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the Netherlands

Proceedings – Full Papers

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(Editors)

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Editorial

Shaping the Future Through Challenge-Based Learning

Education holds the transformative power to shape not just individual lives, but the future of our societies and our planet. In an era defined by complex, interconnected global challenges, **Challenge-Based Learning (CBL)** has proven to be a powerful approach—one that equips students to connect knowledge with action and become engaged, capable problem-solvers.

On **April 7–8, 2025**, **Eindhoven University of Technology** hosted an inspiring international gathering of **educators, researchers, industry leaders, and changemakers**. Over the course of two days, we came together to explore how learning through challenges can drive meaningful educational transformation and contribute to a better world.

Through keynote presentations, hands-on workshops, case studies, and collaborative dialogue, participants shared ideas, questioned assumptions, and pushed the boundaries of what education can achieve. The conference highlighted the richness of global perspectives and the collective commitment to shaping education that is innovative, inclusive, and impact-driven.

Over the course of the event, participants engaged in a dynamic forum centered on integrating educational innovation and research. The program featured plenary sessions on timely themes such as Challenge-Based Learning in the Era of AI and Building a CBL Ecosystem; 38 paper presentations showcasing diverse academic and practical insights; 18 hands-on workshops encouraging active participation; 5 "Test Your Challenge" sessions providing a collaborative platform for participants to validate, refine, and improve their challenges through feedback and interaction with a diverse audience; and 9 poster pitches offering opportunities to share innovative ideas and ongoing research.

This collective experience was more than just a conference — it was a catalyst for action. We leave with new questions, fresh ideas, and stronger connections, ready to continue shaping the future of education.

To all who contributed, participated, and supported this event—thank you. Together, we have taken a step toward reimagining education as a force for global change.

Eindhoven, The Netherlands, 9th of April 2025

Sonia M. Gomez Puente

Eugenio Bravo-Córdova

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STUDENT-BUSINESS SUSTAINABILITY CHALLENGES – AN ALTERNATION TO CBL PEDAGOGY

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ABSTRACT

Global trends of digitalization and globalization, together with the need to mitigate sustainability challenges such as climate change, resource depletion, and loss of biodiversity, have led to significant changes in industries and education. This emphasizes the increasing importance of sustainability in higher education and the role of experiential learning in addressing societal challenges.

One way to achieve this is by incorporating real-life problems (challenges) into the curriculum, thereby enhancing students' understanding and skills. This study investigates how teachers achieve this by using external challenge providers in "Student-Business Sustainability Challenges" (SBSC), a variant of Challenge-Based Learning (CBL) where external stakeholders, such as companies, identify and present challenges to students. Furthermore, it examines to what extent this influences the pedagogical approach of CBL.

Based on semi-structured interviews with teachers involved in CBL and SBSC courses across Europe, we reveal that the involvement of external challenge providers significantly shapes the challenges and enhances the learning experience. This underscores the importance of collaboration between educational institutions and external challenge providers in preparing students to tackle sustainability challenges effectively. The paper concludes that SBSC is a valuable pedagogical approach that combines the strengths of CBL and entrepreneurial education. It recommends further research to quantitatively assess the prevalence and impact of SBSC and to explore its benefits and potential drawbacks.

1 INTRODUCTION

1.1 Background and research aim

The trends of digitalization and globalization have led to both great advancements as well as great disturbances of balances in industries. Many educated people go to work today, using technologies which were not even on the market when they got their education, while competing with people all around the globe. At the same time, the world has been stage to both a global pandemic and environmental and social challenges. To answer to the fast-changing world and to build a more sustainable society, different approaches have been developed to tackle challenges and take advantage of opportunities. One example is EU's mission-oriented research and innovation. The Sustainable Development Goals (SDGs) from UN is another example of setting a desired course for research, entrepreneurship, and development.

In the light of societal sustainability challenges, higher education needs to combine societal context and theoretical courses and subjects for students to develop understanding and skillsets for their coming work-life. One popular way of doing this is Experiential Learning Pedagogics which includes real-life problems in the curricula, where students apply theory to practical cases (Lackéus, 2020). Several educational approaches have been developed to serve this purpose including Entrepreneurial Education, Problem Based Learning, Project Based Learning, Challenge-driven Education, and Challenge-Based Learning (CBL). During the past decade, CBL has establish itself as a pedagogical approach which develop skills as critical thinking and problem-solving and at the same time has shown a high student engagement due to the focus on ownership of learning (Perna et al., 2023).

Parallel to this development, companies have interacted with students in institutes of higher education (HEIs) to develop both their own capabilities as well as inspiring and forming students to become their future workforce. One way is "Student-business challenges", a form of Entrepreneurial Education, which have been around in various forms since the 1980s, when large consulting firms in USA started using case-based competitions to find talented students (Kubr et al., 2013). As society faces growing sustainability challenges, the focus of student-business challenges is shifting to sustainable solutions. To equip students with understanding of societal problems and needs, the mixing of entrepreneurial education and societal challenges has proven to both generate new, innovative solutions and development of students' knowledge and skills.

In an ongoing research project, Challenge4Impact1, we have encountered several HEIs offering courses and modules which use sustainability-oriented challenges generated by external challenge providers, but in the framing of a more classic "Student-business challenge" – i.e. that the challenge provider has narrowed down challenges from a Big Question, and presents these challenges for students to solve (cf. Membrillo-Hernández et al., 2019). The procedure stands out from the regular CBL practice (cf. Norrman et al., 2022) and has yet not been investigated in literature (Gallagher & Savage, 2020; Perna et al., 2023).

Our aim with this paper is to investigate how teachers use external challenge providers in versions of CBL pedagogics, and to what extent it influences the pedagogical approach of CBL.

The paper is structured as follows: First we give a brief introduction to the relevant pedagogic approaches for this paper, including CBL, after which we present the method for approaching this exploratory paper. In the following chapters 3 and 4 we present our findings and propose a new addition to the pedagogical theory with implications both for practice and further research.

1.2 Pedagogical approaches and the role of the external partner

Experiential education is often compared with other pedagogical approaches, like Problem-based learning, Project-based learning, and Service learning, as well as with formats in courses, like Open-ended Group Projects, Serious Games, and Cased-Based Learning. The major difference between Experiential education and all the above is that the learning environment is not on forehand decided, and that there is no single right answer (Lackéus, 2020). Teachers do not know either what is a feasible solution, or the "right" solution, but acts more like guides and mentors to students which must interact with the world outside academic institutions to find answers.

A recent scientific literature review on entrepreneurial learning and education, Shabbir et al. (2022) concludes that Experiential Entrepreneurial Education has its roots in entrepreneurship education, but during the past decades the pedagogy has evolved. The pedagogics in Entrepreneurial Education has moved from learning *about* entrepreneurship to learning

[1] www.challenge4impact.eu

through entrepreneurship, i.e., through experience and "doing". It has also, foremost in EU, moved from *business* creation to *value* creation, which also has changed the roles of external collaborative partners.

Challenge Based Learning was originally conceived by Apple, Inc. in 2008 as a learning framework to foster individuals who can address the large challenges in society (Gallagher & Savage, 2020). Focusing on value creating for external stakeholders, as well as on the experiential learning cycle, it creates a solid framework for teachers and staff who wants to develop courses, modules, and programs in the direction of more Experiential Entrepreneurial learning, focusing on society's great challenges (Nichols et al., 2016).

Private companies as well as public organizations are common partners in advanced courses in higher education, providing real-life interaction. External stakeholders or problem owners can be a part in both PBL, cased-based learning, OEGP, and other pedagogical settings (Lackéus, 2020). In CBL external stakeholders play a significant part both as provider of a Big Idea and in interaction with students to refine their ideas (Perna et al., 2023).

Nichols et al. (2016) defines CBL in three phases: Engage, Investigate and Act. In the Engage phase, the societal need is analyzed and a Big Idea in formed, from which several corresponding challenges are formulated. Possible solutions for challenges are then developed and tested in the Investigate phase. Finally, students realize their solutions in the Act phase, to deploy and learn from the target market. In all these phases, interaction with external stakeholders is of essence. External stakeholders give feedback, are used for testing prototypes, validating the students' thoughts and ideas, and finally acting as a receiving party of the solution.

In certain CBL setups, the challenge provider is an external party, delivering a Big Question to the students and acting as mentor if needed (Norrman et al., 2022). In other settings, the challenge provider is more present and serves the student teams in a closer relation (Membrillo-Hernández et al., 2019).

2 METHOD

In this explorative study we sought to understand a certain pedagogical approach, and the application of this pedagogy in practice. As we wanted to broaden our perspective we searched for teachers and courses in CBL, both on the internet and through our contacts with the European Consortium of Innovative Universities and other partners. We discovered that not all courses and modules which seemingly were interested to us used the terminology of CBL, but rather used the student-business challenge terminology. We added these connections to explore the possible differences. As more detailed information on courses are hard to find on the internet, we chose to conduct an interview study with teachers.

This paper adapts a modified version of design research methodology based on Peffers et al. (2007). First, we developed a guide for semi-structured interviews using the recommendations of Kallio et al. (2016) from the theoretical basis of the CBL procedure and pedagogy. Transcripts from the first round of interviews were then analysed by the two authors of this paper and the framework of CBL was modified to suit the practice of the interviewees. This modified framework was then discussed and further modified in the larger group of teachers in the Challenge4Impact project, before the second round of interviews. In the first round, we interviewed only teachers which had expressed experience of CBL. In the second round, we also included teachers which did not expressly work in the CBL framework. See Table 1 for the interviews conducted in both rounds

Table 1. *First round of interviewees.*

Round	Interviewee - position	Country	Experience of CBL
1	Manager of external relations, contact for companies and municipalities to CBL courses	Italy	5+ years
1	Teacher assistant, operational responsibility for external stakeholders and coaches in a CBL course	Sweden	4 years
1	Responsible teacher for CBL course	Lithuania	5+ years
1	Program director, engaged in several CBL courses and modules	The Netherlands	5+ years
1	Head of Entrepreneurial campus	Germany	5+ years
1	Teacher, CBL courses	Germany	1 year
1	Freelance educator in entrepreneurship, former teacher in CBL courses	The Netherlands	5+ years
2	Teacher, challenge-driven course in environmental innovations	Sweden	None
2	Teacher, CBL course	Sweden	5+ years
2	Teacher, case-driven course in environmental innovations	Sweden	None
2	Teacher, social and environmental entrepreneurship (developing ideas)	Sweden	None

All interviews were conducted via Zoom or Teams, recorded with the permission of the interviewee, and transcribed using MS Word (the sanctioned software of Linköping University).

3 RESULTS AND DISCUSSION

From the analysis of our interviews, we see that the practice of CBL is not always aligned with the theoretical framework of the pedagogy of a full CBL procedure presented by Nichols et al. (2016). The external stakeholder, company or organization (from here-on named the "Challenge provider") takes a more prominent role in the shaping of a challenge for the students and is the recipient of the results. The Challenge provider thus acts as an opportunity identifier. Opportunity identifiers, investigated by Shepherd and DeTienne (2005) can through prior knowledge of market and customers identify not only business opportunities (which the authors mainly focused on) but also business and development opportunities for sustainability innovations.

Now we will digest our findings in all three phases of CBL: Engage, Investigate, and Act.

In the Engage phase, the Challenge provider, with active support from the teacher, formulates the challenge and builds an understanding of the challenge, from the identified opportunity either in its operations or in its markets. The Challenge provider seeks to explore this opportunity with "fresh eyes" – hence the collaboration with education.

As the Challenge provider concretizes and formulates the identified opportunity, teachers use their experience to enrichen the challenge and deepen the understanding together with the Challenge provider. The task is then formulated to suit the students and the educational setting, ensuring the students are equipped to answer to the task. The desired scope and breadth depend on the course prerequisites. Finally, the challenge is presented to students who start their process in understanding the challenge.

Now starts the Investigate phase, in which students deepen their understanding of the challenge, build up their understanding of the customer and its needs. Solutions are iteratively developed between market needs and possible solutions, as students create business artifacts to test with potential stakeholders. These stakeholders can be both the Challenge provider and other stakeholders.

The Act phase is often limited to a presentation of the work in the end of the course. Depending on the course, this presentation can be in form of a business case or a business plan, supported by a mock-up, prototype or sometimes a desktop example of a Minimal Viable Product (MVP).

During this process, teachers act as both coaches and knowledge providers for students, as well as managing the contact with the Challenge provider, as described in Eldebo et al. (2022).

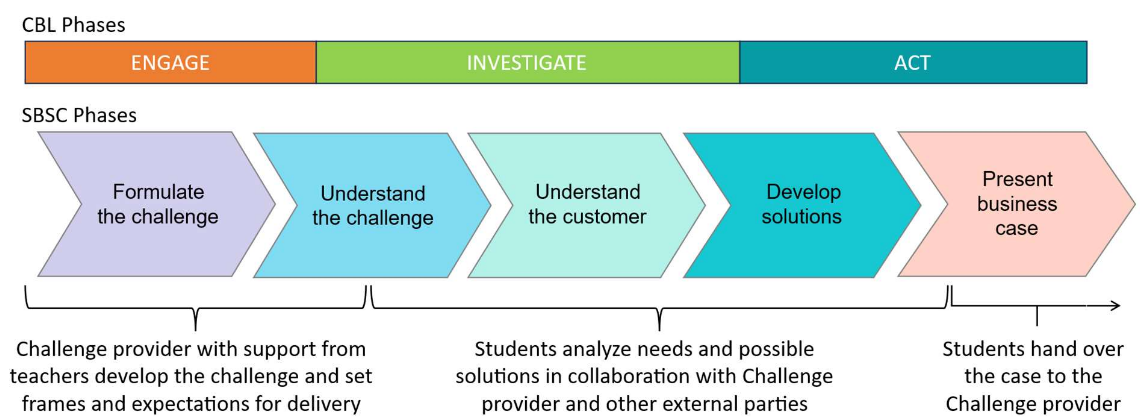

Fig. 1. Visualization of Phases of Student-Business Sustainability Challenges (own design).

The developed version of hybrid CBL, including the involvement from Challenge providers and teachers is visualised in Figure 1.

This phenomenon which we have investigated does not have a unifying name. Some teachers use the CBL terminology, and others use entrepreneurship-inspired terminology for their courses and modules. We therefore suggest the use of "Student-Business Sustainability Challenges", or SBCS, to capture the duality of this version of hybrid CBL.

4 CONCLUSIONS

By investigating the role of external Challenge providers in CBL through several interviews with practicing teachers, we have distinguished an alternation of the full-CBL pedagogy: The Student-Business Sustainability Challenge, SBSC.

This version of CBL uses the pedagogy and phases of CBL (Engage, Investigate, Act) but Challenge providers act as opportunity identifier. The Challenge provider identifies a challenge and formulates it, supported by teachers. Students then adapt the challenge and investigates it with support by the teacher, the Challenge provider, and other external stakeholders, through the phases of the CBL pedagogy.

This alternation of CBL embraces the entrepreneurial education pedagogy and incorporates it in CBL, by focusing on producing innovative solutions for sustainability challenges.

As this paper is limited by its explorative and qualitative nature, we suggest that further research should be conducted in a more quantitative manner, to explore if the phenomena of SBSC is prominent or only a small alternation. We also would suggest a deeper pedagogical analysis of the SBSC to understand the benefits and possible hurdles and negative effects of using a Challenge provider as opportunity identifier.

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REFLECTIONS ON ITERATIONS TOWARDS A CBL METHOD IN DATA SCIENCE & AI PROGRAM FOR PROFESSIONALS (PRACTICE)

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ABSTRACT

In this practice paper, we present our findings of applying problem-based learning (PBL) in the Data Science and AI (DS & AI) professional education programme by EASI Academy at Eindhoven University of Technology (TU/e) in The Netherlands. The program aims at upskilling and reskilling professionals, and has been operational since 2017. Taking a narrative approach, key milestones in the curriculum's evolution are highlighted, culminating in its current format, which integrates PBL principles throughout all stages of learning and phases of the implementation of the Data Science & AI education program for professionals. By retrospectively evaluating this progression using an adaptation of the Challenge-Based Learning (CBL) framework proposed by Van Beemt, et al. (2022), the critical challenges encountered in the program are addressed, including i) managing the diverse backgrounds and skill levels of participants; ii) accommodating the limited time participants can dedicate to their studies; iii) ensuring the correct understanding of machine learning concepts; and iv) supporting personalized learning paths. Building on these insights, we reflect on how the shift from PBL to CBL could further enhance the curriculum's ability to meet these challenges. CBL, with its focus on real-world, interdisciplinary challenges, offers a more flexible and innovative approach to upskilling data science professionals, fostering creativity, adaptability, and deeper problem-solving skills. We conclude our contribution with a critical reflection on how PBL's theoretical foundations can inform the transition to CBL. Directions for future research that explore the impact of this shift in professional education programs and curriculum for data science and AI.

1 INTRODUCTION

In today's rapidly evolving digital landscape, the demand for professionals skilled in data science and artificial intelligence (AI) is growing exponentially. As industries increasingly rely on data-driven decision-making and AI-powered innovations, the need for continuous reskilling and upskilling of professionals has become a critical priority. Lifelong learning is not only an essential strategy for personal and professional growth but also a crucial driver for maintaining competitiveness in the digital economy. The accelerated pace of technological advancements necessitates a shift from traditional learning models to more dynamic, adaptable approaches that can keep pace with the changing demands of the workforce (Shirani, 2019). Despite the demand for reskilled personnel to face current technological advancements, many organizations have neither the specific career pathways nor training capacity or the new knowledge needed to upgrade the industry employees and graduates (Illanes et al. 2018). Therefore, universities and research institutions become an attractive source for up-to-date innovation to bridge the gap between the so-called "Skills Economy" to train individual skills and teams needs in breakthrough knowledge and competences, and organizational goals.

Incorporating experiential learning methods into lifelong learning program not only benefits individual professionals but also enhances organizational agility. Companies that promote continuous learning through experiential frameworks can effectively adapt to technological disruptions, innovate faster, and maintain a competitive edge. However, traditional models of education and professional development, such as problem-based learning, may no longer suffice in preparing professionals to tackle the complex, real-world challenges that data science and AI present. The integration of Problem-Based Learning (PBL) and Challenge-Based Learning (CBL) into upskilling and reskilling programs for data science and AI professionals addresses the need for flexible, dynamic learning methods in today's fast-paced technological landscape. These methods not only enhance technical capabilities but also foster the critical thinking, creativity, and adaptability required to thrive in an ever-evolving digital world.

To address this gap, we consider a transition from PBL to CBL as a more effective approach to upskill data science professionals. Challenge-based learning shifts the focus from solving predefined problems to engaging learners in real-world challenges that require innovative, interdisciplinary solutions. In this study we analyze the Data Science & AI education program for professionals on how challenge-based learning can be applied to better equip data science professionals with the skills needed for success in a rapidly changing technological environment.

1.1 Theoretical background

In the context of rapid technological advancements and the increasing demand for data science and artificial intelligence (AI) expertise, traditional education models often struggle to equip professionals with the dynamic skills needed for these evolving fields. Experiential learning methods, such as PBL and CBL, have emerged as effective frameworks for upskilling and reskilling professionals in industries requiring advanced data science and AI competencies. These methods emphasize active learning, critical thinking, and real-world problem-solving, which are crucial for navigating complex, data-driven environments.

PBL is an experiential learning approach that originated in medical education but has since been applied across various disciplines, including engineering, business, and computer science. In PBL, learners are presented with real-world problems that lack clear solutions, requiring them to engage in self-directed learning, collaborative problem-solving, and critical analysis. The core elements of PBL involve small group discussions, guided inquiry, and the application of theoretical knowledge to practical scenarios. PBL shifts the role of the instructor from that of a knowledge provider to a facilitator, guiding learners as they develop problem-solving skills, research abilities, and interdisciplinary thinking.

PBL is particularly suited for data science and AI professionals because it mirrors the complexities they face in their work. Problems in data science are often ill-defined, requiring a blend of technical skills, domain knowledge, and the ability to synthesize information from various sources. By engaging with such problems in a structured learning environment, professionals can develop the adaptive thinking and problem-solving capabilities necessary to excel in AI and data science roles.

While PBL focuses on problem-solving, CBL extends this framework by introducing real-world challenges that are open-ended and aligned with broader societal or organizational needs. Developed as an educational framework by Apple in 2008, CBL emphasizes the development of solutions to global, regional, or industry-specific challenges, often involving interdisciplinary teams working together.

Indeed, quite a few studies have investigated the efficacy of PBL for teaching data science and machine learning, either in the context of secondary school (Essinger and Rosen 2011), or within a higher education setting, i.e. a polytechnic or university (Chen, Kolmos and Du 2020). At the same time, the PBL has also been studied for a long time in a professional education setting (Perusso and Baaken 2020). Despite its heritage of case-based teaching in health science and business administration there has until recently been little focus on using PBL for teaching skills such as programming and statistics.

CBL is highly applicable to the upskilling and reskilling of data science and AI professionals, as it provides a framework for addressing the complex, systemic challenges these fields are increasingly tasked with solving, such as automating business processes, improving decision-making through predictive analytics, or developing ethical AI systems. The focus on collaboration, creativity, and critical thinking inherent in CBL helps professionals develop not only technical skills but also leadership and teamwork abilities that are crucial in today's data-driven industries.

As Data Science (DS) and Artificial Intelligence (AI), particularly machine learning (ML), continue to shape industries, professionals from diverse fields are increasingly expected to apply these technologies to their areas of expertise. However, many participants and professionals in various domains face challenges in grasping the potential and limitations of ML, hindering their ability to reason effectively about how these techniques can be applied to their work. This paper discusses the root causes of this knowledge gap and proposes strategies to enhance educational methods, e.g. CBL, that foster understanding. By equipping domain experts with the necessary conceptual and technical skills, we can foster more informed and innovative applications of ML across different fields.

2 REFLECTIONS ON CURRICULUM ITERATIONS: TOWARDS A CBL METHOD

2.1 The inception and first redesign of the data science & AI open programme

The "Mastering Data Science & AI" open program (henceforth: the programme) saw its inception in 2017 at Jheronimus Academy of Data Science (JADS) in 's-Hertogenbosch, the Netherlands. JADS was one of the first to offer data science courses at graduate level and post-graduate professional education in the country and was founded especially to this purpose by Eindhoven University of Technology, Tilburg University, the city of 's-Hertogenbosch and the province of North Brabant. As the field of data science was still in its early days, the curriculum was setup pragmatically, where participants had a large say in the subjects and topics to be included in the program. Two courses were offered: an 8-month industry-specific program, and a generic Data Expert Program (DEP) of 12 months. Both courses included PBL elements: the industry-specific programme included a group assignment, while the DEP program included an individual project at the employer of the participant.

In 2020, a major redesign of the programme took place, where the two initial courses were restructured into three modules namely i) an Introduction track of 2 months; ii) and Intermediate track of 8 months; and iii) an Advanced track of 14 months. An important consideration for this change at the time was to accommodate freedom of choice for participants, for whom it was often too large a hurdle to commit to a long and costly programme right from the start. While the modules are intended to be taken sequentially (participants need to have completed the Introduction track before they are allowed to start to the Intermediate track), it became possible to have a break in between the modules, gain some working experience, and return in, say, a year to continue the next track.

The curriculum was redesigned to provide a more structured and foundational approach to data science & AI, covering a combination of:

a) Statistics, focusing on developing skills how to learning to develop predictive models that are based on correlations in labelled, observational data using train-test split and cross-validation (Jordan and Mitchell 2015);
b) Computer science, where participants acquire knowledge how to design and implement the data analytics function within their organization, covering topics such as data engineering, data management; and also acquire practical skills to work with data and perform the modelling, either through coding (Python, R, SQL) or using a workbench with a graphical user-interface (Knime).
c) Application of these analytical problem-solving skills in a business context within their specific domain of expertise, with a strong focus on real-world applications using a structured development model such as CRISP-DM. Adjacent business-oriented skills related to problem formulation and business case, presentation skills, leading data science projects are offered within the programme.

The use of PBL was extended to each of the modules. In the Introduction track, participants are coached to complete at least one Kaggle competition dataset, for which a selection of past competition challenges is offered through a GitHub repository. In selecting these challenges, we evaluated the pedagogic merits of each dataset and ensured a variety of machine learning problems (regression, classification, outlier detection) is available. Detailed examples, background reading materials including peer-reviewed journal papers that have use the dataset, are also offered in conjunction with the dataset itself. The Introduction module is offered in two versions: in the 'expert' version, participants are coached to learn Python as the main programming language, and the Kaggle challenges are solved in Jupyter notebooks. In the 'business manager' version, participants use Knime, being one of the most widely used open-source graphical machine learning applications. The PBL approach in this track is similar to that described by Chow (2019), the main difference being that in our case participants worked on problems individually (rather than in teams) and we did not apply any gamification.

PBL in the Intermediate track is framed as a group project, where participants work on a real-world dataset in a business simulation setting. Each group is assigned a case owner, whose main task is to define the problem that needs to be solved. The business simulation runs for the whole duration of the Intermediate track, parallel to weekly lectures and electives half-day or one-day courses. Examples of cases are prediction of outcomes of hip- and knee replacements surgery based on UK NHS national dataset, predicting sales for an Ecuadorian supermarket chain with over 200,000 different product-store combinations, and a more open-ended challenge addressing the energy transition using data from one of the Dutch electricity network providers.

PBL in the Advanced track is conducted through a real-world project where participants conduct their capstone project at the company they are currently employed. This third PBL project is aimed integrating and applying the knowledge and skills from the two previous tracks. A strong emphasis is put creating business value through defining and solving data-analytic problems, as has been described in more detail elsewhere (de Mast and Lokkerbol 2024).

2.2 The second redesing: flipping the classroom

The first redesigned programme ran from 2020 until 2023. Figure 1 gives an idea of the number of participants per cohort (left) and the evaluation of each cohort (right). Inflow of participants has been consistent, with the majority of participants opting to take the Introduction and the Intermediate course. Per year, between 8 to 12 participants enrolled in the Advanced track, being the most intensive track. The drop in enrolments in 2023 is attributed to the post-pandemic effect, where companies were more hesitant to financially support employees for such an intensive training program. Evaluations based on participant feedback, with an overall score of around 8-points on a 10-point scale. Note that due to the delay in completing the curriculum, the most recent evaluations for the Intermediate and Advanced track are missing for 2023 and 2024 onwards.

