment. As such, they should remain mindful of this risk and adjust their approach as needed.

The CBL Implementation Continuum invites new research endeavours, which can considerably contribute to the scientific understanding of the educational approach. For instance, the model and the tool can be used in research on CBL to operationalise and measure the levels of CBL implementation. Furthermore, investigations could explore the impact of varying levels of CBL intensity on students' learning and skill development. Additionally, empirical recommendations on the most appropriate intensity levels for a course could be explored based on factors such as classroom size, course boundary conditions, and long-term curricula goals.

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