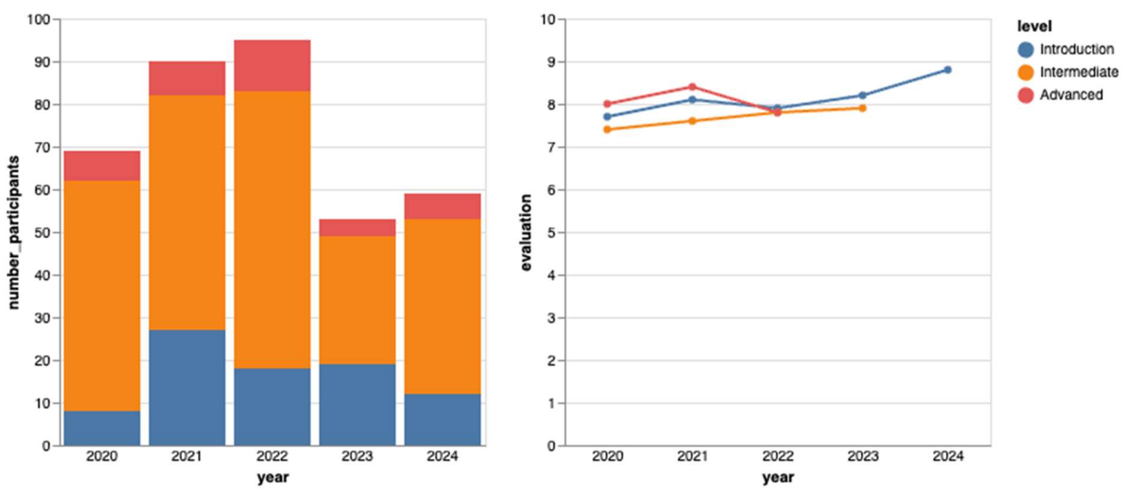

Figure 1: number of participants in the program per year

By 2023, the programme had run for six years. While the results had been satisfactory, a number of observations led to the second major redesign of the program. First, the program continued to attract participants from very diverse backgrounds. For example, a cohort would have diverse range from people with a strong grounding in statistics (STEM, econometrics, epidemiology) to those who never got past high school maths. Similarly, roughly one third of participants had ample experience with SQL, whilst the other two-thirds needed to be taught the basics of SQL and relational modelling.

Second, participants indicated they were continuously under time pressure. The program was designed such that participants should nominally be able to complete it with one day on campus lectures, plus one day self-study. Given that for most participants many of subjects were new, and that PBL-related work also took up a considerable amount of time to do the practical work (data cleansing, modelling), this would in practice take up much more time. Thirdly, and related to these two points, lecturers found themselves challenged to ensure that participants obtained a good understanding of the foundations of machine learning. For example, participants often had misconceptions how the principles of train-test split and cross-validation for prediction relate to conventional statistical learning techniques involving hypotheses testing for inference.

Finally, there was a need to improve the program to support different personalized learning paths. Most importantly, the program needed to cater for a more non-technical learning path, popularly coined 'the Analytics Translator', and a more technical 'Expert' path where participants go more in depth on programming and data engineering in Python.

To address these challenges, a new online learning environment introduced with the aim to support a more blended form of learning and flip the classroom. The online learning environment was realized using the Cradeq platform which has proven effective for task- and problem-based learning in a healthcare setting. The platform includes small, online quizzes to self-assess content regarding misconceptions, and support for rich and interactive visualizations to provide graphical explanations to key concepts. By introducting this online platform, flip-the-classroom methods were applied with the purpose to have participants learn the theoretical insights outside the classroom, provide lecturers more time in class to focus on knowledge integration, discussion etc. rather than information transfer, and work on cases in collaboration with other professionals during the contact hours. We observe extremely high involvement with the online learning environment, where 98% of participants complete the online homework. These paths allow professionals to focus on relevant concepts, learn at their own pace, and apply ML techniques to their domain in meaningful ways. By making ML education more accessible and aligned with individual goals, personalized learning can empower professionals to integrate AI-driven solutions into their work and stay ahead in an evolving technological landscape.

Based on these iterations, and following research results on CBL impact on learners, a new phase is open now to explore the role of CBL in the Data Science & AI professional program.

3 METHODS

In order to evaluate possible future re-designs of the program, a comparative study was conducted to learn to what extent does the CBL dimensions could be introduced in the program. Therefore, the CBL conceptual framework (van Den Beemt et al, 2022, see Figure 2) was used to visualize the potential gains. Educational concepts underscore a complex set of educational principles that support the organization and implementation in both formal and informal settings and practices (i.e. three levels of vision, teaching and learning, and support).

In view of the CBL impact on learners (Farizi et al, 2023), the PBL approach is critically assessed against the CBL dimensions with the purpose of reflecting and identifying opportunities to adjust them towards a more CBL perspective.

Fig. 2. Dimensions of Challenge-based learning

Table 1. *Comparison CBL elements of the vision and DS &AI cases*

CBL Vision	**PBL cases used in the program**
Real-life, open-ended challenges	Represent real-life situations as they are taken from authentic professional environments.
Global themes	Not open-ended. Cases have defined learning outcomes although several solutions can be suggested.
Involvement of stakeholders	Themes are related to Data Science and AI, participants are explicitly coached to apply machine learning techniques in addressing the problem at hand.
	Increasing involvement of stakeholders as participants progress in the three tracks. In the Intermediate track, a case owner acts as the main stakeholder in a business simulation setting. In the Advance track, participants engage stakeholders in their company whilst conducting a real-world project.

Table 2. *Comparison CBL dimensions and DS &AI cases*

CBL dimensions	**Data Science & AI PBL cases Role participant**	**Role teacher/mentor in Data Science & AI program**
T-shaped professional	Define as precisely as possible learning goals, both easy and difficult to measure including knowledge acquisition and application, transversal skills, (social) attitudes.	Guiding participants throughout the cases and problem solving
Self-directed learning	Participants are professionals and are responsible for own learning path	Coach students in making their learning goals explicit

Collaborative learning	Open mindset in class and group work, attention to different levels of expertise and background. Go through cycles of ups-and-downs, iterations.	Assure base-level is attainable for everyone Offer enough extra content and challenges for students wanting
Teaching 'just-in-time'	Responsible for own work and progress ("minder schools")	Teachers should act as coaches and strive for balance between openness and scaffolding.
Assessment Formative vs. summative Product & process Individual & group	Individual and group assessments Content and process assessments	Providing feedback Facilitate group peer review

4 RESULTS

Results of the comparative study of the Data Science & AI education program for professionals against CBL dimensions shows differences between the two approaches. At a glance, the Data Science & AI study program does not include challenges addressing global themes. In addition, the cases are not open-ended and the involvement of real-world stakeholders is only present in the Advanced track. Regarding the assessment, the program emphasizes personalized learning both in individual as well as in group assignments, while reflection on the learning process itself is supported through group peer interaction sessions.

Finally, the case Energy Transition offered in the Intermediate Track is CBL by nature. It provides space for teams to use any data available and to come up with a 'solution'. The set-up of energy transition can be taken as a 'good practice' to redesign the DS&AI cases when more CBL type of projects are required.

5 CONCLUSIONS

The reflections from this study open up opportunities to consider making fundamental changes in the Data Science & AI education program for professionals. First of all, companies demand from employees to technical expertise to meet nowadays challenges in the context of reskilling and upskilling data science and AI professionals from companies. Although, both PBL and CBL offer unique advantages, PBL is ideal for deepening technical expertise and fostering an analytical mindset, as it challenges learners to engage with complex problems that require robust theoretical and practical knowledge. CBL, on the other hand, fosters not only acquisition and application of knowledge, but it provides also innovation and adaptability by encouraging learners to tackle broader challenges with real-world relevance. This dual focus is particularly important in AI and data science, where professionals must not only be proficient in technical skills but also capable of applying those skills to solve complex, interdisciplinary challenges that often extend beyond purely technical domains. By adapting and integrating CBL elements into the Data Science & AI professional programs, participants will benefit from a better preparation to handle the dynamic nature of the AI and data science fields.

Despite the insights of this study, there are interesting venues to further investigate. The emphasis on personalized learning paths that serve to differentiate between categories of professionals and levels, must be further explored. Also, the role of the coach in training senior professionals to meet the needs of experience workforce becomes a priority to investigate. Finally, and ddespite the CBL advantages, teaching professionals these hard skills is a core element of the DS&AI curriculum. Therefore, it will be interesting to investigate whether the CBL open-ended character of the cases would be a suitable approach to teach hard skills.

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USING KNOWLEDGE CLIPS TO SCAFFOLD THE CBL LEARNING PROCESS & SKILLS DEVELOPMENT

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ABSTRACT

In preparing students for their future careers, Challenge-Based Learning has often been named as an educational approach in which students can find and develop their own strengths and interests in the context of real-life wicked problems. In order for students to be able to do this, the development of Higher Order Thinking Skills and transversal competences is required. So, how can scaffolding the development of such skills be facilitated in a way that the students' personal learning needs can be satisfied at any given time, without losing too much efficiency?

At the University of Twente, we are currently exploring the usage of knowledge clips and related learning activities as ad hoc scaffolds for students in any given Challenge-Based course, thereby efficiently providing the students' personal learning needs. Seven different knowledge clips have been created, whose themes are based on both scientific research and practical experience. The clips and related learning activities will be implemented across the academic year 2024-2025 in Challenge-Based social science courses across the Faculty of Behavioural, Management & Social Sciences, with evaluation to follow. By creating and implementing knowledge clips, the aim is to provide flexible scaffolding of the development of Higher Order Thinking Skills and transversal competences in the context of Challenge-Based Learning. So far, the project has been received with much enthusiasm from teachers, students and educational support staff alike.

1 INTRODUCTION

1.1 Scaffolding skills development in Challenge-Based Learning

Universities use educational approaches like Challenge-Based Learning (CBL) to prepare their students to become wicked problem solvers in the context of rapid technological advancement and an ever-changing labour market (Klaassen et al, 2021). Based on experiential learning theories, CBL aims to provide an environment in which students can learn new knowledge and skills by actively working on a wide variety of real-world wicked problems within their education. In this, CBL aims to provide personalised learning paths so that students can learn in a way that suits them and allows them to work towards becoming the kind of professional they would like to be.

Comprehending real-world wicked problems and shaping your own path within them requires the development of Higher Order Thinking Skills (HOTS) and transversal competences. The development of such skills within a CBL environment requires scaffolding. However, if students have different perspectives and personalized learning is preferred, how can we facilitate this without efficiency loss in our education and educational development?

1.2 Taking the students' perspectives

In providing personalized scaffolding of a learning process, the perspective of the student must be taken into account. Different students have different agendas, different learning styles and different preferences. So preferably the scaffold can be used by students at any given time and as many times as they want, regardless of the availability of a teacher. Digital learning tools, such as knowledge clips, can provide in these needs (Meijer, 2023).

There are several ways in which knowledge clips can be set-up. For instance, one could record a teacher giving a lecture supported by slides or tell a character driven story. The latter was chosen. Character driven storytelling has positive effects on student engagement, motivation, and leads to peer discussions in which connections are made to past experiences and prior knowledge (Meijer & Rutters, 2023).

1.3 Blending Challenge-Based Learning

Introducing knowledge clips to a Challenge-Based course in order to scaffold the learning process of the practical application of skills in real-life wicked issues is effectively turning said course Blended. This means that the face-to-face and digital components in the course need to strengthen each other.

In Blended education, face-to-face and digital components are merged in one educational unit in a way that they strengthen each other. This is fundamentally different from Hybrid education, in which a part of a student group follows an educational unit face-to-face, while another part of the student group follows the educational unit digitally.

Merely providing a set of knowledge clips may not be enough to properly scaffold the learning process. After all, gaining knowledge from a clip is different from applying said knowledge. Hence, the content of the knowledge clips should be connected to the face-to-face activities in a course. In the context of CBL, knowledge clips could for instance be connected through Socratic coaching or by providing in-course workshops.

In its implementation, the knowledge clips and related learning activities will both add and replace scaffolds in the existing courses. This makes the implementation of the knowledge clips and related learning activities in line with medium-impact blending (Alammary et al, 2014).

2 METHODS

2.1 Developing knowledge clips

Currently, seven knowledge clips have been developed:

- What is a Challenge
- How to formulate a Challenge
- The Socratic Method
- Reflection: Introspection through Retrospection
- Reflection: Outrospection through Extrospection
- Perspectives: Multi-, Inter- & Transdisciplinarity
- Perspectives: Stakeholder Management

The topics of these knowledge clips are partially based on research and partially based on experiences from practice. Imanbayeva et al (2023) state that some level of multi-, inter- or transdisciplinarity and stakeholder involvement are required for a course to be Challenge-Based, as well as some level of freedom for students to define their own challenge. Educational practice shows that students struggle to define a challenge, especially when asked to integrate different (disciplinary) perspectives and not include a direction towards a possible solution.

Reflection is of paramount importance in Challenge-Based Learning (Klaassen et al, 2021). Without properly reflecting on one's learning process, a student cannot learn from the experiences gained within the context of their Challenge-Based education. As Challenge-Based courses usually have a strong group component, both introspection and outrospection should be scaffolded.

In addition to these knowledge clips, some 'default' workshops will be developed which can be flexibly adapted to the context of the courses in which they are applied. Furthermore, scaffolds will be developed for teachers in case it makes more sense to connect the knowledge clips to Socratic coaching instead.

2.2 Implementing the knowledge clips

The knowledge clips will be implemented in existing Challenge-Based courses on Bachelor and Master level in social science curricula with mixed student populations at the Faculty of Behavioural, Management & Social Sciences of the University of Twente. The manner in which the knowledge clips are implemented is flexibilised, so the implementation can be 'tweaked' towards the context of the course. This means that, for instance, not all courses necessarily use all knowledge clips or the degree to which the knowledge clips are to be connected to the Socratic coaching may vary, depending on what is most logical in the context of said course. The same counts for the aforementioned workshops. It may be that in one course the knowledge clips are to be aligned with the Socratic coaching whereas in the other course the knowledge clips are supported by built-in workshops. Another course may make use of a mix of both. The first round of implementation is taking place in the academic year of 2024-2025.

3 RESULTS

3.1 Evaluations & reflections

The knowledge clips as well as the manner in which they have been implemented in Challenge-Based social science courses, will be evaluated on the extent to which the implementation of the knowledge clips across Challenge-Based courses does in fact support the scaffolding of the CBL learning process, the development of Higher Order Thinking Skills and the advancement of transversal competences. Furthermore, as it is aimed to provide personalised learning, both students and teachers will be asked if this type of scaffold is in line with both their learning and teaching preferences. In total, three criteria will be used:

- Added value to scaffolding the CBL learning process, the development of Higher Order Thinking Skills and the advancement of transversal competences;
- Test if the seven knowledge clips' themes sufficiently cover the students' needs for scaffolding, or if additional themes need to be covered;
- Extent to which the usage of knowledge clips is in line with students' learning preference and the teachers' teaching preference;

These criteria will be measured both quantitatively and qualitatively. For instance, by looking at the amount of views and the number of unique viewers, by conducting surveys and reflective face-to-face meetings with students as well as teachers.

As the knowledge clips may be implemented in different ways across different courses, possible differences in the outcomes of the evaluation will be looked at and analysed. Subsequently, conclusions will be drawn for the future use of knowledge clips and related learning activities to scaffold Challenge-Based Learning processes. This includes the possible development of new clips to facilitate more learning needs or the redevelopment of existing clips on the basis of student and teacher feedback.

3.2 Insights gained so far

Insights into CBL-related skills were obtained through the development of the knowledge clips. Knowledge clips have a maximum length of 5 minutes. Due to this, one has to very concretely make their point in order for it to make sense to viewers. This has led to the further concretization of the insights from practice as discussed in paragraph 2.1.

4 CONCLUSIONS

It is currently too early to draw definitive conclusion with regards to the degree in which knowledge clips are of added value to the scaffolding students' learning processes and skills development in the context of Challenge-Based education. The implementation of the project is taking place at this very moment. There is, however, a high level of enthusiasm among teachers, students and educational support staff regarding the implementation of this innovation in existing Challenge-Based education.

The development of knowledge clips is an insightful exercise for teachers as well as educational support staff to reflect from their perspective on the concrete need for scaffolding in a Challenge-Based Learning process. This is due to the short length of knowledge clips, forcing those who make them to get to the essence of what they wish to say. Due to this, the creation of the knowledge clips already adds value to the further development and implementation of Challenge-Based education.

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THE TUTOR CBL WEB: SUPPORTING TUTORS IN MAINTAINING OPEN-ENDEDNESS IN CHALLENGE-BASED LEARNING PROJECTS

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ABSTRACT

Safeguarding student autonomy in large scale challenge-based learning (CBL) projects presents significant challenges, such as ensuring consistency amongst tutors in guiding the student groups. To aid tutors in consistently maintaining the open-endedness in CBL projects we have developed an instructional tool used in tutor training – the Tutor CBL Web. The key design characteristics of this visual tool are 1) the characterization of different CBL aspects following the principles of constructive alignment and 2) the association of different tutoring approaches with different levels of open-endedness per aspect. To gain insight into the effectiveness of the Tutor CBL Web, interviews were conducted with students, tutors and teachers of projects in which it was used. Overall, the tool is experienced to contribute positively to maintaining open-endedness, with recommendations concentrating on further improvement of the tutor instructions.

1 INTRODUCTION

1.1 Context and Theoretical Background

Challenge-based learning (CBL) is an integral part of the educational vision of the Eindhoven University of Technology (TU/e, 2018). At the department of Mechanical Engineering (ME), the application of the CBL concept is most prominent in the project education in the Bachelor of Science (B.Sc.) program, where it is used to further improve the long-standing project education. Throughout the ME B.Sc. program, students typically take part in at least 7 projects of 5 ECTS (140 hours per project), which surmounts to approximately 20 percent of the program. This significant weight assigned to CBL-based project education makes it of the utmost importance that the concept is optimally implemented.

The projects in the ME B.Sc. program aim to help students to get acquainted with theoretical knowledge from courses in a practical setting. An example of this synergy between courses and projects are the "Introduction to Transport Phenomena" course (1^{st} year, 3^{rd} quarter) and the "Energy Storage and Transport" project (1^{st} year, 4^{th} quarter). Students learn about concepts such as heat transfer and fluid flow in the course and then get the opportunity to apply these concepts in the project the following quarter.

Projects at the department of ME are large scale educational components. Currently, between 300 and 400 students participate in the mandatory projects in the first year of the B.Sc. program. In the later years of the B.Sc. program, 200-300 students participate in the mandatory projects and typically over 100 students participate in the elective projects. The scale at which project education is applied requires continuous consideration of scalability. In general, project components that scale with the number of students require careful capacity management. The most prominent example of this is the individual assessment procedure. To attain scalability, tutors – being ME Master of Science (M.Sc.) students – play a prominent role in the execution of this part of the assessment procedure.

Prior to the curriculum-wide implementation of CBL, potential scalability issues were studied in the context of, amongst others, an educational innovation pilot for the "Energy Storage and Transport" project in 2020 (Verhoosel & Bergkamp, 2021). A key outcome of this study was that – on account of the increased open-endedness associated with the CBL implementation of this project – the tutors experienced increased difficulties with the coaching of their groups. In particular, tutors were often risk-averse in their coaching, thereby impeding the intended open-endedness. The current generation of tutors is more familiar with the CBL concept than the tutor group in this scalability pilot due to the tutor training being gradually tailored to CBL and due to these tutors having experience with CBL projects as students. However, coaching in the CBL context still poses significant challenges for the tutors, which forms a stimulus for developing an instrument that supports tutors in maintaining open-endedness in CBL projects.

We refer to the tutor-support instrument that we have developed as the "Tutor CBL Web" (Fig. 1). For this instrument we have drawn inspiration from the CBL compass developed by Van den Beemt (Van den Beemt, Van de Watering & Bots, 2022). By identifying aspects of CBL-projects, our compass can aid tutors in understanding the ways in which they can act/intervene in guiding CBL groups without compromising the desired open-endedness of the project. Thereby, it has the potential to tailor the tutor coaching style to different projects and components thereof. To effectively use this concept of tailoring the coaching to the specific CBL needs, the Tutor CBL Web differs from the CBL compass in two major ways. First, the number of different aspects as used in the CBL compass is reduced and the terminology is made more practical. This is done to promote the usability of the instrument for M.Sc. level tutors. Second, the numerical scoring system of the CBL compass is replaced by a categorization of coaching styles. This allows the tutors to directly correlate a certain aspect of CBL with the desired coaching style from the perspective of course design. With this practice paper we want to share our insights regarding the Tutor CBL Web as a visual tool to instruct and support tutors. These insights pertain to both the development and implementation of the tool in the B.Sc. curriculum, and to the experienced effectiveness of the tool by the tutors and the students.

This practice paper is organized as follows: In Section 2 (Methods) we introduce the Tutor CBL Web, where we explain the rationale behind the choices of the various aspect axes and the different tutor coaching styles. In Section 3 (Results) we discuss the effectiveness of the tool based on interviews conducted with tutors and students. This discussion focuses on how the tutors perceive the tool regarding aspects such as: their impression of the visual tool and the instruction provided; its contribution to improving their understanding of their roles and responsibilities as a tutor; their overall readiness to become a tutor; and deciding when it is necessary to intervene. Finally, in Section 4 (Conclusions) we discuss the lessons learned from the implementation of the CBL Tutor Web, including experienced strengths and weaknesses.

2 METHODS

The developed Tutor CBL Web is shown in Fig.1, where the "Energy Storage and Transport" project is considered as an example. The web visualization is designed as a practical tool for tutors, offering guidance on when and what kind of actions they can take. In general, we expect tutors to act as a supporting coach, and only be directive when this is needed. The Tutor CBL Web aims to support tutors in assessing whether a more directive coaching style suites a particular situation. With this, we aim to safeguard that when a CBL course is meant to allow students to have more freedom in their learning experience, tutors do not take this away by being too directive in their guidance.

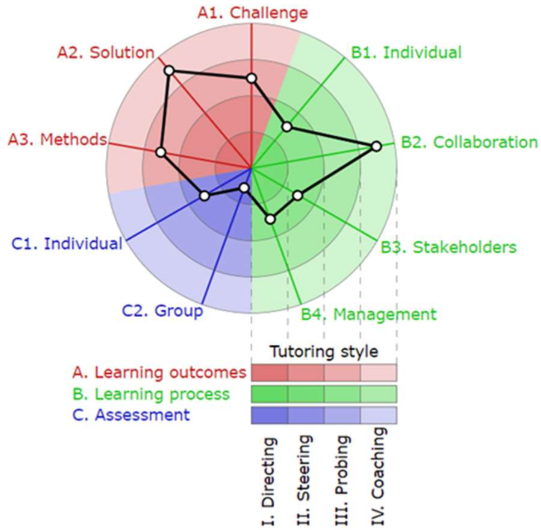

Fig. 1. Example of the Tutor CBL Web. The three segments (red, green and blue) represent elements in constructive alignment. Each axis (A1…C2) represents a distinctive aspect of a CBL project. The desired open-endedness and corresponding tutoring style are mapped by the white dots and black lines. More directive tutoring styles (less open-ended aspects) are closer to the center of the web.

2.1 Overview of the Tutor CBL Web

The Tutor CBL Web categorizes different aspects of CBL in terms of constructive alignment (colours in Fig. 1), with the intention to show tutors where they play a role in these elements of the course design. For instance, within "Learning outcomes", we delve into CBL aspects such as the challenge, solution and methods, *i.e.*, the overall content and skills that students are expected to have mastered by the end of the course. For each of these aspects (spokes A1.C2 in Fig. 1), we aim to visualize how open-ended the course design is; or in other words, "how much freedom do students get?" and consequently "how directive can tutors be?". We visualize this in four levels (the rings of the web), ranging from least to most open-ended or least to most freedom. We instruct tutors that for less open-ended aspects, they should expect to intervene more actively. However, when dealing with more open-ended aspects, tutors are encouraged to adopt a coaching approach, allowing students to take the lead.

In the remainder of this section, we detail the two main design characteristics of the Tutor CBL Web, *viz.*: *i.* categorizing different aspects of CBL in terms of constructive alignment; and *ii.* visualizing open-endedness in the CBL course design. We also discuss aspects of the practical implementation of the instrument.

2.2 Categorizing aspects of CBL in terms of constructive alignment

The visual tool in Fig. 1 is supplemented with a description of each aspect. This includes both a general description – applicable for all projects in the curriculum – and a project-specific clarification. These descriptions are partially based on the CBL characteristics explained in the CBL compass (Van den Beemt, Van de Watering & Bots, 2022) and on a guide for implementing CBL for university teachers (Hermsen & Ambrosi, 2023). For the sake of brevity, below we show the elaboration only for the aspects pertaining to the constructive alignment element "Learning outcomes":

1. *Challenge*
   This aspect refers to the assignment given to the students/groups by the stakeholder(s).

The challenge describes the context in which the students work, without indicating a precise solution. For the example project in Fig. 1, the challenge is fully specified. The tutors are expected to monitor whether the group is aware of the challenge.

2. *Solution*
   This aspect refers to the range of possible end points that the students are allowed to reach in relation to the challenge. For the example in Fig. 1, the students are free in their choice of the system to be considered. The tutors are expected only to interfere in the case of safety concerns.
3. *Methods*
   This aspect refers to the range of (technical) approaches allowed to address the challenges in the project. For the example, the students follow a combined modeling and experimental approach, with alignment between these approaches being an important aspect. The tutors are expected to ask critical questions to stimulate the group's thinking process.

2.3 Visualizing the open-endedness in the CBL course design

To support the tutors in tailoring their coaching style, the axes of the Tutor CBL Web – which correspond to levels of open-endedness – are mapped to different tutoring approaches. We consider four approaches, ranging from a style in which the tutor is very directive (*I.*), to a style in which the students are given a lot of freedom (*IV.*). We describe these four tutoring approaches based on literature on teaching styles in higher education and teachers' roles in different contexts of collaborative learning:

I. *Directing*
   In this approach, we expect tutors to give direct answers and/or show students how to proceed (Van Leeuwen & Janssen, 2019).

II. *Steering*
   In this approach, we expect tutors to steer learning activities in the right direction, *i.e.*, toward what is expected/acceptable in the context of the given assignment (Grasha, 1994).

III. *Probing*
   In this approach, we expect tutors to ask questions to students such that they need to give more details about their approach toward a given task, without providing their own arguments/opinions (Grasha, 1994; Webb, 2009, Van Leeuwen & Janssen 2019).

IV. *Coaching*
   In this approach, we expect tutors to act as a supporting coach by asking open-ended questions, providing feedback on the group progress and motivating students to try different ways of solving a problem (Gomez, Doulougeri & Bruns, 2022).

We note that some literature we referred to is in the context of secondary education, however the concepts discussed are still applicable to – with some adaptations – the context of higher education.

2.4 Practical implementation aspects

The Tutor CBL Web is used to instruct tutors as a part of their training before they start tutoring in a CBL course. The web is explained via a short presentation followed by a discussion on the different components with the tutors, which takes approximately one hour. Along with the instruction, tutors also have digital access to the instrument (incl. the detailed descriptions) so that they can refer to all necessary information. Depending on the course, the Tutor CBL Web is also referred to in weekly update meetings between the tutors and the teachers.

3 RESULTS

We conducted interviews with tutors, teachers and students of two CBL courses in the bachelor program. For the tutors, we mainly focused on asking questions related to the perceived effectiveness of the visual tool and the instruction, whereas we asked students how they would describe the way their tutors guided the groups. We discussed the outcomes of these interviews with the teachers to explore how we can improve the use of the Tutor CBL Web and the instruction for upcoming iterations of the course. In this section we discuss the most prominent outcomes of these interviews.

3.1 Perceived effectiveness of the Tutor CBL Web

Tutors mention that the tool provides a good introduction. However, as the visualization includes quite a few components, it is not immediately clear what the full scope is. They appreciate the examples provided in the instruction for the different axes and mention that the examples help them to understand the different CBL aspects. They find the instruction using the web helpful in understanding their role as a tutor. For example, one of the tutors mentioned that it helped them to understand that their role does not only involve assessing students, but also guiding students as needed during different stages of the challenge.

The tutors indicate that they felt prepared to be a tutor after the initial instruction and that this instruction helped them understand where they should direct/steer students more. They found it helpful to learn about different approaches of intervening in their student groups. They also mention that learning about the course design and the level of open-endedness in different CBL aspects gives them a scope for deciding which instances require active intervention from them. From the interviews, it was understood that their main takeaway was to take more of a student-centred approach and try to be as less directive as possible. This is also confirmed by the student interviews, where they mention that the tutors do not provide explicit guidance, but tend to give suggestions and feedback on the quality of their work and/or collaboration, or ask questions about the approach students have followed.

On the other hand, while tutors find the instruction useful, they mention that they do not actively refer to the tool during the course. One of the reasons being that they rely on their past experiences as a student in CBL courses. A concern we identify with this approach is that some tutors might end up guiding their groups simply based on their own experience, and not necessarily in line with what is expected within the course or as instructed. To address this, we reflect with the teachers that the tool can also be referred to in the weekly meetings with tutors. This can be done by discussing anonymized cases tutors and teachers have experienced during a course and asking tutors what kind of tutoring approach they might follow.

3.2 Tailoring the instruction

As discussed previously, tutors find the tool and the instruction useful. In this regard, they emphasize the usefulness of the discussed examples. In the current format of the instruction, we used generic examples that may be applicable in a broader CBL context. The tutors mention the need for more project-specific examples for each CBL aspect. For instance, they would find it more useful to discuss a scenario that may arise when coming up with a solution in a specific course (along with some technical details, project constraints, *etc.*) and how they could respond to it. Additionally, since the web visualization is not immediately clear, they would like to have some time to understand the web, before delving into the instruction. To address these points, the teachers suggest starting the instruction with some examples followed by a discussion and then introducing the theoretical concepts and the web visualization.

Tutors also mention that they would like to have some documentation of the tool accessible, such that they could refer to it if needed. We find that this contradicts some tutors' points about not referring to the tool during the course. However, from discussions with the teachers we conclude that providing access to a written explanation of the web and the axes might be useful for those who would like to read further. Moreover, we agree that it would be useful if teachers use the tool as a framework during the weekly meetings to guide tutors in scenarios that arise at different stages of working on the challenge and ensure that tutors within a course guide their groups in a similar way.

4 CONCLUSIONS

Although student autonomy is a core principle of CBL, maintaining it consistently in classroom practice presents significant challenges. Especially in a context where CBL projects consist of large student cohorts, consistency amongst tutors in guiding the student groups and ensuring that students do get the desired level of autonomy in the course is what we aimed to address through our instructional tool. We intended for the tool to be a practical guide that provides a framework for tutors on how to act. As we gathered from the interviews, the tool does support tutors in understanding what is expected in their roles and provides them with a scope on how to intervene in different situations that arise during group work in CBL. Therefore, we consider this to be a successful step in our efforts to bring more consistency in the way CBL groups are guided and in ensuring that students can work autonomously, with the required level of guidance.

The tool and instruction do have some limitations. For instance, the four approaches of tutoring provide some descriptions on what tutors may do when they intervene with respect to different CBL aspects. However, in practice, many situations arise where an 'in-between' approach might be best suited or that tutors may start from a less directive approach and gradually move toward being more directive if needed. Given the set-up of the web and the timeframe for the initial instruction, this aspect was emphasized, but not discussed sufficiently. Therefore, we find it important to use the tool as a framework for discussions with tutors while the course is ongoing.

Another aspect to keep in mind is that teachers must clearly distinguish different levels of (intended) open-endedness in their CBL course and the accompanying tutoring style and score them accordingly in the web. Failing to do so, *e.g.* by scoring all axes between a *II.* (steering) or *III.* (probing), does not provide much direction for tutors in their behaviour toward their student groups.

Based on the feedback from the initial use of the tool in the tutor training, we have identified some strengths and areas for improvement. In the upcoming academic year, we will focus on refining the tool and tailoring the explanations in the instruction. Following these developments, we plan to reassess tutors' perception of the effectiveness of the tool, and further focus on investigating how tutors perform their roles in practice. Moreover, exploring the role of peer support to complement the tutor training could offer valuable insights in improving tutors' readiness and confidence in guiding student groups.

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IMPLEMENTING CHALLENGE-BASED LEARNING IN A PROFESSIONAL CONTEXT AT THE UNIVERSITY OF STAVANGER

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ABSTRACT

This practice paper examines the implementation of Challenge-Based Learning (CBL) among administrative communication staff at the University of Stavanger over a six-month period. The project, involving twenty-three participants from various departments and faculties, aimed to address professional challenges, marking the first non-educational CBL implementation at the university. Guided by CBL experts, participants formed interdisciplinary teams to tackle the "wicked problem" of brand awareness, which was identified as the central challenge. Reflections gathered through focus group sessions revealed that participants valued the opportunity to collaborate with colleagues across departments, gaining new perspectives on problem-solving and communication. However, challenges arose due to the long project duration and irregular team attendance, which sometimes disrupted momentum. Despite this, participants appreciated the flexibility of working on the project in their own time. The CBL implementation resulted in practical solutions that were incorporated into the participants' daily tasks, demonstrating the applicability of CBL beyond educational settings. Participants also expressed enthusiasm for continuing to use CBL in future projects. This paper highlights the potential of CBL as an effective method for enhancing collaboration, innovation, and problem-solving among professionals in higher education contexts and beyond.

1 INTRODUCTION

This paper explores a unique CBL implementation in a non-education context at the University of Stavanger with administrative communication staff over a six-month period. This has been the first implementation of its kind at our institution. The project involved twenty-three staff across for their department and communication advisors from the different faculties, including the Museum of Archaeology. Following the completion of this implementation, the authors conducted two in-person focus group sessions held to gather in-depth reflections from the participants on their experiences of the CBL process. We include direct quotations from this focus group sessions throughout this paper to offer participants' reflective voices on their experience of CBL and the insights gained.

1.1 Background

The Department of Communication and Public Affairs (AKS) at the University of Stavanger requested for CBL experts Masoumeh Shahverdi and Tim Marshall to design and implement a CBL learning project for their department project. The thinking behind this exercise was to bring together members of staff who work in the field of marketing and communications but in different departments across the university to choose a '*wicked problem*' that they face in their daily work. By dedicating time to specific CBL sessions, this took participants out of their usual working environment to address the problem with a different way of thinking and arrive at solutions that will be practically implemented in their daily work. It was important for the director to bring together her team and create dedicated sessions to think with a different perspective on their daily challenges.

2 METHODS (IMPLEMENTATION STRATEGY)

The CBL experts in consultation with the Director of Communications (DoC) created an implementation plan/programme over the course of six months from November 2022 to June 2023 with ten in-person sessions, three for each phase, and concluded with two focus group sessions. This is an unusually long implementation period compared to typical CBL implementation in an educational, however, it needed to be scheduled around the availability of busy professionals. The CBL experts introduced each phase with an overview of the framework and detailed examples of the respective tasks such as how to devise essential questions. They also presented tools to use in the later stage such as the fishbone and six thinking hats technique. The participants were divided into five teams to ensure they were working across departments with people that they did not usually work with on a day-to-day basis. This aligns with the multidisciplinary nature of CBL teams that we see in student implementation and encourages participants to step outside of their comfort zone and think differently. The teams used the online collaborative platform Miro to work through the CBL phases, which enabled them to have a space they could return to outside of the fixed sessions whenever they wished to add contributions to the discussions.

2.1 Engage phase

Team formation

As is common in CBL implementations, the *Engage* phase started with the team formation process on the 24th of November 2022. The DoC formed teams by mixing employees based on where they work. Each group had a mix of members from AKS and the faculties or museum and their field of work and competence. The aim was to put together teams with mixed backgrounds, i.e. people that normally work with different subjects and different areas. A team could for instance have a communication advisor from AKS, a communication advisor from a faculty, a member from the marketing team in AKS, an event coordinator from AKS, a member of the web team, the social media team, a public affairs advisor etc. Each team had four to five members in total. This, therefore, aligned with CBL team formation principles to aim for a multidisciplinary orientation. Once teams were formed, the CBL experts-initiated team-building games and activities including collaboration and communication skills in an informal setting.

Establishing the Big Idea

Also, on the 24th of November 2022, the CBL experts presented the *Engage* phase which participants learned how to develop a challenge from a Big Idea in their five teams. A Big Idea is often a singular concept like '*Digitalization*' or '*Sustainability*' to link a global issue to a local problem for CBL participants. In this case, it needed to be adapted to be more concrete and relatable to the work of the UiS staff. The teams identified '*brand awareness*' as the Big Idea. It was decided by the DoC and emerged from a brand awareness survey that had previously been conducted. Participants still thought globally in the sense of contextualising and comparing the challenges faced by their university to others both in their home country and beyond.

The CBL experts explained the concept of the Big Idea using the examples above to foreground the participants in CBL and to get them to start thinking about problem-solving and thinking through a problem holistically and thoroughly without jumping quickly to solutions. They also guided them through the process of developing essential questions using examples from other CBL implementations. This allowed participants time to understand how to apply it to their own context and reflect on the process.

2.2 Developing essential questions and creating a challenge

After this introduction to CBL, participants began to brainstorm on and develop their essential questions and identify their challenge using the Miro board. This phase lasted about two months. During this time, participants worked on the Miro board to continue the process of refining and adjusting their essential questions and seek constructive feedback from CBL experts. Like students in the *Engage* phase, this process led them to revisiting, reflecting and refining their questions into a single essential question.

On the 10th of January 2023 the participants met in person- for the second time for initiating team-working, sharing progress in their challenge and seeking feedback from the CBL experts. The *Engage* phase concluded on the 13th of January, when the participants met physically to present their challenges in five-minute' pitch-sessions'. Here they received further feedback on their understanding of the CBL from their colleagues as the content experts. Below are some reflective quotes from participants on what they gained most from the *Engage* phase:

"It was valuable, the strong focus on the big idea how, how important it is to question things, to come up with lots of questions in the beginning of this process. I that is very useful and something I will try to take with me."- Participant Team 2

"It became very clear how much we all work in silos and how it is important to find who will be a part of the of the project to find a solution." - Participant Team 5

2.3 Investigate phase

On the 17th of January 2023 the participants began the *Investigate* phase and another presentation on the key components of CBL theory in this phase. This included examples of how to identify knowledge about the challenge by asking guiding questions. It also included an overview of the resources to organise CBL research and collect data through this phase. Finally, she demonstrated and practiced problem-solving tools such as the fishbone technique, fish technique, and system thinking. The purpose was to help them understand the causes of a problem and map out relevant stakeholders. It was helpful for participants to look at the problem in the system and zooming out and see all the factors that effect on the challenge or influence by the challenge. Between the 17th of January and 14th of March, the teams could continue to work on the challenge in their own time and to consult the CBL experts for feedback and advice. Examples of these guiding questions included:

- How do we define a success story?
- In what way should the success stories support our strategy?
- How do we identify the fields that are important for building a good reputation?

On the 14th of March there was a dedicated session for teamwork and attention to the outcomes of the *Investigate* phase as per the process for *Engage.* A month later on the 14th of April 2023, the *Investigate* phase concluded with another in-person pitch presentation session, following the same process in the previous phase. The reflective quotes from participants below illustrate their experiences of the *Investigate* phase and what they found most beneficial:

"It's about really investigating what is our goal and what should we do to achieve the goals we have and that is something we have to work through again and again because it's so easy to just jump to conclusions. You have to work really hard to get very good and to get the good results." - Participant Team 1

"The fishbone technique was interesting, and you can call it innovation as well, but it's mostly what you get from working with the CBL method in itself, that's the learning." *- Participant Team 5*

2.4 Act phase

The *Act* phase began on the 18th of April 2023 and the CBL experts presented an overview of how the process of working towards the completion of this challenge. As discussed, in this CBL implementation, the solutions would be practically implemented in the participants day-to-day work-. It was crucial to rigorously test their feasibility according to a range of factors such as resource intensiveness (including personnel), financial constraints, time constraints, and compatibility with the department's existing work plans. Each team, therefore, worked towards solutions that contained one or more measures with one or more sub goals, unlike the single solution that students traditionally work towards in CBL. The final solutions are included in the results section.

To assist the teams in this process, the participants were introduced them to the creative thinking tool the 'six thinking hats' to evaluate potential solutions from different perspectives in brainstorming sessions. After this session in April, the teams had two further in-person meetings on the 14th of April and 12th of May to accommodate staff availability. These sessions reiterated the outcomes process described in the first two phases and were an opportunity to seek final comments, feedback, and input from the CBL experts

The project concluded with the final pitch-presentation session on the 2nd of June 2023. Each team shared their results with the whole team, the CBL experts, and the DoC. This was followed by questions for feedback from their colleagues and a final group discussion of the CBL experience. Below are some reflections from participants on what they liked best about the *Act* phase, and we then listed each team's solutions/action points with their own additional commentary.

"I like the six thinking hats technique where you looked at thing from different angles and you know everyone should try one hat because often, you're very positive about your own solution and you see others are not so positive to your own solution, but I think then to have this practice, seeing it from different angles and you know finding the positive and the negative and the doubts etc."- Participant Team 2

"I also wanted to mention the six thinking hats, I thought it was very good. It took some time to do it properly so maybe some tips or shortcuts on how to do it quicker."-Participant Team 1

3 RESULTS (IMPLEMENTATION OF SOLUTIONS AND GOALS)

The five teams came up with the following solutions to their challenges and associated goals.

Team	Solutions	Goals
1	Solution 1: Establish an editorial team for green transition Solution 2: Create a landing page for research communication/success stories	Goal 1: Convey more success stories about societal contributions Goal 2: Increase the number of success stories related to energy and green transition Goal 3: Enhance visibility of researchers in the public discourse on green transition
2	Solution: An information hub for external collaboration	Goal: Create a solid foundation for further development by making information accessible in one location
3	Solution: The Reputation Box with instructions for collaborative work, including internal seminars	Goal: Raise awareness of the University of Stavanger and enhance connection to departments and their work, with leadership responsibility for follow-up
4	Solution 1: Further develop a strategic user journey for students Solution 2: Organise an academic festival to unite available resources and engage staff and students	Goal: Provide targeted information, build relationships, foster a sense of security, and ensure a smooth start for students
5	Solution: Improve the reputation of the University of Stavanger by highlighting it as an attractive workplace:	Goal 1: Create new standard texts and a photo bank for job ads Goal 2: Test new announcements for administrative positions Goal 3: Measure views on results in terms of the number of views on advertisements on national job websites) - compare with 'before data.' Goal 4: Evaluate the effect.

These solutions have since resulted in several key actions aimed at both communications with students, staff and potential staff and following the CBL project, AKS has looked at how it can be more agile in its structuring to work more effectively in smaller teams. For example, a working group has been established to strengthen the recruitment of students at an organisational level through working across faculties. Insights from the project have informed the development of targeted communications, such as personalised welcome emails for new students and interviews with bachelor’s and master’s students to gain insights into their initial experiences and their user journey.

Other initiatives arising from the project include the establishment of an editorial team focused on the green transition, along with plans for a new information hub for external collaboration which will enhance research communication and collaboration efforts. Furthermore, efforts are underway to improve visibility through initiatives like organising an academic festival. AKS is also now working with HR in collaboration how to make greater use of LinkedIn, such as which images and texts to use for recruiting and has a dedicated advisor to work on this in the future to strengthen its employer branding. These actions are helping to build a stronger, more cohesive approach to both student and faculty recruitment and retention.

3.1 Benefits and skills gained by participants

CBL is usually implemented in an educational setting with student learners. However, we want to demonstrate that CBL can also be beneficial for other groups, in this case professionals working in a university as administrative staff. Therefore, this paper presents a unique implementation of CBL in a different context in which some similarities but also many differences can be noticed in terms of the way the participants experienced CBL. For example, the solutions listed above are now being implemented in the participants’ daily tasks unlike an educational context where solutions to real-world issues can also be conceptual. The reflective quotes below demonstrate that participants highlighted the role of the transversal skills of teamworking, collaboration and communicating, problem-solving and innovative thinking:

“I think that the collaboration with other colleagues was nice and kind of new for us because we know each other but it is very rare that we work together in the way that we did this time across the, the faculty and centres bringing us together as a team.” Participant - Team 3

“Collaborating with other communication advisors at the faculties and at the centres, it's very nice to meet with them and to talk about issues connected to our field of work.” Participant - Team 4

“It was nice to work together for a common goal and to ask and get information from other departments as well. So, it was a nice practice in how the whole university is connected and how we are working on different parts of a common goal.” Participant - Team 2

“I think the best part was well, the teamwork in general. Getting to collaborate with different departments and centres.” Participant - Team 1

“The best part was actually learning how to work in an innovative process and seeing how difficult that is to do in a big organisation.” Participant - Team 5

3.2 Challenges and lessons learned

One of the main challenges that participants raised in the focus group was the length of the programme, which extended to more than six months and created a number of disadvantages, in particular that momentum and progress was sometimes lost with such long gaps between sessions This longevity has a secondary issue which is that if the problem addressed by the team changed significantly during the project it then required a lot of extra time and resources which pressurised busy professionals. They would like to revisit the methods, but with more specific challenges and narrow down the project period to gain more momentum. This would obviously need a bit more planning before starting such an exercise.

However, they also mentioned positive aspects to engaging in the program over a long period as it allowed for flexibility for participants to work on Miro between sessions or that they could approach the CBL experts either in-person or via email for feedback and guidance. It also gave participants time for reflection, reconsideration, and critical idea generation. They had enough time to revisit early CBL phases and one team even changed their challenge altogether during the *Engage* phase, which is common practice in CBL as it encourages learning from failure.

Another challenge was that absence of some participants in some teams throughout the challenge. There were also participants who either left after the first phase or joined mid-way through the project, which created imbalance in the team dynamics. The final challenge was that CBL was challenging for participants since the focus on the application was too broad which hid very specific issues that needed to be solved in their daily work. Below are some reflective quotes that illustrate these challenges:

"It was hard to gather the whole group each time, so we were never the same people who met each time. To do it better we must ensure that everyone who participates in each group is dedicated over the time and can be at all those meetings. It is good if we get the whole timeline from the start and we know all the meetings, we can schedule it the if we have two months, we can schedule it properly." Participant - Team 1"Perhaps it would have been better if the topic was a bit narrower than the university's reputation." Participant – Team 2

"A better way to do it would been if it was more concentrated and with just one day in between each part of the task for instance. We forgot a lot between the gaps, and it took a lot of time to recapture what we have learned." Participant - Team 4

4 CONCLUSIONS

The key findings of this paper demonstrate that CBL can be applied in administrative communication departments as a tool to help tackle problems they face in their day-to-day work and has resulted in innovative new initiatives and ways of working. Although there was some initial hesitation and confusion as to how CBL could be adapted and where CBL could be relevant to their tasks, many of the participants found they felt empowered by the process once they had overcome the challenges they invited and addressed. As the feedback from the focus groups demonstrate, participants gained knowledge of new tools (*systems thinking, fishbone technique, six thinking hats*) and frequently mentioned the benefits of collaborative team working outside of their usual working context and drawing upon the skills and competencies of colleagues they do not frequently interact with. They also enjoyed the creative and innovative approach to problem solving and solution-generation that CBL encourages.

'BUILDING THE UNIVERSITY OF THE FUTURE'-CITIZENSHIP EDUCATION THROUGH CHALLENGE-BASED LEARNING.

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ABSTRACT

Citizenship education is highly important for the future of education since it bridges citizenship and scientific inquiry. Challenge-based learning (CBL) could be a tool to break the gap between the two. The practice of the challenge Building the University of the Future tested this hypothesis. Through the challenge students from diverse universities and backgrounds evaluated the role of CBL as the most suitable learning tool for the future of higher education and reflected upon their experience with CBL as a learning tool for active citizenship. The results revealed the advantages and disadvantages of CBL as a learning method, as well as several recommendations on how to apply it better and how it could be better used as a learning tool for citizenship education.

1. INTRODUCTION

Democracy currently faces significant challenges, leading to concerns about human rights, the rule of law, free speech, and other public values. The rise of populism and extremist ideologies has raised questions about the stability of democracy worldwide, including in Europe. To attempt to counter these developments, one of the initiatives of the European Union (EU) is to encourage its citizens to engage in democratic participation (Deplano 2011) Enshrined in the Lisbon Treaty of 2009, the EU has encouraged its citizens to actively participate in democracy through various initiatives, including the European Citizens Initiative and the 'WeMove' platform.[2] To counter these threats, the European Union encourages citizen engagement in democratic participation through initiatives like The European Citizens Initiative (ECI) to promote values such as human dignity, freedom, democracy, equality, rule of law, and human rights. Some of the core skills and competencies citizens require to participate in bottom-up policy making include:

i) Critical thinking skills: Citizens need to be able to critically analyse information and arguments presented in public debates, to make informed decisions. (Council of Europe 2022)
ii) Communication skills: Effective communication skills are essential for citizens to participate in discussions and debates, present their ideas, and express their opinions. (UNESCO 2023)
iii) Collaboration skills: Participatory democracy requires citizens to work together to achieve common goals, so it is important to have good collaboration skills. (Council of Europe 2022)
iv) Conflict resolution skills: Citizens need to be able to resolve conflicts and find solutions that work for everyone involved, to reach decisions that are fair and just. (Council of Europe 2022)
v) Research and information gathering skills: Citizens need to be able to gather information from a variety of sources, analyse it, and use it to inform their decision-making. (OECD 2016)

[2] https://www.consilium.europa.eu/en/documents-publications/library/library-blog/posts/citizen-participation-in-democratic-europe-what-next-for-the-eu-edited-by-by-james-organ-alberto-alemanno/

vi) Leadership skills: Effective leaders can help guide discussions, facilitate decision-making processes, and inspire others to participate in democratic processes. (Council of Europe 2022)
vii) Digital literacy skills: In an increasingly digital world, citizens need to be able to use technology to access information, communicate with others, and participate in online discussions and debates. (Council of Europe 2022)
viii) Cultural competency: Citizens need to be able to understand and respect the diverse perspectives and experiences of others, in order to work together effectively and make decisions that are inclusive and equitable. (UNESCO 2023).

These are also some of the skills and competencies that students can develop through participating in a Challenge Based Learning (CBL) course, by applying their knowledge onto real-world cases. One such case was the challenge “Building towards the university of the future” (UoTF) offered by the European Consortium of Innovative Universities (ECIU) and developed and hosted by the University of Twente. The main goal of the challenge was to involve students in the envisioning and development of the future of their education. The students choose CBL as their hypothesis, assuming that this could be a possible future for the university of the future. In a sense, the students’ findings can be utilized in a meta-analysis level, comprising simultaneous the educational method of the challenge and the research subject.

The current multifactorial case study discusses the outcomes of the students’ work, as well as the findings of their educators’ reflections regarding using CBL as a learning tool for citizenship education.

2. METHODS

a. Design

The challenge UoTF aimed to allow students to co-create the educational vision of the education of the future. To that end, the students were guided by a challenge coach and their work was evaluated by the challenge providers. The students had the freedom to utilize their prior knowledge, and personal experiences on the topic of education, as well as structural material from other study fields, and scientific disciplines knowledge.

b. Participants

As the challenge was extra-curricular under the alliance umbrella, the team consisted of six members from different countries, institutions and educational backgrounds. This diversity allowed the students to exchange ideas and knowledge within and across their disciplines. The selection of the participants was conducted based on a motivational letter. This information was utilized for the selection of the most suitable team, and the preparation of the fertile ground by the coach.

c. Procedure

The challenge lasted from November 2021 until June 2022. Throughout the time the students had regular meetings with each other and monthly meetings with the coach and the challenge providers, while sporadically the team met also with external experts for inspiration.

d. Analysis

To evaluate the most suitable future design for the university of the future, the topic was researched in diverse ways.

1. Document analysis, where the documents of CBL policy and CBL embeddedness in the educational system of other institutions were analysed
2. Semi-structured interviews, where the educational methods of other universities were evaluated and their use of CBL was reported
3. Reflection papers, where the students and stakeholders evaluated their personal experience with CBL and how they considered that this could be relevant for the future of education.

Those results were analysed by combining the output of the first two methods into a common output and separating those outputs from the data collected from the reflection papers

3. RESULTS

a. Policy & Interviews

The results of the policy analysis and the interviews were best to be summarized in a strengths, weaknesses, opportunities, and threats (SWOT) analysis of the CBL implementation at different European universities within the alliance. The same analysis provided the material for future directions regarding the UoTF concept, quoting the partner universities interviewed and the team's own potential solutions.

This analysis provided that ensuring interdisciplinarity, challenging conventional thinking, and engaging higher education students with popular topics are the most important strengths of the CBL application. However, some CBL weaknesses were also revealed. These include the lack of applicability at all levels and topics, high workload for both teachers and students and practical implications such as the Bologna process contradictions, as well as the departing away from the original challenge. Overall, there appeared to exist a consensus amongst the university representatives interviewed that the CBL implementation maintains room for improvement, especially regarding opening new topics and learning opportunities for teachers, while at the same time ensuring both students and teachers remained engaged.

Furthermore, the time when CBL is introduced to the curriculum of the students seems very important. Most universities apply CBL only at the highest levels of education, in the final years of bachelor's and at the master's programs. Only a few utilised it at all levels of study and others did not at all. The rationale behind this approach was two-fold: Firstly, academics perceived students to not be ready for the CBL approach at the early stages of their studies before they even had received a base level of tuition on their specific subjects. Fundamental content knowledge and simplified project-like applications could be utilised as a springboard to accelerate towards the 'wicked problems' of industry. Secondly, because the organisation and coordination of CBL is by nature more complicated for the professors, only the students who were already familiar with the subject could cope and appreciate more complicated learning structures.

For an overview of the outcome, see Table 1.

Table 1. *SWOT Analysis of CBL for the University of the Future*

SWOT	Positive factors	Negative factors
External origin	**STRENGTHS** •popular topics usually •topics allow interdisciplinary cooperation •Positive experience for students and teachers •richer assessing approaches •challenge conventional thinking/ grading/educating	**WEAKNESSES** •not applicable for all topics •not applicable at all levels •participants must have a lot of engagement •can be overwhelming for teachers •law/Bologna contradiction •mismatch between initial challenge and reality
Internal origin	**OPPORTUNITIES** •opening up new topics •New insights on topics •Learning opportunities for teachers	**THREATS** •No input from the students who did not complete the challenges •no teaching staff available •not enough motivation for students

b. Reflections

3.1 Students' Reflections

As a central part of the CBL learning process, reflection should occur repeatedly during all different stages of any project and should have an equally personal and team-related nature. This was the case in this challenge as well. Throughout the process the students reflected on their progress in a non-hierarchical manner, noting their successes and failures, and redirecting their actions towards the next steps that needed to be obtained. Characteristically, the students displayed deep appraisal of both the positive and negative aspects of self-directed learning.

The collaborative process was both a challenge and a reward of UoTF. In their reflections, many of the students made note of the communication and intercultural skills they needed to develop to work together with teammates from different cultures, disciplines, and with different ways of working and how these evolved as the challenge progressed.

In terms of the fluid nature of roles within a team that the CBL model promotes, all team members had to learn when to take initiative and show leadership skills, as well as when to accept a more following role. Students who were already familiar with CBL were introduced to new ways of being supportive to their team member. And students with less experience in project based or CBL learning were also practicing cooperation in a team for a common goal, as well as taking action and being in a guiding role, when needed.

3.2 Stakeholders' reflections

As a central part of the CBL learning process, reflection should occur repeatedly during all different stages of any project and should have an equally personal and team-related nature. This was the case in this challenge as well. Throughout the process the students reflected on their progress in a non-hierarchical manner, noting their successes and failures, and redirecting their actions towards the next steps that needed to be obtained. Characteristically, the students displayed deep appraisal of both the positive and negative aspects of self-directed learning.

To maintain the equal ratio in the cooperation between CPs and educational institutions on one hand, and the students/ learners on the other, an evaluation of the cooperation of both parties was conducted. To those ends interviews with representatives of both institutional bodies were conducted a year after the completion of the challenge to assess the challenge's impact.

The educational institution (in this case the University of Twente) considers this challenge to have been a success, since the students appeared to obtain large amounts of knowledge. From the educational point of view this was the main goal. However, the representative of the institution would propose a different approach should the challenge be offered again in order to provide higher connection to the local community. More specifically, it appears that guidance towards the students from the CP at the first stages of the challenge would be of great added value. Defining the actual problem premises that bridge the needs between science and society is more informative rather than coming up with a solution for a well predefined problem. Early on the involvement of the stakeholders would be of crucial importance, as they could support the students to understand what the impact of their actions is at every stage of the challenge, as well as what their final output would be for the society. However, defining the challenges is a challenge on its own.

Finding teachers that are already experienced with the CBL process and know how to guide the students during the different phases is another. As CBL is a new teaching method, not many teacher and university professors are experienced with it. Their strong motivation is of high value, however, CBL requires different teaching and guiding approaches that diverge from the traditional methods. This European alliance is on a good path to creating learning databases to cover the instructional needs of the educational institutions. The premises of a short teaching challenge comprise, however, another issue that often arises; the actual evaluation of the implementation of the challenge solution is not covered in the evaluation. In other words, the impact that the challenge has on the society is unclear, even a year after the completion of the challenge. Solid action should be undertaken to ensure to gradual strengthening of such educational endeavours outside of the educational settings.

On the other hand, the CPs appeared to have a less positive experience from the challenge outcomes. As the student team only involved them in their learning process towards the last CBL phases, the outcomes were not yet validated and hence were of lower quality. Making good use of the skills and knowledge of the CPs early on could have allowed them to tap into their already existing knowledge and avoiding covering ground that has already been covered by them in advance. The infusion of CBL practices in the curriculum of the studies could possibly offer superior and more tangible results.

Furthermore, the project was granted extra time allowing its participants to extend even longer to ensure quality. This prolonged period, however, might not have been that beneficial for the project after all, since the CPs were already developing further in their knowledge, while the students were making small steps on the same matter. The results did not need to be life-changing, of course. Rather adding up to the CPs already existing databases and adding up towards something bigger. A valuable advice on this matter could be the utilisation of predefined milestones which the students need to achieve to reach next levels of development in their projects.

4. CONCLUSIONS

In conclusion, this practice has provided insights into the CBL as a learning tool for citizenship education. Throughout the course, the most important advantages and disadvantages of CBL were outlined and the basic connection between this learning tool and citizenship education were outlined. The next paragraphs provide a short overview of the most important points.

Advantages

The core added values of CBL as a citizenship education tool differ for its beneficiaries. Through CBL the students are engaged with real-world problems, which enhances their critical thinking and problem-solving skills. Their active role in their learning enhances further their self-directed learning skills. On the other hand, the CBL educators understand the learning development process of the students better, by observing their engagement with the material in every CBL phase. These observations can be leveraged to develop better educational methods and approaches for real-world application cases, regardless of the CBL application. By developing educational methods that bridge the gap between education and industry, students can avoid the shock of suddenly stepping into the job market's wicked problems from the safe and controlled environment of education.

This can allow educators to better prepare the students for their careers where preparedness to cope with wicked problems will be required.

Disadvantages

Similarly, the core disadvantages of CBL can also be divided per beneficiary. For the students, the core problem with CBL is the method's vast openness. Just like in real-world cases, the uncertainty of the open-ended nature of the challenges leads the students to confusion and sometimes stagnation during the initial first steps in their learning process.

Similarly, for the educators, the core issue appeared while guiding the students in those initial steps. More research needs to be conducted, and adjustments need to be made in the CBL curriculum to prepare the educators on how to support the students better. Furthermore, CBL reflecting the real-world applications, requires intense teamwork, where students from diverse educational, cultural and institutional backgrounds are challenged to work together on a common product. The approach towards this process also requires more attention and development.

Limitations & Recommendations

The outcomes of the current practice were in line with the goals of it. However, several limitations have been observed, which could be utilized as starting point for future approaches. Firstly, the current study was only focused on the analysis of the opinions of members already involved in CBL, students, educators and other stakeholders. To evaluate CBL as an accurate learning tool for the future of citizenship education, assessment of the opinions of other members, not directly involved with CBL, would be recommended. To those ends, the students of the challenge has already proposed a questionnaire structure for all relevant members. Furthermore, the current study, the evaluation of CBL as a learning tool for citizenship education was not imposed to the students. The added value of it was only revealed later. The students only evaluated CBL as the most visible learning model of the future. Further research would be required to evaluate whether CBL could indeed be the educational model of the future due to its character of teaching about citizenship.

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FORMULATING CHALLENGES TO SCAFFOLD TEAMWORK: EXPERIENCES FROM A NORDIC INNOVATION COURSE

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ABSTRACT

A central component of challenge-based learning are the challenges which scaffold a learning process. Considering the importance of these challenges, there are surprisingly few guidelines on how to formulate such challenges so that they may scaffold the learning process in the desired way. In this paper, we therefore explore experiences over the past 10 years with formulating real-life challenges, instructing external stakeholders (such as companies or NGOs) and conveying challenges to the students, in order to extrapolate general guidelines for how to formulate challenges so they support constructive alignment in challenge-based learning courses. As a case study, we use a large course on innovation, which brings together engineering students from 18 different engineering disciplines, where they are tasked to work in interdisciplinary teams and develop innovative solutions to a real-life challenge.

1. INTRODUCTION

With the global challenges of the 21st century, universities need to educate engineers who can work together across disciplines to solve wicked and complex challenges from a more holistic, sociotechnical perspective. In order to teach engineering students the necessary competences to deal with these complex, global challenges, engineering educators need to provide them with learning opportunities, where the students can gain experiences with working on open-ended challenges in interdisciplinary teams. In engineering education, the pedagogical approach challenge-based learning (hereafter CBL) has gained increased popularity as way to provide exactly these learning opportunities where students work interdisciplinarily on developing solutions for complex sociotechnical challenges (Bombaerts et al., 2021). The work students do within the CBL approach has been described as the “identification, analysis, and design of a solution to a sociotechnical problem. The learning experience is typically multidisciplinary, involves different stakeholder perspectives, and aims to find a collaboratively developed solution that is environmentally, socially, and economically sustainable" (Malmqvist et al., 2015). In other words, the CBL pedagogy is centered around connecting students’ discipline-specific knowledge with professional practices, by bringing key features of the engineering workplace into the classroom (Sukackė et al., 2022). It therefore provides a learning space for practicing problem solving as well as applying and developing transversal skills, such as communication and teamwork (Sukackė et al., 2022).

In CBL, students are tasked with working on a challenge, which is based on a real-life problem proposed by an external stakeholder such as a company, government, NGO, research group or members of a community (Doulougeri et al., 2024). There is little or no predetermined curriculum for the student projects in CBL, and many different stakeholders, not just the teachers or facilitators, but also external ones, interact and support the student teams during their work (Gallagher & Savage, 2023). CBL often has a focus on sustainability in its challenges and the developed solutions, but most importantly, the challenges must be formulated as open-ended, as to not restrict the student teams’ work too much, and they must have a solid grounding in a real-life problem. This is to increase students’ motivation and engagement by letting them work on something concrete and real, rather than giving them a theoretical problem to solve (Gallagher & Savage, 2023). Furthermore, the challenges should be formulated in a way which encourages collaboration, creativity and the use of different competencies and disciplinary knowledge and skills (Martin & Bombaerts, 2024).

The formulation of the challenges in CBL is crucial to scaffold the learning process and ensure the desired learning outcomes. As described above, there are not many rules for exactly how a challenge should be formulated, but there are a few very important characteristics that challenges must live up to. However, in many cases where CBL was used in practice, it has been found that the challenges were predefined by teachers or even, in some cases, by students (Gallagher & Savage, 2023). The reason for cases such as this, can be that there might be certain institutional considerations, such as alignment of the challenges with certain specific intended learning objectives or that it can be very time-consuming to develop challenges in collaboration with external stakeholders, as they may have their own preferences and interests on what the challenges are and how they should be solved (Doulougeri et al., 2024). Thus, it takes many resources to develop these challenges and align expectations with external stakeholders, so that they can be used to scaffold a constructive and meaningful learning process for the student teams (Doulougeri et al., 2024). However, research about the CBL approach has predominantly been focused on the pedagogical implementation of the approach into course design, and not much research exists on the formulation and definition of the challenges the student teams must work on. With this paper, we therefore aim to begin filling in that gap, by exploring experiences with formulating challenges for a large, mandatory innovation course at a Nordic engineering university. We will show examples of challenges used for the course and discuss how the formulation of the challenges can impact the teamwork of student teams going through a challenge-based learning process. We also discuss how the cases can create obstacles and/or opportunities for students' participation in the teamwork, and how we as educators can mediate these through the challenges are conveyed to the student teams.

2. COURSE DESIGN AND CONTENT

Characteristics of the Course

As previously mentioned, the case used for this paper is an innovation course for Bachelor of Engineering-students at a Nordic engineering university. The course is available for students to take every semester, and once every year as an intensive six-week course taking place during the summer. Because it is a mandatory course, there is a large number of students participating; every year, around 800 students take part in the course. The students typically participate during their fifth or sixth semester, meaning they are usually fairly close to finishing their degrees. The course is also weighted at 10 ECTS, making it one of the larger courses offered at the university, emphasizing the importance of its content and learning objectives.

The course is based on a CBL approach, allowing students to engage deeply with real-life challenges. Central to the course is the collaboration between students and external stakeholders, who are usually companies, particularly small and medium-sized enterprises (SMEs), but can also be, for example, NGOs or multi-national corporations (MNCs). During the course students work in interdisciplinary teams to tackle specific challenges or ideas defined by these companies. The course emphasizes cross-disciplinary collaboration, and students' teams are made up of up to six students, with no more than two students from the same engineering discipline. This approach simulates real-world innovation environments, fostering diverse perspectives in the teams' problem-solving. The course also emphasizes practical application and a hands-on approach, where the students get to apply their engineering knowledge to solve complex challenges, to help them in developing an innovative mindset. This hands-on approach enables them to practice organizing and executing cross-disciplinary innovation processes using different relevant models and methods. During the course, the students engage in various activities essential to the innovation process, such as:

- Problem identification and definition
- Idea generation and divergent thinking
- Collecting and evaluating quantitative and qualitative information
- Designing and building prototypes
- Testing and validating ideas, prototypes, and concepts

To guide the students through the challenges and the problem-solving process, the course is organised using the Double Diamond Model (Design Council, 2024). The model is an iterative, non-linear problem-solving process that shifts through divergent and convergent phases. The first diamond is focused on exploring, defining and delimiting the challenge, and the second diamond is focused on developing solutions for the problem through generating multiple ideas for solutions, prototyping and testing, until the team finally ends up with selecting the most appropriate solution for the challenge. In addition to the Double Diamond Model, a range of different innovation and creativity tools are also offered to the student teams, and they are encouraged to do their own research relevant to their specific challenge as well as bring in knowledge, methods and experience from their own disciplines and lives. The student teams also work closely with a facilitator team, consisting of a faculty member and a teaching assistant. The facilitator team works as a sparring partner for the student teams throughout the innovation process, and they can provide support and guidance regarding project management, conflict resolution and communication.

The course culminates in a presentation event where students showcase their innovative solutions and prototypes to the collaborating external stakeholders, and the teams are assessed on things such as:

- Pitching skills and communication
- Prototype design
- Written proposals that argue for the group's recommendations and implementation strategies

By focusing on real-world challenges and emphasizing practical applications of innovation theories, this course provides students with a comprehensive challenge-based learning experience.

Examples of Challenges

The challenges used in the course are focused on broad and open-ended problems within engineering. Typically, the challenges address problem in areas such as: Sustainability, diversity and inclusion in technology, process optimization, innovative usage of materials and/or products, business development or technology development and technology implementation. In Table 1 below are examples of the types of challenges that are used for the course (in a shortened version):

Table 1. *Examples of challenge descriptions according to the type of stakeholder*

Type of Stakeholder	Challenge Description (Short format)
SME	On a yearly basis we sort 2,5 million items, making sure that people across city of Copenhagen have access to them all them. Today the set-up is a machine that runs optimally with five people working in shifts between 08.00 and 17.00: Two people feed the machine and three people patrol the sides of conveyer belt, removing filled crates and replacing them with empty ones. The work requires a lot of lifting and manual handling of the materials, but there is equipment available to aid the workers. How can we achieve a higher degree of automatization of the sorting process? Is there any industry with similar sorting processes that can be adjusted and used?
MNC	Logistics companies around the world are developing at a rapid pace, with increased automation and AI as key drivers. We also want to increase automation and reduce the number of touch-points per item, which is currently far too high. We also have challenges with our drivers spending a lot of time sorting the items in connection with loading the cars. We have been in dialogue with several developers of automation solutions, but we have difficulty navigating the many solutions that we don't know will solve the challenge. Solutions are often both expensive and resource-intensive to implement.
NGO	People who have both a vision and a hearing impairment experience difficulties in accessing the environment – i.e. knowing what and who is around them, and where things are. This target group consists of more than 10.000 people in Denmark. The majority are over the age of 80. This presents challenges in situations like: • Realizing that a person is approaching you or recognizing other people or familiar objects • Finding 'queue numbers' at the pharmacist and knowing when it is your turn - Finding your way in buildings, train stations etc. • Understanding what is being said in the PA system at train stations about platform changes etc. • Understanding the mood, humour etc. of the other person in a video meeting when you cannot see the facial expression or hear the nuances in the voice • Knowing what is in the fridge – and how old it is.

	So how can we develop innovative ways of enabling people with sensory impairments to live more independent lives and experience more quality of life?

During the course, the external stakeholders participate in several meetings where they have the opportunity to clarify their expectations to the given challenge and give feedback to the student teams, typically based on a pitch or oral presentation by the team. As part of the participation, external stakeholders must also be open do communication and visits from the student teams as a way to support the teamwork and problem-solving. In other words, the external stakeholders must commit to provide the necessary insight into the challenge to give the student teams the best opportunities to develop innovative, useful solutions.

3. INSIGHTS AND REFLECTIONS

At present, the course we have described in this paper has been running for 10 years, and we evaluate and develop our practices every year on the course, so there have been many smaller gradual adjustments made to how we formulate our challenges and how we prepare the external stakeholders for the course. Based on our experiences with the continuous development of the course, we would like to share our reflections and insights and offer suggestions for future work within teaching and researching challenge formulation in CBL.

For the course described in this paper, developing the challenge formulations is an iterative process, where we every year build up more experience in the teacher team regarding how a challenge should be formulated, both in regard to the length and level of detail, but also in regard to the specific formulations of the challenges.

All challenges used in this course are formulated in close collaboration with the external stakeholder as part of the preparation for the course, to ensure a strong alignment between the learning objectives of the course and the challenges from the companies. Developing a challenge can take quite some time, depending on the expectations of the external stakeholder and how easy it is to create alignment with the learning objectives of the course. For this course, the teacher team meets with each of the external stakeholders ahead of the course to discuss and align expectations. During these meetings, the stakeholders can hear about the course design and pedagogical approach, as well as the learning journey the student teams will go through. Expectations towards their participation is also clarified; we make it explicit that they are expected to be open to supporting the student teams and provide information if needed, and they cannot order a particular solution or a prototype of something specific. They must be open to the student teams taking a different or surprising direction as part of their work process, including using different skills, knowledge or methods than what the stakeholder might normally engage with. The stakeholders also present their ideas for challenges and express their wishes and interests, as it is a goal to have a fruitful and constructive collaboration between all parties. The teacher team gives feedback and helps shape the challenges, so that they become as open-ended as possible and can appeal to a wide variety of engineering disciplines to encourage interdisciplinary collaboration and creative, innovative problem-solving. The challenges are, in other words, developed in close collaboration between the teacher team and the external stakeholders.

However, from time to time, it may be difficult to align the expectations of the stakeholders with the learning objectives of the course, in which case the teacher team must not be afraid to let the stakeholder know, that their challenge will not work for the course. In those cases, we try to find another challenge or find another way of collaborating outside of this specific CBL course context. Therefore, based on our experience, it is important to spend time developing the challenges in collaboration with the external partners to align the interests and expectations with the learning objectives for the course. This can help alleviate any issues with challenges and ensure they have the desired characteristics before the course begins.

As shown in Table 1, the written challenge descriptions are relatively short and, besides the descriptions shown in the table, students are only given a brief written introduction to the stakeholder with some background information relevant to the challenge and contact information to a representative from the stakeholder. We keep the descriptions short on purpose, as a way of encouraging the student teams to reach out to the stakeholders and seek out information they find relevant during their problem-solving process.

As a part of the course design, there are three official meetings between the stakeholders and the student teams: the first meeting is in the beginning of the course, where the stakeholders can present their challenges live to the student teams and answer clarifying questions. The second meeting is halfway through the course, where the student teams present their work so far and can showcase their progress. The third meeting is at the end of the course, where student teams present their final solutions and prototypes to the stakeholders and receive feedback. Between these meetings, we expect the students to maintain contact with the company, because, in our experience, a lack of communication between a stakeholder and a student team can create problems with developing solutions for the challenges, as the student teams may not get important information and/or feedback. It can also impact the students' motivation if, for example, they feel they cannot get in touch with the stakeholders and/or find the information necessary to move forward with their work. Therefore, we strongly emphasize the need for clear and open communication to both student teams and to the external stakeholders.

4. CONCLUSIONS

Based on experiences from the case of this paper, we have showed how important the formulation of the challenges can be in terms of shaping and impacting the teamwork process for student teams. We therefore recommend teachers and facilitators of CBL courses to carefully consider how challenges may be interpreted and if they seem to encourage certain disciplines or types of solutions, because it can bias the student teams work process and halt the development of creative and innovative solutions. Teachers can mediate this problem in two ways: the first way is through the initial development of the challenges, by taking to the external stakeholders and giving them instructions on the characteristics a challenge must have, as well as emphasizing that the course, and therefore stakeholder participation, must first and foremost be focused on scaffolding a constructive learning process for the student teams, and therefore the stakeholders cannot dictate exactly what result or solution they would like - although they are of course welcome to provide feedback on the work. The second way is through careful support and scaffolding of the student teams during their teamwork process, where a teacher can help push the students towards a more divergent and creative development process, as well as mediate conflicts and bias as if it occurs during the teamwork process.

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CHALLENGE BASED LEARNING AS A MULTICOMPONENT INTERVENTION FOR WORKPLACE AND SOCIETAL READINESS IN HIGHER EDUCATION

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ABSTRACT

Challenge Based Learning (CBL)'s seven core components - complex authentic challenges, stakeholder involvement, interdisciplinary perspective, workplace and life skills development, student agency, entrepreneurial attitude, and focus on impact - offer a promising framework for addressing insufficient workplace and societal readiness in higher education graduates. This paper presents "Designing Inclusive Education at Montclair," a recurring CBL course where undergraduate student cohorts work continuously on an institutional challenge across multiple semesters. We first document how this innovative course structure enables students to tackle complex challenges employing a unique "fade-in, fade-out" structure where subsequent student cohorts “fade-in and fade-out” on an ongoing challenge that spans several semesters. Current students build upon previous cohorts' work while maintaining the flexibility to pursue new directions as the challenge evolves, mirroring real workplace scenarios. We then propose a multicomponent intervention framework for evaluating how CBL's core components contribute to workplace and societal readiness, which is experienced as an issue by employers. Our approach combines careful analysis of component interactions with structured assessment of student development outcomes, providing higher education institutions with both a practical model for implementing sustained challenge-based learning and a methodology for evaluating its impact on post-graduation workplace and societal readiness.

1. INTRODUCTION

Background

Higher education (HE) faces a number of issues such as often –and increasingly– lacking student engagement and the diminishing provider satisfaction experienced by faculty, programs and the HE institution. HE also faces another critical challenge which is the one explored in this paper: graduates are inadequately prepared for workplace and societal demands. Studies consistently show a misalignment between academic preparation and employer expectations, particularly in areas of practical skill application, professional development, and adaptability to rapid industry changes (Krishnamoorthy & Keating, 2021; Messaoudi, 2021). This gap extends beyond academic or technical knowledge and includes crucial workplace competencies such as project management, stakeholder engagement, and evidence-based decision-making.

While higher education institutions implement various experiential learning approaches to address this challenge, Challenge Based Learning (CBL) offers a particularly comprehensive framework through its distinctive Engage-Investigate-Act iterative learning cycle (Apple, 2008). CBL's effectiveness stems from its unique integration of seven key components: authentic challenges, stakeholder engagement, student agency, work and life skills development, interdisciplinarity, entrepreneurship, and impact creation (DePryck and Wambacq, 2023). More than other experiential learning approaches, CBL emphasizes metacognitive development and active engagement with real-life challenges, providing students greater opportunities to develop essential workplace competencies (Green et al., 2018; Lang, 2021). Through its focus on authentic complex problems and extensive stakeholder collaboration, CBL creates learning experiences that mirror workplace dynamics while fostering critical analytical and interpersonal skills. CBL's emphasis on reflection and application helps students develop immediately useful life and work skills while preparing them for long-term career readiness (Olivares et al., 2021).

Multicomponent Intervention

Multicomponent interventions combine two or more intervention approaches to address complex issues, creating impact across individual, local, and systemic levels. Originally applied in health and social sciences, for example in fighting obesity, these interventions achieve greater impact through the strategic alignment of different components than any single component could achieve independently (Higgins et al., 2019).

Challenge-based learning, with its seven key components and iterative –sometimes fuzzy– learning cycle, presents an inherently complex educational intervention where components interact in non-linear ways. This complexity makes CBL particularly suitable for multicomponent intervention analysis. First, CBL assessment must consider both immediate learning outcomes and longer-term professional readiness indicators. Second, like health interventions, CBL aims to create sustainable behavioral changes through ongoing engagement with real-world challenges. Third, the framework emphasizes context adaptability, allowing the approach to be adapted to different disciplines while preserving fundamental principles of experiential learning and real-world engagement.

This alignment between multicomponent intervention principles and CBL's structure provides a framework for evaluating how, and how effectively, CBL prepares students for workplace and societal demands. The multicomponent intervention approach allows us to examine the individual impact of each CBL component as well as their collective contribution to student development. This provides a comprehensive assessment methodology for measuring and improving educational outcomes.

This practice paper has two primary goals. First, we document the development and implementation of "Designing Inclusive Education at Montclair," a student-designed CBL course that demonstrates how complex challenges can be effectively addressed across multiple student cohorts. We share both the course structure and preliminary, observational outcomes from three semesters of implementation, providing a practical model for institutions seeking to implement sustained challenge-based learning experiences. Second, building on these early implementations, we propose a multicomponent intervention framework for evaluating how CBL's seven core components contribute to workplace and societal readiness. By sharing both our practical experience and multicomponent intervention framework, we aim to contribute to the growing body of knowledge about effective CBL implementation in higher education while offering concrete tools for assessing its impact on students' workplace and societal readiness.

2. METHODS

Course Curriculum Context

The development of "Designing Inclusive Education at Montclair" followed an innovative, student-centered approach. The first iteration was a 7-week mini-course (2.5 hours per week) where undergraduate students explored the topic and designed the syllabus for what would become a full-semester course offered to a next cohort. This initial phase established the foundation for subsequent iterations and reflects CBL's emphasis on student agency. The course has now completed two additional semesters of implementation, with each cohort building upon previous work while maintaining autonomy to pursue new directions within the broader challenge of improving campus inclusivity. Notably, the course structure allows students to enroll for up to two semesters, with returning students taking on leadership roles and mentoring new participants. This creates a realistic model where institutional knowledge is preserved and transferred between cohorts, similar to workplace practices.

Study Population

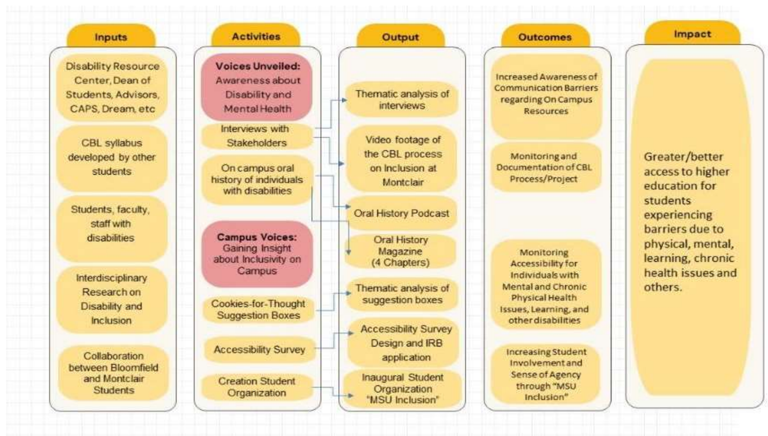
The course enrolls undergraduate students from diverse academic disciplines across campus, including, but not limited, to psychology, business, policy studies, journalism, and disability studies. The multidisciplinary nature of the student population resonates with CBL's emphasis on bringing multiple perspectives to complex challenges. Each semester enrolls 6-20 students, with approximately 10-20% continuing on for an additional semester in mentorship roles. The number of returning students is relatively low due to course schedules interfering with enrolling a second semester. This mix of new and returning students stimulates the need to document and transfer, and creates a dynamic learning environment where fresh perspectives infuse accumulated project experience.

Students represent various academic levels (sophomore through senior), major academic fields and diverse personal backgrounds. The course attracts a significant number of students who either have disabilities themselves or have experience advocating for disability rights, adding valuable lived experience to the project's perspective. This diversity enriches the approach to inclusive education challenges.

Intervention/innovation implemented

“Designing Inclusive Education at Montclair" innovates by extending and also iterating CBL's Engage-Investigate-Act cycle across multiple semesters. Unlike traditional courses that restart each semester, this course maintains continuity through a unique "fade-in, fade-out" structure. As new student cohorts join the ongoing challenge, they build upon work from previous cohorts, while maintaining flexibility to pursue new directions. This structure not only addresses faculty’s concern about having to tailor a challenge to the format of a single course but also deliberately mirrors workplace reality, where projects often span beyond individual team members' tenure, requiring effective documentation and knowledge transfer. Students learn crucial professional skills as they manage project handovers, maintain progress documentation, and orient new team members - experiences rarely available in traditional semester-bound courses. So far students have engaged in two major initiatives through stakeholder consultation: "Voices Unveiled," focusing on disability and mental health awareness, and "Campus Voices," gathering data about campus inclusivity (Table 1). The current cohort is administering a student-designed survey on campus accessibility, research approved through the Institutional Review Board, while simultaneously engaging with key stakeholders - including faculty experts and facilities management – with the goal of developing evidence-based proposals to the university administration. This innovative structure develops important workplace competencies including project continuity management, stakeholder engagement, and evidence-based decision-making, while fostering meaningful institutional change in campus inclusivity and accessibility.

Table 1. *Logical framework of the past semesters' implementation of the student-designed CBL course "Designing Inclusive Education at Montclair"*



Next steps: Multicomponent Intervention Design

Building on three successful semesters of implementation, we are now developing a comprehensive evaluation framework to systematically assess how CBL's seven components - complex authentic challenges, stakeholder involvement, interdisciplinary perspective, workplace and life skills development, student agency, entrepreneurial attitude, and focus on impact - individually and collectively contribute to workplace and societal readiness. The evaluation framework will track student development across the seven key CBL components (Table 2). Each CBL component will be evaluated both independently and in combination with others. Students will document specific examples of skill development tied to component interactions. Weekly guided reflections will explicitly connect experiences to workplace and societal competencies. Standardized documentation templates will be used regularly to monitor progress. Structured stakeholder feedback will evaluate students' professional capabilities. To provide implementation support we will give clear guidelines connecting each CBL component to specific readiness outcomes, craft reflection prompts guiding students in exploring competency development, and use progress tracking tools such as surveys for monitoring development across all components.

This systematic approach will allow us to identify which combinations of CBL components are most effective for different student populations and project contexts, while providing evidence-based insights about the effectiveness of CBL experiences in preparing students for their professional and societal roles.

Table 2. *Intervention Dimensions with Integrated CBL Components*

CBL Component	Workplace Readiness Impact	Societal Readiness Impact	Implementation
Authentic Challenges	• Problem framing in complex situations • Working with real constraints and deadlines • Deliverable-focused project management	• Understanding community needs • Connecting individual actions to broader impact • Ethical decision-making in real contexts	• Students identify and define campus accessibility challenges • Document constraints, resources, and success criteria • Create project timelines with clear deliverable
Stakeholder Involvement	• Client relationship management • Needs assessment skills • Professional networking	• Community partnership building • Inclusive decision-making • Participatory process facilitation	• Regular meetings with campus stakeholders • Documentation of stakeholder input • Integration of feedback into solution
Student Agency	• Initiative-taking • Decision-making responsibility • Resource allocation choices	• Civic leadership development • Community advocacy skills • Change agency mindset	• Students choose specific accessibility challenges • Determine project scope and priorities • Make team role and responsibility decisions
Interdisciplinarity	• Cross-discipline collaboration • Integration of diverse perspectives • Systems thinking	• Understanding complex social issues • Holistic problem-solving • Multi-stakeholder consideration	• Teams include students from different disciplines • Solutions must address multiple aspects (technical, social, economic) • Integration of various disciplinary approaches
Work and Life Skills	• Project management • Professional communication • Team collaboration	• Cultural competence • Inclusive practices • Community engagement skills	• Weekly project management check-ins • Structured stakeholder communication • Team effectiveness assessments
Entrepreneurship	• Innovation mindset • Resource optimization • Value proposition development	• Social innovation skills • Sustainable solution design • Community resource leveraging	• Solution feasibility analysis • Resource requirement planning • Implementation strategy development
Creating Impact	• Results orientation • Outcome measurement • Implementation planning	• Social impact assessment • Community benefit analysis • Sustainable change creation	• Development of impact metrics • Regular progress assessment • Documentation of outcomes

Through Qualitative Comparative Analysis (QCA), we will examine how the seven CBL components combine to produce successful outcomes in student development. For instance, in projects where students have limited prior work experience, the combination of authentic challenges, strong stakeholder engagement, and focused life/work skills development might be crucial for achieving workplace readiness. The authenticity keeps students engaged, stakeholder interaction provides professional exposure, and explicit attention to work skills fills knowledge gaps. The QCA approach helps us understand which combinations of components are most effective for different student profiles, and how components interact to support workplace and societal readiness. This analysis would help allocating resources effectively across components.

3. RESULTS

Our three-semester implementation of "Designing Inclusive Education at Montclair" has generated significant insights into effective CBL practice while revealing key patterns in how components interact to develop workplace and societal readiness, two skill sets identified as often problematic in existing HE outcomes.

Each cohort's work contributes to a growing body of documentation, including thematic analyses of interviews conducted with stakeholders as well as of suggestion box data, multimedia documentation, white papers and project reports, ensuring continuity and progress toward long-term goals while maintaining the flexibility to respond to emerging needs and opportunities (Table 1). The student-designed aspect of the course has proven particularly powerful for their engagement. When students took ownership of the course design process, they demonstrated notably higher commitment to project outcomes and sustained involvement. This ownership translated into increased interest and confidence in professional skills, particularly when students faced authentic but sometimes difficult project decisions. The opportunity to enroll for multiple semesters created natural leadership progression, with returning students effectively mentoring new cohorts and facilitating transfer of earlier results.

Stakeholder relationships emerged as a crucial success factor. Early and consistent involvement of campus stakeholders, including administrators, faculty, and service providers, provided students with authentic professional interactions. Through these repeated engagements, students developed sophisticated stakeholder management skills. The "fade-in, fade-out" course structure proved effective in maintaining consistent stakeholder relationships despite changing student cohorts.

Project continuity has been successfully maintained through structured documentation practices. White papers and detailed project documentation enabled smooth transitions between cohorts, while returning students effectively bridged knowledge gaps. This ongoing nature of the challenge created realistic workplace scenarios, requiring students to manage long-term project progression and knowledge transfer.

Our observations and student reports on their development during the previous semesters reveals several high-impact combinations. The pairing of authentic challenges with stakeholder involvement consistently accelerates the development of professional communication skills and organizational understanding. Similarly, when student agency is combined with focused work/life skills development, students show marked ability in project management capabilities. Cross-disciplinary teams, while requiring more initial support, achieve stronger outcomes by integrating multiple perspectives into comprehensive solutions.

Component integration and iteration emerged as critical to student development. Authentic challenges, co-selected by the students, created immediate engagement, while gradually increasing stakeholder involvement allowed students to build confidence naturally. Entrepreneurial aspects emerged organically as students identify implementation opportunities and develop solution strategies. Students with limited work experience particularly benefit from structured stakeholder interactions, while returning students demonstrate stronger integration of entrepreneurial thinking with impact creation.

The institutional impact has been substantial. Student-led research has provided valuable data about campus inclusivity, while the "Voices Unveiled" initiative has increased awareness of disability and mental health issues. Stakeholder feedback indicates growing institutional support for the student-led accessibility initiatives.

These observations inform our planned multicomponent intervention design (Table 1) and suggest that CBL's effectiveness depends heavily on thoughtfully structuring component interactions while maintaining flexibility for organic skill development. The patterns observed in component interactions will guide our future assessment framework, particularly in understanding how different combinations of components support various aspects of workplace and societal readiness.

4. CONCLUSIONS

The implementation of "Designing Inclusive Education at Montclair" demonstrates how CBL can effectively bridge the gap between academic learning and workplace readiness while creating meaningful institutional change. Our experience yields several interconnected recommendations for future CBL implementations. Institutions should begin with a pilot phase that empowers students to shape the course design, as demonstrated by our successful 7-week mini-course where student involvement in syllabus development created strong engagement and ensured alignment with student needs. Course timelines should maintain flexibility to accommodate the unpredictable nature of real-world challenges, allowing projects to evolve naturally while meeting academic requirements.

The integration of multi-semester enrollment opportunities proved crucial, enabling authentic leadership development as experienced students mentor new cohorts. This continuity depends on robust documentation practices, including regular reflection protocols, established from the outset. Early and sustained stakeholder engagement not only develops important professional skills but also helps maintain project momentum. These structural elements, when thoughtfully implemented, create a foundation for sustainable CBL that develops workplace competencies while maintaining academic rigor.

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ON-LINE CHALLENGE-BASED LEARNING FOR ENGINEERING STUDENTS FROM DEVELOPING COUNTRIES – REFLECTION AND EVALUATION OF AN INTERNATIONAL ONLINE PROJECT (PRACTICE PAPER)

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ABSTRACT

This paper advocates for Challenge-Based Learning (CBL) as an effective pedagogical approach within South African engineering education, addressing the gap between theoretical knowledge and practical application in a context marked by socio-economic challenges and limited resources. The study aims to evaluate the potential of CBL, specifically through remote competitions like the BRICS Future Skills Challenge, to support student engagement with real-world engineering problems and provide access to advanced technology despite infrastructural limitations. Utilizing a qualitative approach, the research also reflects on the alignment of CBL activities with the Engineering Council of South Africa's (ECSA) Graduate Attributes (GAs), that are essential competencies expected of engineering graduates.

In examining the BRICS Future Skills Challenge, a drone-focused competition accessible remotely, this study found that CBL effectively supports the development of critical skills in problem-solving, interdisciplinary collaboration, and ethical awareness. Participants engaged in complex, real-world tasks such as autonomous drone navigation, gaining hands-on experience with advanced mobile robotics control systems. This CBL framework not only met ECSA requirements but also provided a scalable, cost-effective model for addressing educational disparities in resource-constrained environments.

In conclusion, integrating CBL into engineering curricula, particularly through remote-access competitions, offers a promising pathway for developing essential engineering skills in students from developing countries. This approach fosters practical, relevant learning experiences, promoting innovation, adaptability, and a commitment to societal impact, preparing students effectively for the modern engineering landscape.

1. INTRODUCTION

With this practice paper, the authors argue for more inclusion of Challenge Based Learning (CBL) within a South African engineering education context. The engineering council of South Africa (ECSA) prescribes that South African universities incorporate and assess eleven graduate attributes (GAs) in engineering programmes (ECSA, 2018). ECSA requires that when engineering students graduate with an engineering degree, they should have proven competence in all eleven GAs. The GAs are listed as problem solving, application of scientific and engineering knowledge, engineering design, investigations, experiments and data analysis, use of engineering tools, the engineer and the world, individual and collaborative teamwork, independent learning ability, engineering professionalism and project management and finance (ECSA, 2023).

With these requirements, problem and project-based learning has been widely practiced by engineering faculties due to the expected benefits of improving students' academic achievement and transferable skills (Kolmos and Fink, 2004). CBL has however become an increasingly popular learning methodology in higher education institutions (HEI) (Doulougeri, Vermunt & Bombaert, 2024). CBL follows a workflow that contributes to preparing students for the workplace and allows for students to be creative and self-directed while support, boundaries and check points are provided (Nichols & Cator, 2008). Traditional teaching and learning strategies are therefore becoming increasingly ineffective to meet ECSA requirements and for a generation who has instant access to information, vast on-line social networks (Nichols & Cator, 2008).

Following this, one of the authors of this research was the nominated South African expert for drone operations in the BRICS Future Skills Challenge. The skills challenge involved using drones to solve real world problems through control systems developed by competitors. The format of the challenge is on-line with teams competing internationally. Hence, the aim of this research is to reflect on this engineering activity in terms of meeting requirements set by ECSA, framed as a CBL pedagogy and to explore the benefits and provide recommendations for developing a similar experience for students within the formal engineering curricula.

To meet these aims, this paper starts with defining and discussing CBL and then proceeds to provide context and background to engineering education in HEI in South Africa. Thereafter a discussion of the BRICS Future Skills Challenge is provided, and a reflection on how it meets the criterion for CBL, ECSA requirements and its benefits.

1.1 Challenge-based learning (CBL)

CBL is a pedagogical approach that is increasingly being used in engineering education, however, there appears to be little consensus in literature about how CBL is practiced in engineering faculties. Doulougeri et al., (2024) further provides a summary of CBL as seen in Table 1 below:

Table 1: *Definition of CBL (Extract from Doulougeri et al., 1079:2024)*

Type of problem	Learning process	Teachers' role	Outcome
CBL starts with a real-world global challenge. Challenges are interdisciplinary, requiring students to integrate knowledge and skills from multiple areas. Often, challenges are presented by external stakeholders.	Students propose a solution for the global challenge by choosing the focus of the specific problem within the challenge, investigating, ideating, and implementing solutions.	Teacher acts as a facilitator, coach, or co-creator of the solution for the challenge.	The primary outcome is a proposed actionable solution for the identified challenge. The learning process & knowledge and skills students gain during the process are equally important.

CBL enhances traditional active learning methods by promoting autonomous and collaborative learning in a relevant context. Its primary goal is to develop both disciplinary and transversal competencies in students through engagement with real-world challenges. What distinguishes CBL is the focus on challenges that are socially relevant and aligned with sustainable development goals (SDGs), often presented by external partners, including industry and local communities. The learning process emphasises collaboration among students, educators, and external stakeholders, fostering a co-creative approach to problem-solving. This collaboration ultimately leads to the development of practical solutions that address both technical and societal issues (Doulougeri et al.,2024).

Malmo university argues that with a CBL approach HEIs can transform learning and will actively contribute to the building sustainable learning societies (Christersson et al., 2022). Furthermore, they propose that the CBL approach encompasses the following key elements:

- Advancing the role of higher education institutions in society.
- Includes theories of lifelong learning in addition to theories of knowledge.
- Actively integrating interdisciplinary research, education, and innovation in HEIs.
- Acknowledge and build on students' individual experiences, background, and identity.
- Collaborative and pedagogical methodologies for student-centred learning.
- Applying real-world challenges to initiate learning processes.
- Including national and international cooperation with a variety of societal partners.
- Promoting the impact of change toward a learning society.

The eight elements were further grouped into three domains namely diversity and inclusion, co-creation and collaboration and change agents and contextual challenges. Malmo University argues that HEIs will play a vital role in fostering a sustainable global learning society by embracing CBL. The social mission of HEIs is crucial, particularly in supporting the CBL domain of Diversity & Inclusion, as they develop innovative and collaborative approaches to learning and research aimed at driving social innovation. Additionally, HEIs are essential in responding to the rapidly evolving technology landscape and labour market, which require active and creative citizens who are prepared to reskill and relearn. This responsibility highlights the need for the CBL domain of collaboration and co-creation, where students, faculty, and community stakeholders can address complex societal issues through interdisciplinary learning that integrates practical application with theoretical understanding (Christensson et al., 2022).

Based on the preceding literature, the following benefits of CBL becomes evident (Doulougeri et al., 2024) and (Christensson et al., 2022):

- Student engagement: CBL promotes student engagement with complex societal challenges within real-world contexts.
- Competency development: It aims to develop both disciplinary and transversal competencies in students.
- Relevance: CBL focuses on socially relevant challenges aligned with sustainable development goals (SDGs).
- Collaboration: It fosters collaboration among students, educators, and external stakeholders, including industry and local communities.
- Practical problem-solving: CBL leads to the development of practical solutions addressing both technical and societal issues.
- Transformation of learning: Higher education institutions can transform learning through CBL, contributing to building sustainable learning societies.
- Interdisciplinary approach: CBL actively integrates interdisciplinary research, education, and innovation in higher education.

- Student-centered learning: It incorporates collaborative and pedagogical methodologies for student-centered learning.
- Real-world application: CBL applies real-world challenges to initiate learning processes.
- Societal impact: It promotes change toward a learning society and fosters social innovation.
- Adaptability: CBL prepares students to be active and creative citizens capable of reskilling and relearning in a rapidly evolving technology landscape and labor market.
- Change agency: Students, staff, and stakeholders become scholarly change agents, working collaboratively to co-create an uncertain future. These benefits demonstrate the potential of CBL to enhance engineering education by providing a more holistic, practical, and socially relevant learning experience.

Having explored the concept and benefits of CBL, it is essential to contextualise its application within the South African higher education engineering landscape in the section following.

1.2 The South African HEI engineering context

The causes of South Africa's poor academic performance are vast and multidimensional and includes factors such as low socio-economic status and lack of resources (Kutu et al., 2020). Furthermore, the education system in characterised by unequal education structures between affluent and no-affluent schools, poor academic performances, and high drop-out rates (Kutu et al., 2020).

Student retention and programme completion are challenges faced by most faculties (Bantjes et al., 2020; Bantjes et al., 2021), and more so in demanding programmes such as engineering (Pocock, 2012; Mapaling, 2023). Previous research (Lourens & Mapaling, 2023) indicated that engineering is not always students' first choice of study as the choice is often made for them by other family members. Therefore, it's important for universities to ensure they retain the students they attract. Students list perceived challenges that could influence their ability to successfully complete their studies as life skills in addition to worries about accommodation, meals, family members at home and lacking resources such as data and laptops (Lourens & Mapaling, 2023). In a study by the University of Windsor (2022), they also underscored the importance of life skills as a factor that can influence student success and retention and found that students often struggled with personal finance management, time management and self-care.

The shortage of qualified people in the areas of science, technology, engineering, and mathematics is a recurring problem in South Africa and regarded as one of the obstacles to economic growth in the country (Erasmus and Breier, 2018). They further suggest that the skills shortages in STEM can be traced back to the inefficiencies in the current education and training pipeline which is known for low math and science output.

In 2018, the Sunday Times Live published an article by Govender titled "Joint effort needed to fix university dropout rate: Engineering students find going toughest of all, with half of them ditching their studies". More recently, ECSA reported that only 54% of students enrolled in the selective four-year Bachelor of Engineering (BEng) programs graduated within five years, with just 19% remaining registered after that period (ECSA, 2022). This data aligns with findings from Scott et al., (2007), which indicated minimal progress in student retention and success over the past 15 years. Moreover, the implications of this issue extend beyond students, affecting their potential income and future opportunities, as well as leading to burdensome student debt. These factors pose personal and social concerns for students and have financial repercussions for universities regarding subsidies and fees (Pocock, 2012).

In summary, given the challenges faced by the South African HEI engineering context, CBL can play a pivotal role. By fostering a more engaging and supportive learning environment, CBL can help mitigate the effects of socio-economic disparities, improve student retention, and enhance the overall educational experience.

By integrating CBL into the engineering curriculum, universities can create a more inclusive and effective educational environment that addresses the unique challenges faced by South African students. In the section following, the BRICS Future Skills Challenge is discussed as a potential CBL pedagogy.

1.3 BRICS Future Skills Challenge

The BRICS alliance, composed of 9 countries, represents a coalition of emerging economies committed to driving global progress across various sectors, including education. BRICS aims to foster educational cooperation through initiatives that promote digital literacy, technical skill development, equitable access to quality education, and sustainable knowledge exchange among member nations. Their educational policies emphasise creating digital education frameworks, supporting vocational training, and enhancing collaboration between institutions. One key initiative aligned with these goals is the BRICS Future Skills Challenge, an international competition designed to equip students with vital skills for the 21st century, including advanced technologies like robotics and drone operations.

Through challenge-based and remote learning models, these competitions provide students with opportunities to engage in real-world problem-solving, access high-tech resources, and participate in collaborative learning, regardless of their geographical or resource limitations. By supporting practical skills development and digital access, the BRICS Future Skills Challenge helps to advance BRICS' commitment to inclusive, quality education and prepares students for dynamic global workforce demands (http://inpdp.org/en/brics/).

2. METHOD

There has been increased emphasis on the role of reflexivity in qualitative research (Deggs & Hernandes, 2018) and Valandra (2012) argued that reflections can be useful while conceptualising the study, implementing the study and as in this case, writing about the study and it helps to make meaning. In this paper, the researcher will reflect on the planning and execution of the BRICS world-skills project in terms of it bringing the benefits of CBL whilst also meeting ECSA GA requirements.

2.1 Research design

Learning Setting

One year process where experts in industry define real world challenges. Together they agree on the challenge to be accepted for that year’s competition, and then make it available to students as a technical spec and outcome requirement. Students are invited to attend free online workshops hosted by experts in the industry where students are introduced to the software tools and hardware knowledge that they would require.

Participants

University students, however even outside parties may participate who are not affiliated to a university.

Methods and tools used

Experts identify a centralised testing facility where equipment can be installed that students will have access to over internet connections. The facilities may include robotic production lines, small, scaled roads and robotic cars or in the case of aerial robotics, a large 3-dimensional indoor space where obstacles have been set up to mimic the layout of factory environments. Multiple electric multirotor drones are placed within the flying area able to receive code from students over an internet connection. The drones will fly the mission developed by the students and at the time of the competition demonstrate each student's solution to the challenge. These solutions may require implementation of sensors, cameras, and actuators on the drones that the students have designed as part of the challenge solution.

Resources required

Industry experts and mentors. The setup of a centralised test facility requires funding from interested members of industry. These test facilities are often funded by multiple nations and their respective industry experts. A single venue in one country can act as a test site for students from all corners of the world with industry partners often willing to support such cost-effective training facilities.

The individual universities no longer need the financial resources to fund a venue, equipment, and technicians. Students only need access to the internet, ideally through a laptop or PC that they own, to have access to relevant equipment that is being used in industry at present or in the near future.

Industry experts will attempt to make use of software that is open source or freely available to students. The software used in the BRICS 2024 challenge consisted of Robot Operating Software (ROS), Gazebo, Linux Ubuntu, Python and various social media platforms and online meeting tools which are all freely available to students.

2.2 Analysis and reflection

This section provides a reflection on the alignment of BRICS Future Skills Challenge with CBL principles and the resultant benefits specific to the South African context in terms of ECSA requirements and challenges faced by HEI and engineering students.

2.2.1 Alignment with CBL

The BRICS aerial robotics challenges engage students in complex, real-world tasks that require collaboration, problem-solving, and critical thinking. The challenges immerse students in scenarios that are directly relevant to engineering, robotics, and drone technology.

CBL is driven by inquiry, where students are encouraged to explore solutions and refine their approaches iteratively. In the BRICS challenges, students research literature on drone navigation and control, investigate various control methods (like using ROS and Python), and analyse each step in the drone's sequence of tasks. Each test flight in Gazebo or real-time feedback from a physical drone offers data for further inquiry and refinement.

Many tasks, such as controlling drones in obstacle-filled environments or analysing data from sensor feedback, are team-oriented. Students must work with others in multi-disciplinary and often multi-cultural teams, using shared knowledge to devise strategies, troubleshoot, and optimise their solutions. This collaborative environment strengthens communication and adaptability, central aspects of CBL.

In competition settings, students can observe the impact of their scripts on live video feeds as drones perform their commands in real environments. This direct observation lets them adjust parameters (like drone speed or wait times) to improve accuracy and efficiency. Real-time feedback enhances their ability to think critically and refine their approach iteratively.

Tasks like GPS-denied navigation or indoor object detection using colour analysis require students to apply higher-order thinking. They must break down problems into manageable steps, sequence commands logically, and think strategically to accomplish multiple objectives in a single flight sequence (e.g., navigating, analysing colour, and landing). This experience builds not only technical knowledge but also system-thinking skills, essential in advanced robotics and engineering.

Challenges like traffic monitoring and autonomous pesticide spraying align with sustainable development goals, making technology applicable for societal needs such as public safety and agriculture. Students learn to create solutions with consideration for societal impact, understanding how drone technology can be used responsibly for sustainable purposes. Through challenges that involve surveillance, students engage with ethical aspects, such as privacy and public safety. Learning to respect privacy while harnessing drone capabilities highlights the societal responsibilities of technology, a key component of CBL. The BRICS challenges assess students on progress and approach, not just on reaching a perfect result. Points are awarded for each step completed in the drone's journey, such as taking off, reaching a destination, analysing colour, or landing, regardless of perfect execution. This process-based assessment reflects CBL's emphasis on learning from mistakes and improving over time.

By allowing students to use Python libraries and ROS commands creatively, the challenges promote experimentation. Students can devise their own unique solutions to each problem, exploring different approaches and finding innovative ways to achieve goals.

In summary, the BRICS aerial robotics challenges integrate CBL by placing students in real-world, socially relevant scenarios that require innovation, collaboration, and higher-order thinking. By using advanced tools like ROS and Gazebo simulation students engage in a cycle of inquiry, testing, and refinement, mirroring professional engineering problem-solving. This approach not only enhances technical skills but also develops adaptability, teamwork, and ethical awareness, preparing students to meet the demands of modern engineering fields with a focus on continuous improvement and societal impact.

2.2.2 Alignment with ECSA

Table 2 below explains how the challenges align with the GA requirements of ECSA:

Table 2: *Summary of alignment of challenge with ECSA requirements*

GA	EVIDENCE
GA 1: Problem-Solving	Students identify and define complex tasks, such as autonomous indoor navigation, and research ROS and Python libraries to analyse solutions. Long term testing in Gazebo simulation, or on real drones, gives them data to refine code, allowing them to reach informed, data-backed conclusions.
GA 2: Application of Scientific & Engineering Knowledge	Controlling drones in 3D space requires students to use mathematical modelling and apply physics principles. Programming in a ROS environment requires them to apply these principles as well as computing logic fundamentals.
GA 3: Engineering Design	Students are required to design and prepare files for production of any component necessary to achieve a solution to the challenge. These may include mechanical actuators, sensors, and camera stabilisation gimbals.
GA4: Investigations, Experiments, and Data Analysis	Due to the potential for physical damage if a drone is not controlled correctly, students are forced to engage digital twins in a Gazebo simulation environment first. Analysing flight paths and drone responses over time they gather data and refine their methods, using each test to validate or adjust their conclusions.
GA 5: Use of Engineering Tools	Using ROS, Digital Twins and Gazebo Simulation exposes students to real world engineering tools used in engineering prediction. Drones are becoming more relevant to industry challenges.
GA 6: Professional and Technical Communication	Working in international teams, students must communicate their plans and findings clearly, adapting technical language as needed. The required reporting and presenting of their results to other international teams teaches concise and accessible communication skills.
GA 7: The Engineer and the World	Drones are becoming an ecologically sound solution to many engineering challenges. Students learn to consider the broader societal implications of their work, such as public safety and responsible resource use when competing in BRICS challenges.
GA 8: Individual and Collaborative Teamwork	Team-based tasks require students to work collaboratively, leveraging each member's skills. The need for sensor and actuator design, coding and analysis requires essential teamwork and adaptability skills.
GA 9: Independent Learning Ability	Students learn the new tools independently. They adapt to new tools and refine their solutions autonomously, building confidence in self-directed learning. Thereafter they form teams and work collaboratively.

GA 10: Engineering Professionalism	Ethics are emphasised especially in challenges involving surveillance or populated areas of operation. Students consider privacy and safety. Understanding these principles helps students uphold ethical standards in professional practice
GA 11: Project Management and Finance	Students manage code structure, resources, and timing in preparation and testing before the final challenge, as well as in the execution of their final solution demonstration. This experience builds project management skills essential in engineering, particularly within time and resource constraints.

These GAs reflect the core goals of CBL by requiring students to apply theory in real-world scenarios, collaborate effectively, adapt to tools and environments, and focus on sustainable, ethical solutions. The BRICS aerial robotics challenges are structured to foster these skills, preparing students for diverse engineering roles.

2. RECOMMENDATIONS AND CONCLUSION

Integrating CBL through remote competitions into engineering curricula can provide students with practical skills, enhance motivation, and prepare them for real-world engineering challenges. Remote CBL competitions could be included as capstone projects in final-year courses. This will not only benefit students but allow for closer industry partnerships. In addition to technical skills, competitions can be used to develop and assess soft skills like teamwork, communication, and time management. Students could be required to work in diverse teams to complete tasks, with performance evaluations reflecting both technical and interpersonal contributions. Remote CBL competitions align with graduate attributes such as problem-solving, effective communication, and ethical awareness. These competitions can be mapped to these attributes in the curriculum, providing tangible ways to demonstrate competence across core engineering skills.

Furthermore, it is suggested that CBL can specifically help alleviate the following problems:

Engagement and Motivation: CBL involves real-world challenges that are relevant to students' lives and future careers. This relevance can increase student motivation and engagement, making them more likely to persist in their studies.

Skill Development: CBL emphasises the development of critical thinking, problem-solving, and collaboration skills. These skills are essential for success in engineering and can help students manage their time and resources more effectively.

Supportive Learning Environment: CBL often involves teamwork and mentorship, which can create a supportive community for students. This sense of belonging can improve retention rates, especially for first-generation students who may feel isolated.

Practical Application: By working on real-world problems, students can see the direct impact of their education, which can be particularly motivating. This practical application can also help bridge the gap between theoretical knowledge and practical skills, making students more prepared for the workforce.

Resource Utilization: CBL can leverage available resources more effectively by integrating technology and community partnerships. This can help alleviate some of the resource constraints faced by students, such as access to data and laptops.

Life Skills: Through CBL, students can develop essential life skills such as personal finance management, time management, and self-care, which are crucial for their overall success and well-being.

The analysis of the BRICS Future Skills Challenge, with a specific focus on the drone challenges, provides valuable insights into the effectiveness of CBL in enhancing engineering education. This in not only relevant for developing countries but can be used as an effective teaching pedagogy world-wide.

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HOLISTIC DESIGN PEDAGOGIES: BSc BOUWKUNDE CURRICULUM RENEWAL EXPERIENCES

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ABSTRACT

This practice paper deals with the curriculum renewal of the Bachelor's *Bouwkunde* program of the Faculty of Architecture and the Built Environment, TU Delft. It focuses on design education as a form of CBL and its pedagogical fundamentals in particular. The paper describes the program and the intentions for curriculum renewal, followed by an explanation of the new learning objectives and assessment strategy. Finally, it touches upon the team development process and lessons learned so far.

Holistic learning objectives and a holistic assessment strategy were developed to foster the curriculum renewal objectives and accommodate the integrative nature of design, design thinking, and design education. The design program's learning objectives are based on four strongly related skills that were further detailed for every course: position, knowledge, research, and communication. To do justice to the importance of coherence and interaction between these four different parts, design needs to be assessed holistically. At an abstract level, aspects that count for all spatial designs were formulated, no matter how different they appear in various design outcomes: coherence & meaning, correctness & elaboration, communication, and research. However, they are strongly connected and are hard to assess independently.

In the academic year 2024-2025, the renewed learning objectives and assessment strategy are used in education practice. We expect these will help to address the essence of developing and assessing (design) proposals to intervene in complex systems. Its use will be actively monitored, and the outcomes will be used to improve next year's curriculum.

1. INTRODUCTION

Curriculum renewal

In 2022, the TU Delft Faculty of Architecture and the Built Environment decided to update its Bachelor's *Bouwkunde* Program (BSc Architecture, Urbanism and Building Sciences) after ten years of intensive use (Hoekstra et al., 2023). The ambition of the broad bachelor's program is to educate students to become "skilled, academic and context-aware designers of the built environment" (ibid: p31). Design education (*Bouwkundig ontwerpen*) is one of the fundaments of the program and integrates architectural, landscape architectural, urban, and building technological design thinking. The design of the (un)built environment is full of socio-spatial challenges that our students are confronted with during their studies: the climate crisis, the housing crisis, the urban inequality crisis, and the scarcity of resources crisis, to name four important ones (Van Gameren, 2021). The *Bouwkunde* discipline and pedagogy itself have shifted towards interdisciplinarity and transdisciplinarity. Also, technological developments in the field of design and the field of teaching and learning urged us to reconsider our pedagogies.

Design education

The bachelor *Bouwkunde* design education – particularly the second and third-year program – is challenge-based (Cavallo & Quist, 2023; Rooij & Mooij, 2022, 2024). Design challenges come from practice or are developed in collaboration with stakeholders from practice. The definitions of the design challenges need reinterpretation and positioning by the students. The intended project outcomes are not fully clear at the beginning of the project. The design process and the working method must develop and settle over time. There are different ways how students collaborate. The roles of teachers are diverse.

Designing is a layered and complex skill (Van Dooren, 2024; Lawson & Dorst, 2009). It is open-ended: there is an endless solution space. It can be 'vague'; very often, it is goal searching and not always goal-oriented. Many things that need to be integrated into the design are unknown initially; they are 'discovered' during the design process, such as form, space, material, function, situation, and societal context. In design, one works at and across several spatial and temporal levels: from building detail to regional landscapes, from here and now to far in the future. Design is personal and has different (cultural) traditions; there are many design approaches and methods. At the same time, certain generic elements can always be found in design processes (Van Dooren, 2020). We aim for students learning to master and maneuver within this field.

Problem to address

In our faculty, we heard quite some complaints about the (inter)subjective nature of design assessments. Students often had a hard time understanding the process and outcomes of design assessments. Our design project coordinators and design tutors - tenured university teachers, external practice teachers, individually or paired in teams - feel responsible for coming to fair and transparent assessments but do not always have the knowledge, experience, language, or tools to do so. Also, the curriculum lacked an explicit, well-structured, aligned, progressive, and systematic assessment approach for all design projects in the curriculum. In the recent bachelor renewal, this issue was taken up by the team that had to renew the Design program, first and foremost, by reconsidering its fundamentals: the learning objectives, assessment structure, assessment criteria, and the language used to present and explain these to students and staff.

Paper objective and structure

This practice paper's objective is to present the curriculum team's decisions and discussions regarding the descriptions of the learning objectives and assessment strategy of the Design program (*leerlijn*) within the BSc *Bouwkunde* degree program renewal. The following section presents more information about the program and the intentions for curriculum renewal. In the results section, we explain the learning objectives and assessment strategy's why, what, and how. We will also briefly touch upon the team development process. The concluding section will present our lessons learned and the next steps.

2. CONTEXT

BSc *Bouwkunde* at TU Delft

The TU Delft Faculty of Architecture and the Built Environment has one broad, 3-year bachelor's degree program taught in Dutch. There is a Numerus Fixus of 450 students, and about 1400 students are enrolled in the program. The renewed program (Figure 1) that started in September 2025 for all study years and cohorts has five so-called Throughlines (*Leerlijnen*):

Design (*ONtwerpen*): six 10-EC design project modules that culminate in a bachelor final project (*Bachelor Eind Project*) consisting of two connected, integral design projects (*Integrale Ontwerp Projecten*)

Technology (*TEchnologie*): five 5-EC modules focusing on the technological dimensions of construction and the built environment, such as systems thinking, circularity, physics, mechanics, climate design, etc.

Fundamentals (*GRondslagen*): four 5-EC modules focusing on basic concepts in architecture, urbanism, and landscape architecture, past-present-future thinking, and spatial morphological analysis approaches.

Society (*MAatschappij*): three 5-EC modules focusing on studying topical socio-spatial challenges such as climate change, urban resilience, spatial justice, livability, and energy transition that spatial designers work on.

Science and Skills (*Wetenschap en Vaardigheden*): six 5-EC modules focusing on *Bouwkunde* as a scientific design discipline within the engineering sciences and the academic skills that accompany it.

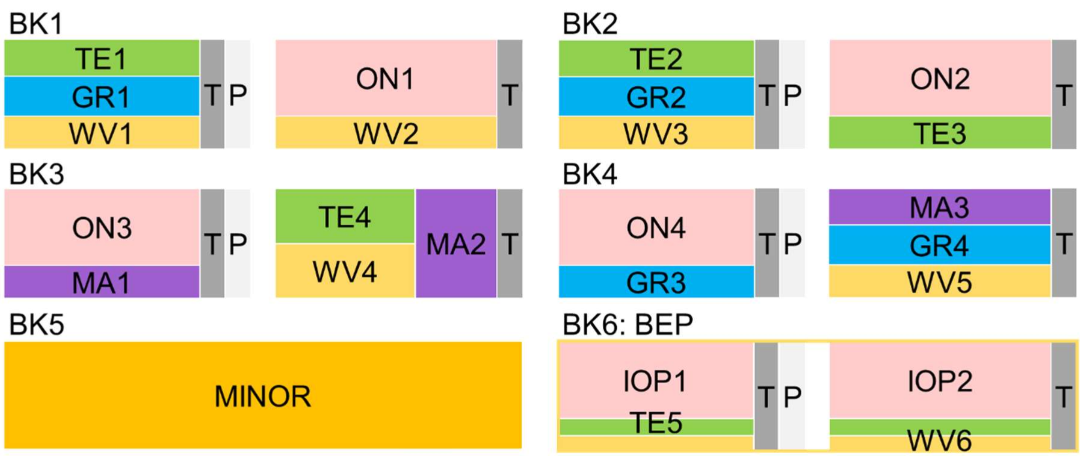

Fig. 1. Curriculum renewal scheme; three study years, four quarters per year, six throughlines, 24 modules, 30EC minor, T-weeks, P-weeks.

Each quarter has a week for tests, exams, and submission moments. Twice a year, a Personal Development Week (Bohm et al., 2023) is offered in which students can freely choose an activity that supports reflection on their personal learning and professionalisation journey.

Each module has a coordination team of two colleagues, ideally from two different Departments: Architecture, Urbanism, Architectural Engineering & Technology, and/or Management in the Built Environment.

Curriculum renewal objectives toward CBL

Three curriculum renewal objectives (Hoekstra et al., 2023) have direct relations to CBL thinking: "Strengthen a more academic attitude via stimulating critical reflection and enlarging the freedom of choice", "Connect the program to topical, socio-spatial sustainability challenges by updating module content and strengthening digital, intra- and interpersonal skills", and "Innovate pedagogies and didactics". The fourth objective – "Less workload and pressure" – trickled down in particular in a slightly adjusted curriculum structure via the T- and P-weeks and a slight reduction of the number of learning objectives. All module and throughline teams were asked to integrate and respond to all four objectives.

3. RESULTS

Challenges in the Design throughline

The bachelor's 60EC Design program is organized and structured in such a way that students systematically develop more in-depth design experiences and skills. Over the years, students encounter various design themes, approaches, methods, and subdisciplines within the field of spatial design. Projects become more complex over time, and students are asked to integrate more diverse and in-depth knowledge each time. All projects are connected to one or more Sustainable Development Goals (Bouwkunde, 2024).

In projects ON1, ON2, and ON3, the assignments are relatively simple to learn the basic skills of architectural, landscape architectural, urban, and building technological design: (ON1) *House and Anchoring in the Landscape* focuses on the living quality of a small residential house, (ON2) *Design and Technology* focuses on sustainable materials and construction for a small public building. In this first-year ON1/ON2 program, all students enroll for the same kind of studio (and thus design) approach.

In the second and third years of the bachelor's program, the design projects focus on relatively more complex, challenge-based assignments, and students can choose their perspectives, focus areas, design approaches, and/or interests:

ON3 City and Public Space. This studio focuses on the structure of urban space and the city's public and private relations. Students choose a particular focus and starting point for their urban design studio enrollment: a socio-morphological, landscape, ecological, cultural-historical, or computational approach. Different specialised teacher teams support and coach the different theme-based student groups.

ON4 - Residential Building and Environment. Upon enrolment, students choose one (out of 5-10) studio with a specific design approach connected to a topical, real-life theme, such as collectivity, affordable housing, renovation, green densification, sustainable (bio-based) materials, or living concepts. Teams of design tutors from both practice and academia lead the different studios.

IOP1 – Area (Re)Development. In this project design, teams of 10 students collaborate in role-play and are asked to develop a spatial vision and redevelopment strategy for an urban district with a time horizon of 50 years. Students can choose their roles: Economic Affairs, Sustainability Specialist, Geo-data Specialist, Landscape Architect, Project Leader, Regional Planner, Real Estate Developer, Real Estate User, Urban Designer, Joker (differs per case, per year). Students are supervised by role tutors – one tutor per role – and group tutors – one tutor for two design teams.

IOP2 – Public Building. This project focuses on an integral and sustainable architectural design of a public building, in line with the Area (Re)Development of IOP1. Students can choose one of three directions to emphasise in their technical detailing: building technology, urban & landscape technology, or building & construction management. For this specialisation, students receive specific and additional tutoring besides their main tutor. Part of the assignment is the development of a personal design vision, statement, or position.

Holistic learning objectives

Students become more proficient in design by doing and practicing, analyzing existing designs and design processes, learning from feedback (self, peer, and expert), and becoming aware of what is essential in the design process. The design process is characterised by four strongly related skills (Van Dooren, 2024), which are the foundation of our Design program's (generic) learning objectives: position, knowledge, research, and communication.

Position

The objective here is learning to develop a position for a specific design situation—also referred to as theme, concept, or vision—and for the student as a designer—also referred to as a value-based design attitude.

This means developing and thinking about one's position or vision as a designer for the design assignment, the socio-spatial challenge, or the theme that characterises the final design proposal. Developing such a position is a dynamic and time-consuming process that involves several iterations. At the same time, constructing such a position helps the designer find the focus for the design and the anchor for the design process. It guides and steers design decision-making.

Knowledge (scholarly design)

The objective here is learning to develop a knowledge-based or knowledge-informed attitude and working method.

This means applying, combining, contextualizing, and transforming evidence, theory, and/or knowledge in a design proposal. This kind of design knowledge has been developed and tested over the years. Usually, you can find this knowledge in and via existing (reference) projects and in the form of principles, guidelines, or patterns. The designer is not (and cannot be and does not have to be) a specialist in all relevant knowledge domains but understands, embeds, uses, and inserts these in order to come to a coherent spatial proposal.

Research (design scholarship)

The objective here is learning to develop a research-oriented design attitude.

This consists of two ways of working. First, it is about exploring, experimenting, evaluating, and reflecting, a cyclic-iterative process of developing various ideas, variants, and/or alternatives, comparing, testing, evaluating these, and zooming in and out. The designer continuously examines whether the ideas still fit in the bigger picture (Position) and if they comply with the tried and tested knowledge (Knowledge).

Second, it is about analysing: formulating relevant research questions, researchable design questions, and researching relevant aspects. Relevant questions cannot only be formulated based on the design assignment but also pop-up during experimenting and exploring.

Communication

The objective here is learning to communicate during and about the design (outcomes and products) and design process.

This relates to clearly explaining and presenting a design proposal in words and images via oral, written, and visual presentation means, both digital and face-to-face. It also relates to collaborating, co-design, co-creation, and discussion skills. Thirdly, it relates to addressing and making explicit and insightful the activities and arguments that resulted in design decisions. And finally, all communication moments, like presentations, deliberations, and exchanges, are meaningful for the design process. They contribute to the process of thought determination and (re)structuring those thoughts and the development of a project as a whole.

Learning to design is a holistic activity. The four learning objectives influence each other directly and indirectly and should not be seen as disconnected skills. These four themes are used for all bachelor design projects to further detail learning objectives in comparable language (Appendix 1). The reasoning behind the learning objectives also resonates in the assessment strategy.

Holistic assessment strategy

The objective of the assessment strategy is to support and structure effective feedback, which—at the same time—should allow room for the unique character of each design proposal, design process, and the expertise of each design tutor (Vliet et al., 2024). We do this not only at the end of a project but particularly during the various design supervision sessions. Just like designing, design assessment is also not an exact science. Design tutors make context-specific assessments based on their specific interests, expertise, knowledge, and experience.

It is our view that it is impossible, even undesirable, to develop a detailed, analytical assessment rubric for design education that in advance lists all aspects that the result needs to have or show. For creative, explorative kinds of work like challenge-based design education, the quality of the whole is not simply the sum of scores of all parts. The assessment of design proposals is about the coherence and interaction between the different parts, and their meaning in relation to the whole. To do justice to this, design needs to be assessed holistically. At an abstract level, we can name aspects that count for all spatial designs, no matter how different they appear in various design outcomes: coherence & meaning, correctness & elaboration, communication, and research. However, they are strongly connected and are hard to assess independently.

To illustrate the approach (Appendix 2 and 3), the IOP1 role-play urban redevelopment project has one rubric for the specialist tutor (role teacher) and one for the design team coach (group tutor). The four rubric aspects are operationalised into a project and perspective-specific (role versus group) description of that aspect and several performance levels. This approach has been applied– the four aspects, project-specific descriptions, and performance levels–to assess all bachelor design modules in a recognizable and comparable language. This aims to have a more consistent, more transparent, and systematic way of assessing design projects that should support students in their journey to becoming better designers.

4. DESIGN THROUGHLINE RENEWAL PROCESS

For our faculty, the bachelor renewal is a significant educational (re)development and innovation project (Hoekstra et al., 2023). We work with a large team of tens of university teachers, student assistants, educational advisors, and educational support and management (ibid.: 46-47). The renewal is led by the bachelor's degree program leaders and the director of education. Besides, there is formal advice and decision moments with the Faculty's Management Team, Board of Studies, Board of Examiners, Department Education Managers, and the Students Council. For advice on sustainability program content and sustainability pedagogies, bachelor leadership is advised by a faculty specialist on sustainability engineering education.

The Design throughline team consists of two throughline leaders, two coordinators per module, one educational advisor, two student members, and one supporting student assistant. During 2022-2024, the team met bi-monthly. Module teams also have so-called quarter meetings with colleagues from other throughlines who teach in the same quarter; throughline leaders meet regularly with other throughline leaders. For the learning objectives and assessment strategy development, the Design team was advised by a senior faculty colleague who specialized in her research on architectural design pedagogies.

Developing the learning objectives and assessment strategy itself can be named a co-creative design process: a cyclic-iterative process of posing and presenting, evaluating and discussing, and deciding and adjusting in several rounds. Despite the sometimes-sharp discussions among colleagues, everybody unanimously agreed on this pedagogical step and renewal. Everybody had the opportunity to collegially co-develop the texts for the rubrics with our advisor, who helped the team be consistent in structure and language. The persistence of our educational leadership – throughline leaders and the bachelor program leader – was also helpful in continuing our discussions till the results were satisfactory for all.

Unfortunately, we did not have such an intense and rich collegial discussion on CBL principles (Cavallo & Quist 2023: p13-17) and the definition and description of sustainability challenges per project (ibid: p12). That would have enriched and strengthened our pedagogies without any doubt. But it would have cost the team another year of preparation, which was unavailable. Individual module teams made detailed choices and decisions on these aspects of CBL and sustainability themselves. An evaluation after one year is envisioned to see what worked out as planned and what did not. This evaluation allows for further discussion on and elaboration of CBL principles and sustainability challenges throughout the online process.

5. CONCLUSIONS

The curriculum team's decisions and discussions regarding the descriptions of the learning objectives and assessment strategy of the Design program (*leerlijn*) within the BSc *Bouwkunde* degree program renewal were all based on our holistic view of design education. The throughline leaders, module coordinators, and design education advisor unanimously agreed on this view. In many educational practices, course and curriculum developments, and University Teaching Qualification programs, there is an (over)emphasis on analytical assessment strategies. For CBL pedagogies such as design education, analytical assessments usually do not address the essence of developing (design) proposals to intervene in complex systems: you never know in advance which aspect will be most important and most influential

In analytical assessments, the criteria are clearly described, and each criterion's weight is also defined. This clarifies to students in advance how their final grade is built. In general, this sounds fair and transparent. For CBL-type pedagogies, however, it is impossible to imagine how a project will go and what outcomes it will deliver. Every project and every design is different. That makes it impossible to foresee how a criterion will work out specifically and which criterion will be most important. One criterion can be crucially important for one project and less relevant for another. Besides, the total quality of creative work is not simply the sum of all scores of all separate elements. That is why the emphasis on assessment as feedback is so important. It should be helpful in the learning and professionalisation process of students. That is also why, at the curriculum level, there needs to be a shared approach and vocabulary for assessing. Otherwise, students (and tutors!) might end up in unhelpful debates about grading.

Will this work? Is this renewed approach to design education helping us? Does it help all bachelor's students and staff? Does it contribute to avoiding unclarities (and frustrations) in design assessments? These questions will be actively monitored as part of the program renewal evaluation strategy that the faculty has prepared in collaboration with a 4TU Centre for Engineering Education PhD candidate who specialises in education innovation evaluation.

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7. APPENDICES

Appendix 1 – Table 1. *Learning objectives for the second and third-year bachelor Bouwkunde design projects ON1, ON2, ON3, ON4, IOP1, IOP2 (in Dutch).*

Project	Position	Knowledge	Research	Communication
ON1	het ontwikkelen van een betekenisvolle en aan het ontwerp richtinggevende positie ten aanzien van de woonkwaliteit van een woonomgeving en de verankering van huis en tuin in het landschap	het in samenhang toepassen en combineren van kennis in de voor deze opgave relevante aspecten zoals ruimte, compositie en gebruik en schaalniveaus zoals woning, tuin en landschappelijke situatie	onderzoeken in de vorm van analyseren, met name het begrijpen en beschrijven van de eigenschappen van de locatie en het (woon-/tuin)programma en in de vorm van experimenteren met name de verankering van huis en tuin in het landschap en de ordening van vorm, ruimten en het gebruik en hierop reflecteren	het uitleggen, verbeelden en verantwoorden van een ontwerp en onderzoeksresultaten via bouwkundige handtekeningen, schetsen en maquettes
ON2	het ontwikkelen van een betekenisvolle en aan het ontwerp richtinggevende positie ten aanzien van de technische, architectonische en duurzame toepassing van materialen en technieken	het in samenhang toepassen en combineren van kennis in de voor deze opgave relevante aspecten; materialen, (bouw- en draag)constructie, klimaat, gebruik, ruimte, situatie en duurzaamheid en schaalniveaus; materiële structuur en publiek gebouw	onderzoeken in de vorm van analyseren, met name het herkennen en begrijpen van de bouwkundige principes in relatie tot de verschillende technische systemen en in de vorm van experimenteren, met name het ontwikkelen van ontwerpvarianten met de focus op technische, functionele en duurzame aspecten en hierop reflecteren	het uitleggen, verbeelden en verantwoorden van een ontwerp en onderzoeksresultaten via handmatige schetsen, diagrammen en ruimtelijke modellen en maquettes en bouwkundige (digitale) lijntekeningen
ON3	het ontwikkelen van een betekenisvolle en aan het ontwerp richtinggevende positie ten aanzien van de ruimtelijke relatie tussen de openbare ruimte, de bebouwing en de structuur van stad en landschap	het in samenhang toepassen en combineren van kennis in de voor deze opgave relevante aspecten; gebruik, ruimte, materiaal, structuur, openbaar-privé overgangen en schaalniveaus; bebouwing en openbare ruimte en stedelijke structuren	onderzoeken in de vorm van analyseren, met name het begrijpen van ruimtelijke structuren, relaties tussen de verschillende schaalniveaus, privé en openbaar en veranderingen in de tijd en in de vorm van experimenteren, met name het ontwikkelen, vergelijken en testen van verschillende ideeën en varianten voor de relevante ruimtelijke aspecten op verschillende schaalniveaus en hierop reflecteren	het uitleggen, verbeelden en verantwoorden van een ontwerp en onderzoeksresultaten via schetsen, analysetekeningen, montages, collages, impressies, plankaarten, profielen, (schets)maquettes en (bouw)regels
ON4	het ontwikkelen van een betekenisvolle en aan het ontwerp richtinggevende positie ten aanzien van hoe maatschappelijke ideeën over privaat, publiek en collectief te vertalen zijn in een architectonisch ontwerp	het in samenhang toepassen en combineren van kennis in de voor deze opgave relevante aspecten; situatie, gebruik, ruimte, materiaal, maatschappelijke context en schaalniveaus; woning, woongebouw en stedelijk landschap	onderzoeken in de vorm van analyseren en experimenteren, waarbij het met name gaat om een ontwerp te leren ontwikkelen als een vraagstuk met een bepaalde thematiek en hierop reflecteren	het uitleggen, verbeelden en verantwoorden van een ontwerp en onderzoeksresultaten via passende middelen en technieken
IOP1	het ontwikkelen van een betekenisvolle en aan het ontwerp richtinggevende positie ten aanzien van een gebiedsvisie en strategie, waarin een duurzame stedelijke herontwikkeling circulair, klimaatadaptief, natuurinclusief centraal staat	het in samenhang toepassen en combineren van kennis in de voor deze opgave relevante aspecten en schaalniveaus: gebruik (programma), functie, ruimte, (milieu)techniek, recht, besliskunde, economie en (maatschappelijke) context	onderzoeken in de vorm van analyseren, met name het formuleren en onderzoeken van relevante vragen en aspecten met betrekking tot een gebiedsvisie en strategie voor stedelijke herontwikkeling en in de vorm van experimenteren, met name het disciplinair (eigen rol) en interdisciplinair (ontwerpteam) verkennen en testen van verschillende ideeën en varianten en hierop reflecteren	het uitleggen, verbeelden en verantwoorden van een ontwerp en onderzoeksresultaten in overleg, presentaties en rapporten en het reflecteren op het rol- en groepswerk
IOP2	het ontwikkelen van een betekenisvolle en aan het ontwerp (proces) richtinggevende positie ten aanzien van een integraal architectonisch ontwerp (opgave) van een publiek gebouw in een stedelijke context	het in samenhang toepassen en combineren van kennis in de voor deze opgave relevante aspecten en schaalniveaus: architectonische expressie, ruimte en vorm, gebruik en situatie, materiaal en structuur (constructie en klimaattechniek), context en duurzaamheid	onderzoeken in de vorm van analyseren, met name het begrijpen en formuleren van vragen en onderwerpen die binnen de opgave en ingenomen positie relevant zijn en in de vorm van experimenteren, met name de afweging en prioritering van de verschillende aspecten en de architectonische expressie in relatie tot de technische en materiële variabelen en hierop reflecteren	het uitleggen, verbeelden en verantwoorden van een ontwerp en onderzoeksresultaten via voor de situatie passende, analoge en digitale middelen, zoals tekeningen en maquettes

Appendix 2 – Table 2. *Assessment rubric for the third-year IOP1 design project: Group (in Dutch).*

	Description	Onvoldoende / Insufficient	Voldoende / Sufficient	Goed / Good
Samenhang & Betekenis / Coherence & Meaning	In het ontwerp is een thematiek herkenbaar, die tot samenhang leidt tussen alle aspecten en schaalniveaus en betekenis geeft aan een duurzame stedelijke herontwikkeling - circulair, klimaatadaptief, natuurinclusief.	Heeft niet de juiste, of slecht verantwoorde thema's, onderwerpen en producten ingebracht, waardoor de rol nauwelijks en dus niet voldoende vertegenwoordigd is in het groepsresultaat – producten en proces.	Heeft voldoende gedocumenteerde, inhoudelijke thema's, onderwerpen en producten aan het groepsresultaat - producten en proces - geleverd.	Heeft goed gedocumenteerde, inhoudelijke thema's, onderwerpen en producten aan het groepsresultaat - producten en proces - geleverd en is daarmee bepalend geweest voor de thematiek en samenhang van het geheel.
Juistheid en Uitwerking / Correctness and Elaboration	De volgende aspecten en schaalniveaus zijn op relevante kennis gebaseerd, en ver genoeg uitgewerkt: gebruik(programma), functie, ruimte, (milieu)techniek, recht, besliskunde, economie en (maatschappelijke) context.	Heeft een (te) weinig uitgewerkte inhoudelijke inbreng en een beperkte, defensieve positie in het onderhandelings- ontwerp- en uitwerkingsproces.	Heeft voldoende inhoudelijke inbreng en een constructieve positie in het onderhandelings- ontwerp- en uitwerkingsproces.	Heeft een goed uitgewerkte inhoudelijke inbreng en een constructieve en sturende positie in het onderhandelings- ontwerp- en uitwerkingsproces.
Onderzoek / Research	Het ontwerp is gebaseerd op onderzoek. Er zijn relevante vragen geformuleerd en onderzocht en relevante aspecten en precedenten geanalyseerd. Er is geëxperimenteerd met opties binnen 'de gegeven context' van de herontwikkelingsopgave en met de roleigen waarden, doelen en middelen als input voor de groepsvisie en -strategie.	Heeft (te) weinig inbreng vanuit de roleigen bronnen, vragen, precedenten, ontwerpideeën, of varianten. De eigen inbreng wordt slecht beargumenteerd en onvoldoende in relatie gebracht met het (ontwerp)onderzoek van groepsgenoten.	Heeft voldoende inbreng vanuit de eigen bronnen, vragen, precedenten, ontwerpideeën, of varianten. De eigen inbreng wordt beargumenteerd en in relatie gebracht met het (ontwerp) onderzoek van groepsgenoten. Zorgt ervoor dat in het ontwerpproces van het team geëxperimenteerd wordt op de relevante schaalniveaus.	Heeft sterke, agenderende en sturende inbreng vanuit de eigen bronnen, vragen, precedenten, ontwerpideeën, of varianten. De eigen inbreng wordt zorgvuldig beargumenteerd en constructief in relatie gebracht met het (ontwerp)onderzoek van groepsgenoten. Zorgt ervoor dat in het ontwerpproces van het team geëxperimenteerd wordt op de relevante schaalniveaus en alternatieven zorgvuldig geëvalueerd worden.
Communicatie / Communication	Het ontwerp, de thematiek en het onderzoek zijn op inzichtelijke wijze gedocumenteerd, gevisualiseerd en beargumenteerd, met name in een mondelinge groepspresentatie en groepsposter en vanuit de eigen rol een schriftelijk rolrapport met de verantwoording van het onderzoek en de ontwerp-, inrichtings- en/of investeringskeuzes.	Is passief in voorbereiding, presentatie en discussie. Krijgt negatieve peer-feedback. Geeft weinig relevante en/of impactvolle feedback aan de teamleden.	Is actief in voorbereiding, presentatie en discussie. Krijgt positieve peer-feedback. Geeft voldoende relevante en/of impactvolle feedback aan de teamleden.	Is constructief sturend in voorbereiding, presentatie en discussie. Herkent, benoemt en benut de bijdragen van anderen. Krijgt zeer positieve en breed gedragen peer-feedback. Geeft zeer relevante en/of impactvolle feedback aan de teamleden.

Appendix 3 – Table 3. *Assessment rubric for the third-year IOP1 design project: Role (in Dutch).*

	Description	Onvoldoende / Insufficient	Voldoende / Sufficient	Goed / Good
Samenhang & Betekenis / Coherence & Meaning	In het ontwerp is een thematiek herkenbaar, die tot samenhang leidt tussen alle aspecten en schaalniveaus en betekenis geeft aan een duurzame stedelijke herontwikkeling - circulair, klimaatadaptief, natuurinclusief.	Heeft een niet juiste, slecht verantwoorde en/of inhoudelijk beperkte thematiek bestudeerd, waardoor de diepgang in de rol niet is bereikt.	Heeft een juiste en voldoende verantwoorde inhoudelijke thematiek bestudeerd, waardoor de diepgang in de rol is bereikt met potentiële waarde voor het groepsontwerp.	Heeft een juiste, originele en goed verantwoorde inhoudelijke thematiek bestudeerd, waardoor de diepgang in de rol is bereikt en er inhoudelijke potentie is om van grote waarde te zijn voor het groepsontwerp.
Juistheid en Uitwerking Correctness and Elaboration	De volgende aspecten en schaalniveaus zijn op relevante kennis gebaseerd, en ver genoeg uitgewerkt: gebruik(programma), functie, ruimte, (milieu)techniek, recht, besliskunde, economie en (maatschappelijke) context.	Heeft een beperkt inzicht ontwikkeld in de eigen rol en positie en heeft dat onzorgvuldig uitgewerkt in rolproducten (kaarten, beelden, beschrijvingen ed).	Heeft een voldoende inzicht ontwikkeld in de eigen rol en positie en heeft dat uitgewerkt in passende rolproducten (kaarten, beelden, beschrijvingen ed).	Heeft een diep inzicht ontwikkeld in de eigen rol en positie en heeft dat zorgvuldig uitgewerkt in passende rolproducten (kaarten, beelden, beschrijvingen ed).
Communicatie / Communication	Het ontwerp, de thematiek en het onderzoek zijn op inzichtelijke wijze gedocumenteerd, gevisualiseerd en beargumenteerd, met name in een mondelinge groepspresentatie en groepsposter en vanuit de eigen rol een schriftelijk rolrapport met de verantwoording van het onderzoek en de ontwerp-, inrichtings- en/of investeringskeuzes.	Heeft een niet of weinig toegankelijk rolrapport met geringe diepgang, onderbouwing en verantwoording. Is passief in voorbereiding, presentatie en discussie.	Heeft een toegankelijk rolrapport met voldoende diepgang, onderbouwing en verantwoording. Is actief in voorbereiding, presentatie en discussie.	Heeft een uitnodigend rolrapport met grote diepgang, onderbouwing en sterke verantwoording. Herkent, benoemt en benut de bijdragen van andere rolcollega's. Is constructief sturend in voorbereiding, presentatie en discussie.
Onderzoek / Research	Het ontwerp is gebaseerd op onderzoek. Er zijn relevante vragen geformuleerd en onderzocht en relevante aspecten en precedenten geanalyseerd. Er is geëxperimenteerd met opties binnen 'de gegeven context' van de herontwikkelingsopgave en met de roleigen waarden, doelen en middelen als input voor de groepsvisie en -strategie.	Heeft het rolwerk niet of nauwelijks gebaseerd op (ontwerp)onderzoek. Heeft te weinig relevante vragen geformuleerd. Is academisch onzorgvuldig te werk gegaan (methoden, verantwoording, informatievaardigheden, brongebruik ed).	Heeft het rolwerk gebaseerd op (ontwerp)onderzoek. Heeft relevante vragen geformuleerd. Is academisch te werk gegaan (methoden, verantwoording, informatievaardigheden, brongebruik ed).	Heeft het rolwerk gebaseerd op breed en diep (ontwerp)onderzoek en brengt daarmee originele en waardevolle inzichten naar voren. Heeft meerdere relevante vragen geformuleerd. Is academisch zorgvuldig te werk gegaan (methoden, verantwoording, informatievaardigheden, brongebruik ed).

EXPLORING THE CBL PROCESS WITHIN A EUROPEAN ALLIANCE

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ABSTRACT

The European Universities Initiative, spearheaded by the European Commission, seeks to foster collaborative networks comprising higher education institutions across the European continent. These alliances serve to enhance the international competitiveness of European universities, while simultaneously promoting European values through the medium of long-term cooperation. A particular emphasis has been placed on Challenge-Based Learning (CBL), a student-centred, active learning approach that addresses societal challenges and cultivates competencies such as teamwork, problem-solving, and communication. CBL affords students the opportunity to address authentic, real-world problems without the constraints of predefined solutions, thereby fostering creativity and self-leadership. The European Consortium of Innovative Universities (ECIU) is one of 64 alliances within this initiative, aiming to integrate CBL into its educational offerings. These learning opportunities, designated as "Challenges," are distinguished by their interdisciplinary nature, practical relevance, and collaboration with external partners. They are designed to facilitate the development of competencies in a manner that is integrated into the academic trajectory of students. The objective of this paper is to disseminate insights regarding the facilitating and hindering factors involved in conducting CBL across a network of 12+ partners, as well as to present strategies for the creation of a comprehensive portfolio of learning opportunities (by July 2024, a total of 203 opportunities will have been developed, not connected to a specific study programme or joint degrees). The review of the past two years, conducted during our second funding period, has yielded a number of educational and organisational insights, which have highlighted both strengths and areas for improvement.

1. INTRODUCTION

In June 2024, the European Commission's "European Universities Initiative" will comprise 64 alliances, the objective of which is to enhance the competitiveness of European higher education and to promote European values through long-term, strategic cooperation between institutions.

Since the launch of the Erasmus+ European Universities call, there has been a notable focus on student-centred, active learning methodologies that facilitate meaningful societal transformation and foster the development of essential transversal skills, including problem-solving, teamwork, critical thinking, and communication. The European Union's initiatives, such as HEInnovate and Horizon 2020, in conjunction with the funding programme for European University Alliances, facilitate collaboration among learners, teachers and researchers, as well as a diverse array of societal and economic stakeholders, with the objective of addressing tangible challenges in a real-world context. Consequently, innovative pedagogical approaches such as Challenge-Based Learning (CBL) have gained considerable traction. The connection between the EU alliances and CBL is a natural fit, as both initiatives are based on collaboration, innovation, and the development of 21st-century skills (Thornhill-Miller et al., 2023), including teamwork, self-leadership, and creativity. This makes CBL especially popular in higher education (Helker et al., 2024; Galdames-Calderón et al., 2024). The alliances provide an optimal environment for CBL, facilitating the formation of a shared learning environment where learners from diverse countries and academic backgrounds can collaborate to address real-world challenges and implement viable solutions (Membrillo-Hernández et al., 2021; Pepin & Kock, 2021).

An ECIU Challenge is structured as an authentic learning experience with a focus on engineering science. Typically, students engage in a project-based approach to explore, discuss, and construct meaningful concepts and solutions (Gallagher & Savage, 2020; Sukackė et al., 2022). The efficacy of the solution can only be evaluated when implemented in a real-world context. The evaluation should focus on the development of students' competencies, rather than on the outcome (Membrillo-Hernández et al., 2021). Furthermore, the Challenges identified by ECIU are characterised by the following criteria:

The challenges are of varying sizes, from 1 to 15 ECTS, and may span a duration of three days up to an entire lecture term. They are designed to align with the vision and mission of the alliance and are intended to be interdisciplinary and multicultural in practice, with considerations such as team formation and the lens through which the challenge is explored. They are provided and actively supported by external partners from industry, NGOs or public organisations, preferably, or alternatively by researchers from member universities. They are open to all students of ECIU partners with a minimum of 120 ECTS as well as English language proficiency level B2 minimum and independent of their study programmes. They are taught in English, with exceptions of language courses.

The portfolio, which serves as a comprehensive repository of all learning opportunities offered within ECIU, is accessible via an online, public database [https://engage.eciu.eu/]. In ECIU, our objective is to develop a stable, coherent, and collaboratively developed portfolio of Challenges (and other courses) that strategically organises and aligns the educational offerings in a way that seamlessly integrates the strengths and efforts of each university partner. At present, the portfolio comprises both Challenges and so-called Micro-Modules. Later are brief learning experiences with a workload of 1-3 ECTS, which are designed to facilitate the development of new skills and transversal competences without following the CBL pedagogy in a step-by-step manner. While the primary focus of this paper is on Challenges, Micro-Modules are included because they equip learners with the requisite skills and competencies to effectively engage with the Challenges and actively participate in the CBL pedagogical approach. The review of the past two years in our second funding period has yielded several valuable insights, as outlined in Section 3, which highlight both strengths and areas for improvement, as discussed in Section 4.

2. METHODS AND DATA COLLECTION

The data presented here were collected through two principal methods: platform-based analysis (desk analysis) for the quantitative aspects and semi-structured interviews for the qualitative data. This approach is aligned with the principles of design-based research, although it does not fully align with all the criteria typically associated with this approach in the context of educational research. It is therefore proposed that this paper be regarded as a contribution to the field of Scholarship of Academic Development (Geertsema, 2016).

Quantitative data were gathered from the digital platform of ECIU, which was created ad hoc for the alliance and allows for collaboration and the tracking of learning offerings, as well as several characteristics useful for detailed analysis and reflection. The data set comprised the number of Challenges, the number of students enrolled in each Challenge, the dates on which they were implemented and delivered, completion rates, the topics addressed, and other variables. For the analysis of the Challenges and Micro-Modules, topic-wise, ChatGPT (version 3 from April 2024) was employed, prompted to identify the UN Sustainable Development Goals (SDGs) from the given text.

The majority of the information presented here was obtained through semi-structured interviews conducted between April and June 2024 with key representatives from each of the 12 partner universities in ECIU. The objective of these interviews was to obtain qualitative insights into the implementation and operational challenges of CBL within the alliance. This allowed participants to elaborate on the facilitating and hindering factors they encountered in their specific institutional contexts. Furthermore, a reflective survey was implemented to address the primary topics identified for discussion during the interviews. The survey was distributed to the partners two weeks prior to each interview, allowing them to focus their attention and, if necessary, consult with others at their institution to ensure optimal preparation for the meeting.

3. RESULTS

State of the art of the CBL Portfolio

From October 2022 to July 2024, there was a notable increase in the number of Challenges (n=64) and Micro-Modules designed to support these challenges (n=139), resulting in a total of n=203 learning opportunities. Additionally, an initial effort was made to stabilise the portfolio, comprising six repeated Challenges with the same overarching concept but differing solutions developed during the action phase. Furthermore, 52 repeated Micro-Modules were incorporated, with a particular focus on language learning and transferable skills, and half of these were designed as self-paced modules. In order to ensure a stable portfolio, it was necessary to identify a clear pattern for the challenges. This was done in order to establish a rhythm and timing that would be conducive to the project's success. The pattern identified showed peaks in the number of Challenges starting in February and October. The month of February, which saw the majority of Challenges commence, aligns closely with the academic calendar, with only two of the twelve partners on winter break while the remainder are engaged in lecture periods.

With regard to the number of students, it was observed that Challenges associated with more than 8 ECTS points were associated with a higher incidence of dropout. The initial analysis yielded no discernible correlations between the number of admissions and either the ECTS value or the specific topics or Big Ideas associated with the Challenges, the university hosting the Challenges, or the time points at which they commenced.

In order to analyse the portfolio's synergies and coherencies, the United Nations Sustainable Development Goals (SDGs) were identified as being related to each challenge and micro-module. In order to achieve this, the description information was analysed with the assistance of ChatGPT, rather than the tags that had been assigned to each learning offering by the teacher. The analysis revealed a strong alignment with several SDGs, particularly SDG 11 (Sustainable cities and communities), SDG 7 (Affordable and clean energy), SDG 9 (Industry, Innovation and Infrastructure) and SDG 13 (Climate Action). These topics are aligned with the goals of the EU initiative and the research focus areas of the alliance, which include energy and sustainability, the circular economy, transport and mobility, resilient communities and entrepreneurship, technology, and innovation. It was unexpected given that all teachers from ECIU were invited to participate and there were no restrictions on engineering sciences. Moreover, a positive correlation was observed between the content of the Challenges and the Micro-Modules, indicating that suitable Micro-Modules can facilitate the achievement of the Challenges. This is corroborated by the fact that students who register to enrol on our platform typically take 1.5 courses, indicating that a significant proportion of students combine several offers. The analysis of the Challenges revealed that students from three or more study programmes and three or more partner universities participated. The term "three or more" is used as a measurable criterion for interdisciplinary and international Challenges. However, the majority of students were from engineering science programmes, which may be attributed to the composition and history of the network. Efforts will continue to ensure balanced participation of students from all academic disciplines.

Facilitating and hindering factors in conducting CBL in a network of 12+ partners

The interview analysis yielded qualitative data regarding the partner universities, identifying challenges and focal points that facilitated the delineation of subsequent steps in the implementation of CBL in a network of 12+ partners.

The facilitating factors pertain to the holding of several meetings or training sessions for project personnel, thereby ensuring a constant flow of communication and adherence to formal quality criteria. Additionally, bottom-up initiatives have been co-created with the objective of connecting teachers, as well as the creation of important documents that guide the process and address all stakeholders involved. To guarantee a uniform and coherent approach throughout the alliance, a steering document for the Challenge process was developed, including templates for teachers at the beginning of 2023. This is because the information required for the platform promoting all learning offers necessitates additional details regarding typical module descriptions, handbooks, and syllabuses. While student autonomy in the CBL format is considerable, it is nevertheless necessary to define the schedule and type of activities in advance, as students from diverse academic programmes and universities must plan their mobility and financing. A discrepancy was identified between the alliance's guidelines, ERASMUS + regulations, and requirements for CBL in terms of flexibility. This highlighted the necessity for precision in determining which CBL cycle stages should be conducted on campus and which should not, as well as how to align CBL with the ERASMUS + definition of virtual mobility. Approximately two-thirds of all challenges include an on-campus phase, which typically lasts for five days. In three-quarters of these cases, on-campus meetings are held during the action phase to implement solutions or engage in activities on external partners' sites. In the remaining quarter of cases, on-campus meetings are held during the engagement phase to facilitate team-building activities and define the challenge from its Big Idea.

The majority of educational activities within the Challenges, and to a greater extent within the Micro-Modules, are conducted online. It was therefore unexpected to find that within a 24-month period, a central digital collaboration platform set up *ad hoc* was used by only two partners across seven challenges. This was unexpected, given that the initial review and evaluation process of the pilot phase (2019-2022) indicated that an easily accessible collaboration tool linked to the IT tools of the alliance was highly sought after by partners (Daunorienė and Ellinger, 2023). Further analysis is required, as well as information gathered through discussions and queries, in order to gain a comprehensive understanding of the reasons behind this limited uptake. It is possible that insufficient information and instructions on integrating the tool may have contributed to this outcome. Alternatively, it could be that teachers do not perceive a need for this option, given the significant progress made in the digitalisation of teaching and learning as a result of the corona crisis.

Another facilitating factor that was considered is the proposal to provide funding incentives for teachers to offer more Challenges. Six universities have existing calls that are tailored to the specific needs and internal structures of each institution. This supplementary assistance is accompanied by an enhanced readiness among instructors to disseminate their expertise as exemplars, to engage in pedagogical training, and to permit project personnel to contribute to the aggregated assessment of the courses. In addition, the establishment of a collaborative working group comprising administrative personnel and educational developers from each partner institution has proved beneficial, with effective communication and coordination achieved through regular meetings at both the central and local levels.

In addition to the facilitating factors, the CBL Portfolio has also been found to present a number of hindering factors. The results of the interviews indicated that nine Challenges, offered by six organisations, were terminated or cancelled due to insufficient student participation. Two Challenges were terminated due to a high rate of student attrition during their respective implementation periods. With each instance of a student withdrawing from a programme, there is a concomitant loss of funding, as well as feelings of disappointment and frustration among both teachers and students. It is noteworthy that extracurricular activities and Challenges that are not embedded in the courses that the hosting team is conducting as part of a study programme are the most frequently cancelled or delayed due to low enrolment or high dropout rates. Conversely, Challenges associated with existing courses, in which students from the host university are already enrolled, do not experience the same level of cancellation or attrition. In accordance with this, our findings indicate that four universities provide curricular offerings, four partners deliver extracurricular offerings, and four universities offer both.

In general, due to the diverse organisational frameworks of each member university, it has been challenging to adhere strictly to a standardised process and set of guidelines. Significant differences in administrative structures and internal processes mean that each institution must adapt the guide to fit their unique context. This raises questions about the criteria used to select offerings for the portfolio.

4. CONCLUSIONS

The initiative has yielded a number of insights with regard to educational and organisational matters, which serve to highlight both the strengths and the areas in need of improvement. It is encouraging to note that this work has served to highlight the significance of a bottom-up approach to the co-creation of a process for portfolio management, based on the principle of constant communication. Furthermore, the exchange of best practices between consortia and local initiatives encourages a culture of collaboration and innovation. A further key lesson concerns the importance of managing expectations through enhanced transparency and alignment regarding the approach taken, the clear objectives and the data provided for self-evaluation.

Nevertheless, challenges persist, including difficulties with grading. Right now, due to technical necessity, we are operating on a fail-to-pass basis. Additionally, the CBL pedagogical format, which is conducive to individual learning objectives and competence development, does not align perfectly with the ESCO classification system and the necessity of providing a substantial amount of highly detailed information prior to the commencement of a Challenge. It is therefore evident that there is a requirement for educators or educational developers who are proficient in the effective formulation of Learning Outcomes and the utilisation of the ESCO classification system.

The analysis of the competences demonstrates that a significant proportion of learners engage with offerings that encompass transversal skills. While these skills are fundamental, given the mission of the alliance to address real-life challenges and drive change, an expansion of offerings related to the alliance's core topics would serve to enhance the portfolio's overall relevance.

Furthermore, given the high dropout rates, it is essential to conduct a more comprehensive investigation into the factors that contribute to students' decisions to abandon their courses. The preliminary findings indicate that integrating learning opportunities into the formal curriculum is associated with lower dropout rates. However, further analysis is required to investigate the presence of a consistent pattern, which would elucidate further decisions. Up to now, a variety of formats and incentives have been employed in an effort to engage students who have discontinued their participation. However, a notable reluctance to disclose reasons for withdrawal, coupled with an insufficient response rate, has precluded the formulation of informed statements or the implementation of effective actions. In light of the balanced distribution of universities offering curricula, extracurricular activities, or a combination of both, it is imperative that the offerings become an integral component of students' academic programmes in order to ensure the long-term sustainability of the portfolio model.

In conclusion, the findings emphasise the necessity of adopting an evidence-based approach that incorporates both quantitative and qualitative data in order to inform processes effectively. The utilisation of a mixed methods framework facilitates a comprehensive understanding of the phenomena under study, thereby enabling more robust conclusions to be drawn. In light of these insights, we put forth a co-constructed, participatory framework that is adaptable to a diverse array of institutions. This collaborative process not only enhanced the relevance of the research but also fostered a sense of ownership among stakeholders, thereby facilitating more effective implementation of strategies. It is imperative that a continuous evaluation and improvement process be implemented to ensure a sufficiently large, synergistic, coherent, and stable portfolio of challenges. The regular assessment of the quality and impact of the offerings, in conjunction with the implementation of strategies informed by feedback and reflection, is of paramount importance in ensuring the long-term success and relevance of the portfolio. In accordance with the aforementioned principles, the portfolio management team is undertaking a series of measures with the objective of achieving the primary objectives identified above. In particular, the team offers training on pertinent updates or for new members; conducts regular assessments of the learning offerings; convenes monthly meetings with all partners to share best practices; and, every six months, engages in bilateral meetings with each partner university to provide support. It is essential to examine how these actions contribute to the quantitative and qualitative growth of the portfolio, exploring the facilitating as well as hindering factors and planning further steps.

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BEFORE THE CHALLENGE THERE WAS A PROBLEM (PRACTICE)

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ABSTRACT

Challenge Based Learning (CBL) in its usual implementation in engineering education starts with students being presented with a challenge, which makes them instantly focus on the solutions. The approach as such omits the phase of problem identification, and thus, results in a lack of opportunity for students to develop their capacity to analyse the context and identify a problem. In this practice paper, we offer a description of our approach to developing a CBL opportunity within the context of [blineded] EuroTeQ collider. We propose an educational design where students first explore the scope of potential problems connected to broad topics of nature, people and economy, and then practise context analysis using problem trees. We use the suggested core problems that students identify through this practice as starting points to create challenges with our industrial or non-governmental partners. This approach supports students' critical thinking and allows them to understand the complexity of problems, before proposing appropriate solutions.

1 INTRODUCTION

Challenge-based learning (CBL) is a pedagogical approach that supports students' skills development by bringing theoretical concepts in touch with practical complexities of real-world problems. In its basis, CBL is a dynamic and problem-centred approach, promoting active, experiential learning, as students must research, analyse, and collaboratively solve the proposed challenge.

Rooted in inquiry-based and problem-based learning, CBL focuses specifically on complex, open-ended challenges that are meaningful and relevant to students, as well as to potential partners outside academia (Helker et al., 2024; Leijon et al., 2022). In their systematic literature review, Leijon et al. (2022) point out that while the concept of CBL finds its roots in Apple's initiative to shake up the school system in 2008, there has been a rapid takeup of the approach by higher education institutions, yet that the definition remains quite similar. This includes CBL being "multidisciplinary approach to teaching and learning that encourages students to leverage the technology they use in their daily lives to solve real-world problems. Challenge-Based Learning is collaborative and hands-on, asking students to work with peers, teachers, and experts in their communities and around the world to ask good questions, develop deeper subject area knowledge, accept and solve challenges, take action, and share their experience" (Nichols & Cator, in Leijon et al., 2022).

Since most of the approaches to CBL are case-study-based or interdisciplinary challenges, students involved in CBL have a chance to work on vital transversal skills, such as communication, teamwork, self-awareness and self-leadership (Helker et al., 2024). These skills are increasingly important in today's workforce, where the ability to collaborate and solve problems in diverse environments is critical. By linking academic content with real-world applications, CBL prepares students for life beyond the classroom, making learning both relevant and impactful.

Some of the key parts of designing a CBL experience are to set up a challenge, investigate the context and develop the solutions. In engineering education, most often the solution development takes the majority of time and work. Students tend to spend little time in setting out the context and relatively much more time in ideation and solution development. This becomes a problem because the solutions might be tackling the inappropriate “problem”, the consequence rather than the root cause or the core problem. As defined by Rådberg et al. (2020), CBL in engineering education consists of “the identification, analysis, and design of a solution to a sociotechnical problem”. Nonetheless, the identification, and also the analysis, is often proposed by external stakeholders, or by the teachers involved in CBL, rather than by the students involved in CBL.

In this paper, we put an emphasis on the initial phase of the CBL, the problem identification and analysis of the context. We use the case of [blinded] EuroTeQ collider to unpack CBL practice, and how we have designed the collider as a CBL practice to better prepare student teams for the international competition EuroTeQathon 2024 and 2025. We present the considerations behind spending at least one-third of the teamwork on defining and identifying problems at large and based on that experience propose future options for boosting the impact of CBL opportunities.

2 CONTEXT

EuroTeQ Engineering University is a large European consortium that draws on alliances between partner universities in order to support quality engineering education for their students. Initiated by six leading technical universities in Europe, the partnership has for its mission to offer “a cross-border future-oriented competitive education format that would equally suit both the locally residing and the EuroTeQ participants” (Vodovozov et al., 2022). The mission of the EuroTeQ alliance is delivered through several different poles, including a joint course catalogue, lifelong learning courses and continuous education of engineers, a research repository and, of course, the EuroTeQ collider.

In this paper we focus on the EuroTeQ collider as a challenge-based learning initiative that “aims at bringing learners together to collaborate to find solutions to solve real-world challenges” (EuroTeQ, 2024). While “collider” is a term that emphasises the generation of ideas when students from different disciplines come together to solve a real-world problem, the tracks through which students work are based on Sustainable Development Goals (SDGs). EuroTeQ colliders are local competitions at each respective university, culminating with the EuroTeQathon - the large annual gathering of the best/winning local projects, a place where partner universities bring the best student groups to compete against each other in responding to the proposed tracks.

Even if the competitive element gives an edge to the overall idea of EuroTeQathon, the competing teams are prompted to look at the experience from the learning perspective, particularly focusing on development of transversal skills, such as interdisciplinary problem-solving, team communication, developing a team working strategy, managing time and other resources, financial planning and, very importantly, presenting their idea in an attractive format to a wide audience. The capacity to solve complex problems is an extremely important skill and the students have the chance to work by responding to the challenges. Given this context, the EuroTeQ collider also includes important elements usually attributed to project-based learning, a driving task (using technology for a sustainable future), the teacher as a facilitator of the learning process, providing feedback and resources, with the final outcome being a presentation, all the while keeping the skills and knowledge gained during the process equally in focus (Doulougeri et al., 2024).

At EPFL, the first EuroTeQ collider was developed in the spring semester of 2024 to prepare teams for the EutoTeQathon in June 2024. In the academic year 2024/2025 the approach was refined based on the first edition experience and some of the institutional constraints.

Table 1. *Comparison of the CBL experience design in the first two years of implementation* EuroTeQ Collider

	2023/2024	**2024/2025**
Duration	March to May (2 months)	November to May (7 months)
Approximate number of hours of CBL experience	3 workshops x 2.5 h 2h of group work x 6 weeks = 20h	5 workshops x 2.5h (kick-off, challenge, effective teams, business plan, pitch)
Participants profile	4 Bachelor and 1 PhD student, forming a single team	20 to 30 PhD students, to form a maximum of 3 teams by January

3 EDUCATIONAL DESIGN

In this section of the paper, we will present the outline of the 2024/2025 EuroTeQ collider challenge and how it incorporated the key element of the so-called Phase 0 - what we critically observed as missing in the usual collider challenges based on the CBL approach. We explain Phase 0 in detail and further explore how the other phases unfold. Fig.1 provides a visual outline of the educational design, specifying phases and their objectives.

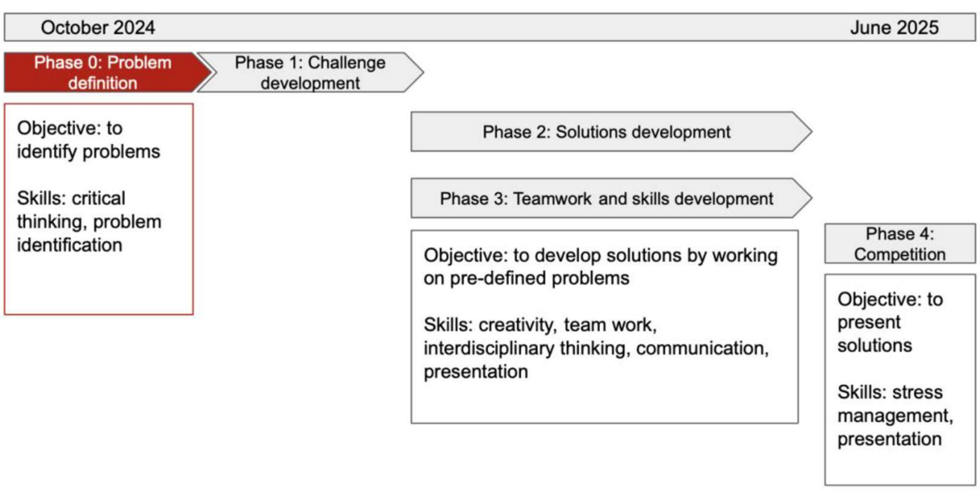

Fig.1: visual representation of educational design implemented for the EuroTeQ collider 2024/2025

As represented in Figure 1, Phase 0 is crucial for fostering students' critical thinking and problem-definition skills and identifying problems from the students' perspective. These problems are then used to create draft challenges and approach the relevant sectors, companies, and organisations for potential collaboration on our Challenge-Based Learning (CBL) approach (Phase 1). Once these external stakeholders help define the final challenges, we present them to students, leading to Phases 2 and 3. In Phase 2, students develop solutions, and in parallel develop creativity, teamwork, interdisciplinary thinking, and communication skills through workshops and mentoring (Phase 3). Finally, in Phase 4, within the EuroTeQ framework, student teams from all partner universities compete to persuade juries of their solutions.

It is important to note that in a typical CBL setting, students are only involved at Phase 2 and 3, because Phase 1 is usually done by the instructor creating the challenges in collaboration with the external partners.

3.1 Phase 0: detailed explanations

While the usual CBL educational design starts with Phase 1 where the instructors develop challenges based on their interactions with industry and other non-academic partners (e.g. governmental and non-governmental institutions, international organisations), in our approach, we propose Phase 0, a step that comes before creating challenges and presenting them to students.

Phase 0 directly involves students to very broadly think about problems in today's society. It is a blank sheet for students to engage in understanding the world we live in and identifying issues that surround them. In connection with the EuroTeQ context, we use three pillars: environmental, social and economic pillar to ask students to list problems without constraints by individually and anonymously writing issues on post-its. In this step, students are also prompted by supportive questions, to think from the perspective of an old person, or a child, or to compare issues today with those that already existed 2000 years ago.

Once the students have finished their individual work on identifying the issues in three pillars, they are split into three equal groups, each group allocated one of the three pillars. In the following activity, the students need to work as a group to define at least one problem tree (eawag resource), starting with clustering the issues on the post-its. Once they clustered the issues, students were asked to pick one of the clusters and try to develop a problem tree by defining causes (roots), main issue (trunk) and consequences (leaves). They can add more items and also connect their initial problem tree with other problem clusters.

At the end of Phase 0 each of three groups presents their work to the others, explaining the problem tree and answering questions of other groups and instructors.

Table 2. *Phase 0 workshop outline*

Time	Activity	Description	Form
15'	Introduction	Present objectives of the workshop and EuroTeQ collider	Plenary presentation
20'	Issues brainstorming	- Students take several post-its and write anything that	Individual

		comes to mind as an issue within the three pillars - Issues can be described as sentences or in few words - Once students start slowing down with writing, the instructor supports more ideas with prompting questions	
15’	Clustering	- Students split into three equal groups and each group is given one of the three pillars - Students need to cluster all issues and if time allows, make a hierarchy of clusters / issues	Group
40’	Problem tree	- Students need to decide on one of the clusters and develop a problem tree by identifying core issue/problem, root causes and consequences - More post-its can be added and also connections can be made to other clusters	Group
5’	Presentation preparation	- Each group needs to develop a short 3-minute pitch of their problem tree	Group

15’	Presentations and questions	- Each group presents and answers questions (5 min per group)	Plenary

While there are elements of interdisciplinarity and presentation involved in this phase, we try to focus more strongly on students’ capacity to critically observe the world around them, to identify and define problems and to understand the tight connections between causes and consequences.

4 RESULTS AND FINDINGS

Engineering education is oftentimes solution-oriented. Students and graduates are prompted to think about solving problems and challenges, yet to a much lesser extent they are taught to identify and think of the complexities of these same problems and their potential redefinition. In our pilot edition of Phase 0 in 2023/2024, we have seen how difficult it is for students to “sit with the problem” and understand the main problem, and identify the root causes and consequences of the main problem. This was rather different from the situation when the same students engaged in Phase 3, where they worked on the solutions by applying their disciplinary knowledge and skills. Even the interdisciplinary aspects in solution development seemed to have been easier than engagement with the problem identification of Phase 0. In the following we present some of our reflections, observations, and lessons learned from the experience of implementing Phase 0 in the academic year 2023/2024 and 2024/2025.

4.1 Reflection on the Process

Our team comprised three individuals with diverse expertise: a social scientist, an engineer with industry experience, and a life scientist. The social scientist introduced the "problem tree" approach, a tool commonly used in social sciences to dissect context and define problems. The life scientist, with experience in interdisciplinary problem-solving and project-based learning, supported this method, confident in its potential effectiveness. However, the engineer was sceptical about its applicability to our target audience. This concern proved valid during our first EuroTeQ Collider with bachelor’s and master’s engineering students. These students struggled to disentangle the connections between causes and effects and to understand the "zooming in and out" required to build a problem tree, necessitating our extensive guidance. The second EuroTeQ Collider iteration, which involved doctoral students in engineering programs, revealed a notable shift. While problem generation was smoother, students still needed help with structuring the problem tree. Specifically, we had to encourage them to ask "5 WHYs" to dig deeper into core issues instead of jumping to solutions. This adjustment demonstrated the importance of tailored support, particularly in guiding students to explore underlying causes rather than prematurely focusing on seeking solutions. Observing these differences across student levels, from bachelor and master to doctoral students, highlighted the importance of carefully designing the learning experience, observing the reactions of students, taking into account students’ prior experience in engaging with interdisciplinary methods, and modifying the facilitation based on their needs.

4.2 Key Insights and Lessons Learned

Engineering students may benefit from additional support in two main areas: idea generation and problem tree analysis. To stimulate divergent thinking, prompts that encourage perspectives from different demographics (i.e. what would an old person or a child think of this problem) or historical contexts (i.e. was this a problem 2000 years ago) may be helpful. Furthermore, reminders to use techniques like the "5 WHYs" help students drill down to root causes while guiding questions assist them in mapping out consequences. Explicitly teaching divergent thinking, problem-defining defining and interdisciplinary communication is essential, as assuming students will naturally embrace interdisciplinary thinking can lead to challenges in engagement and understanding.

Finally, we observed that concluding the Phase 0 session with a reminder about the importance of problem definition and contextual understanding can have a broader impact. Encouraging students to recognize how foundational these elements are to clear communication, particularly when pitching their projects, is crucial. Building skills in problem tree analysis not only aids in solution generation but also provides a powerful structure for effective pitch introductions, enabling students to convincingly convey the essence of their work to stakeholders and juries.

5 EDUCATIONAL IMPACT

The modern engineer plays a critical role in addressing complex societal challenges, from environmental sustainability to digital security, demanding both technical skills and a deep understanding of the broader context of each problem. Today's engineers must go beyond designing solutions; they need to analyse root causes and potential consequences to ensure that solutions are sustainable, effective, and socially responsible. By examining underlying issues and potential ripple effects, engineers can anticipate unintended outcomes and create resilient designs that address core problems rather than superficial symptoms. This approach not only enhances the impact and relevance of engineering work but also fosters public trust and ensures that technological advancements truly benefit society.

Challenge-Based Learning (CBL) offers a powerful platform to develop transversal skills in engineering education, as it immerses students in real-world problems and provides ample opportunities for reflection and growth. Yet, how can we ensure that the challenges we set are truly impactful? And how do we prepare future graduates to deeply understand the problems behind the challenges they are trying to solve?

Our Phase 0 goes a step further: it empowers students to identify key issues before these are even framed as challenges in CBL. By starting with this exploration, students pinpoint significant problems within their local or global communities, giving them a deeper sense of purpose and relevance. This approach encourages them not only to fix problems but to truly see and understand them.

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CHALLENGE-BASED LEARNING AND EPISTOMOLOGY: BRIDGING ENGINEERING AND ARCHITECTURE EDUCATION

PRACTICE PAPER

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Challenge-based learning (CBL) is perceived and practiced differently in engineering and architecture education due to each field's unique goals, pedagogical needs, and disciplinary approaches. Both use CBL to cultivate problem-solving skills and prepare students for real-world challenges, but engineering education often adopts structured, technical, and quantitative methods, while architecture education favors open-ended, qualitative, and context-sensitive explorations. This disciplinary divergence in epistemology provides an opportunity for cross-disciplinary learning, where students and educators can benefit from sharing different ways of thinking and working, broadening perspectives and fostering interdisciplinary collaboration.

Research Questions: This presentation addresses the following questions:

1. How is CBL perceived and practiced differently in engineering and architecture education?
2. What are the epistemological assumptions underlying these differences?
3. What insights can be gained about interdisciplinary epistemological exchange by examining both published and active cases?

CBL, as a pedagogical approach, encourages students to tackle real-world problems through active, hands-on learning. Its roots are grounded in constructivist learning theory, which emphasizes learning as an active process where knowledge is constructed through experience rather than passively absorbed.

This approach is particularly suited to professional fields like engineering and architecture, where hands-on problem-solving in realistic contexts is crucial to professional development. Constructivist theories suggest that students learn best when they are actively involved in the learning process, especially through problem-solving, experimentation, and reflection. Despite their shared use of CBL, engineering and architecture have distinct epistemological foundations. Engineering values objective, measurable solutions, aligning with a positivist outlook that often prioritizes precision, predictability, and reproducibility. Engineering problems typically have specific, quantifiable goals, and the discipline seeks solutions grounded in technical accuracy and efficiency. In contrast, architecture emphasizes subjective interpretation, context sensitivity, and the cultural implications of design, valuing open-ended approaches that allow for ambiguity and exploration of multiple solutions.

This presentation investigates how these epistemological differences impact interdisciplinary CBL programs, where students from both fields collaborate to address complex challenges. By examining both published and current CBL cases, this study seeks to highlight the role of epistemological exchange in enhancing students' adaptability and problem-solving capabilities across disciplines. To examine how CBL facilitates interdisciplinary learning between engineering and architecture, this paper reviews five case studies – two published and three currently active.

These cases provide insights into the structure of interdisciplinary CBL, how engineering and architectural epistemologies interact, and the impact on student learning.

1. Transdisciplinary Elective Design Studio (University of Michigan): The "SmartSurfaces" module engages upper-year students in materials science engineering, art and design, and architecture. Initially, it emphasised engineering epistemologies with a focus on technology development but later integrated architectural approaches by situating projects in an under-resourced neighbourhood. This shift underscores CBL's flexibility in accommodating disciplinary priorities, highlighting how socially relevant projects can foster interdisciplinary understanding.

2. Transdisciplinary Elective Module (Virginia Tech): The "StartUp" module involves 41 students from engineering, business, industrial design, and architecture in collaborative challenges. Researchers used King and Kitchener's reflective judgment model to track students' progression from pre-reflective to reflective thinking. Initially uncomfortable with flexible assessments, students grew to appreciate multiple perspectives, ultimately enhancing their ability to tackle complex, real-world problems.

3. International Solar Decathlon: This competition unites students from diverse fields, including engineering and architecture, to design net-zero homes that are later evaluated on-site using standardized metrics. Since its inception in 2002, the Solar Decathlon has illustrated the value of interdisciplinary teamwork for addressing sustainability challenges, encouraging students to merge technical precision with creative design.

4. BSc and MSc in BIM/Digital Construction (TU Dublin): In this program, engineering and architecture students collaborate on simulated construction projects, including 3D modeling, clash detection, and construction management tasks like cost estimation. This case exemplifies how CBL can simulate professional interactions, helping students develop essential interdisciplinary communication and problem-solving skills.

5. NewGiza University Challenges (Egypt): Inspired by UCL's CBL framework, NewGiza University engages engineering students in semester-long interdisciplinary challenges.

Tailored to local needs, the program showcases CBL's adaptability across cultural contexts, emphasizing global competencies in problem-solving and interdisciplinary collaboration. Across these cases, a pattern emerges: CBL fosters a unique environment for epistemological exchange, encouraging students to grapple with different disciplinary assumptions.

Engineering students often enter these programs with a preference for structured, analytical approaches, while architecture students are more accustomed to ambiguity and contextual variation. Through CBL, students learn to appreciate these differences, with interdisciplinary projects pushing them to adopt more flexible, reflective modes of thinking. The SmartSurfaces and StartUp cases, in particular, underscore CBL's role in advancing reflective judgment, as students transitioned from pre-reflective to reflective thinking, appreciating multiple perspectives and the contextual considerations of their work.

This exploration reveals that CBL can bridge epistemological divides between engineering and architecture, fostering a mindset that values interdisciplinary collaboration. These findings have practical implications for educators aiming to prepare students for complex, interdisciplinary careers. By exposing students to diverse ways of thinking and working, CBL cultivates adaptability, empathy, and reflective judgment—qualities essential for addressing global challenges. Moreover, the results highlight the importance of framing CBL projects with a socially relevant mandate, as seen in the SmartSurfaces and NewGiza cases. Such projects resonate with students and enhance engagement, encouraging them to think critically about the societal impact of their work.

CBL offers a valuable framework for interdisciplinary education, particularly in engineering and architecture, where differing epistemologies shape problem-solving approaches. By fostering epistemological exchange and reflective judgment, CBL can prepare students to navigate the complexities of real-world challenges. As academic communities increasingly value interdisciplinary collaboration, further research on CBL's role in bridging disciplinary divides will be essential for optimising its educational impact.

CASE STUDY OF CBL INTEGRATION INTO STRATEGIC PROJECT MANAGEMENT COURSE FOR MASTER STUDENTS

PRACTICE PAPER

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Dewey's (1916) idea that if we teach today's students as we taught yesterday's, we rob them of tomorrow has likely never been more relevant. Therefore, Challenge-Based Learning (CBL) is increasingly recognized as a transformative pedagogical approach. This case study describes the integration of CBL into a master's-level strategic project management course, addressing the growing demand for professionals skilled in managing complex projects within dynamic and uncertain environments. Theoretical Background & Rationale The Project Management Institute (PMI) tracks trends and best practices in project management. The latest "Pulse of the Profession" report emphasizes the critical role of "power skills" (often referred to as soft skills), including communication, strategic thinking, and problem-solving, as key drivers of project success (PMI, 2023). Similarly, the International Project Management Association (IPMA, 2021) emphasizes these competencies in its Individual Competence Baseline (ICB4). Alongside technical and contextual skills, project managers should develop interpersonal skills such as communication, leadership, and teamwork. Research shows that CBL provides considerable benefits in the context of project management education. It enhances student motivation and performance by involving real clients/sponsors and realistic scenarios, which demand practical solutions from learners (Karim et al., 2019; Zhang, 2021). Additionally, CBL fosters the co-creation of value between students and external stakeholders, leading to mutually beneficial outcomes (Garrido-López et al., 2018). In gerenal, CBL approach responds to the educational need for dynamic and adaptive learning, offering a clear link with the objectives of strategic project management. Educational Design & Context The Strategic Project Management course is offered by the School of Economics and Business (SEB) for first-year master's students. It is designed to equip students with strategic project management knowledge and to develop competencies in managing project portfolios. The integration of CBL is structured around a three-week intensive cycle, during which students tackle challenges presented by industry partners. In the spring semester of 2024*, the course teachers initiated a collaboration with a leading food and feed production company (hereafter referred to as FPC). The company provided the Big Idea "Global Business," which was later narrowed down to the Essential Question: How can global business opportunities be leveraged? and the Challenge: Utilize global business opportunities to enhance FPC's performance. Teachers have observed that the CBL phases—Engage, Investigate, and Act (Nichols et al., 2016)—correlate well with the project management phases of Initiation, Planning, Execution, Monitoring & Control, and Closure (PMI, 2017). Engage Phase/Project Initiation I began with an introduction session, where students became familiar with the principles and processes of CBL and the study module. Team formation and expectation setting followed, serving as a foundational activity for student engagement. Representatives from FPC visited the university to present the company's vision, mission, and its current strategic projects. During this period, students collaborated with the company to narrow down the "Big Idea" into an actionable challenge statement: Utilize global business opportunities to enhance FPC's performance. The Engage phase concluded with a session for intermediate self-reflection and discussion. Investigate Phase / Project Initiation II focused on in-depth analysis and data gathering to analyse the challenge and the potential solutions. First, students assessed FPC's project portfolio and analyzed its project management maturity level. This activity helped students to analyse the organization's current strengths and areas for growth. Then, students conducted interviews with FPC representatives, asked various financial and other data, consulted course teachers and investigated scientific resources. In the end of this phase, a formal "go/no-go" decision was made by FPC representatives, helping students to determine which potential solutions aligned best with FPC's strategic goals and operational capabilities in order to exploit global business opportunities. The Act Phase/ Project Planning & Pitch, aimed to structure findings and develop a comprehensive project plan of the selected solution. Students began by defining the project's goals, objectives, outcomes, and success criteria. Afterwards, they formed a work breakdown structure, a detailed project schedule, and a resource allocation plan. In the next step, students identified potential risks, planned mitigation actions, and established a quality assurance plan. Throughout this phase, consultations, self-reflection activities, and pitch training were offered. In the end, students prepared a full report and pitched their projects to the FPC representatives who provided feedback, focusing on practical relevance and industry standards. Finally, as the project execution phase was handed over to the FPC for practical implementation, students practiced managing the full project cycle in the scenario-based, computer-driven simulation. The phase concluded with a roundtable discussion, peer feedback and an anonymous course overall evaluation report. Results and Findings Students reported difficulties working in teams assigned by the teachers (Belbin test was used), particularly when grouped with peers from different study programs or with varying styles of communication and commitment. A few students felt that they were carrying the workload for less engaged teammates. Regarding time boundaries, extending the course from three to six weeks was suggested as it would allow for deeper engagement and thorough project completion. However, in general, students appreciated working in the CBL method, with a real-world challenge, as it made the course content feel relevant and actionable. They enjoyed project management techniques, Moodle's centralized repository of course materials and the general flexibility of teachers who supported self-paced learning and overall balance. Educational Impact Collaboration in teams and focus on stakeholders' needs mirrored the project-based nature of professional environment. Students proposed projects tailored to market demands: one team suggested adopting a dropshipping model to streamline logistics and expand reach. Another focused on gluten-free flour products like breadcrumbs, meeting rising demands for dietary alternatives. Others designed a concept for an instant food vending machine for Asian market. Overall, the integration of CBL led to a quadruple-win scenario: (1) higher education institution can deliver relevant, up-to-date education; (2) students achieve study outcomes by practically applying theoretical frameworks to create tangible value; (3) partner organizations gain adaptable solutions and access to a pool of potential employees; (4) society benefits from enhanced products and services.

EXPLORING THE CONCEPT OF CHALLENGE IN CHALLENGE BASED LEARNING AND BEYOND

RESEARCH PAPER

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This paper addresses a fundamental gap in Challenge-Based Learning (CBL) literature by examining the concept of "challenge" across multiple domains to establish a more precise understanding of its meaning and qualities. While several definitions of CBL exist in the literature, the concept of "challenge" remains largely undefined, often used with an implied sense that the meaning should be self-evident. The term "challenge" appears in multiple forms — as a noun, verb, and adjective — across different contexts, with varying meanings. Since CBL's emergence in the early 2000s, the lack of a clear, consistent definition of "challenge" has hindered its theoretical development and practical implementation. This ongoing study addresses this lack of clarity through a methodological approach that combines discourse analysis, systematic conceptual analysis, and conceptual framework synthesis. By adopting a constructivist perspective, the study acknowledges that the meaning of "challenge" is socially constructed and context-dependent. The research examines how "challenge" is constructed, conceptualized, and operationalized across multiple fields and sources, including literature on CBL, education, psychology, organizational studies, governance, popular media, and gaming. A broad and preliminary exploration of the term "challenge" across multiple domains and sources already offers a multifaceted range of usage. In Challenge-Based Learning (CBL) literature, a "challenge" is defined as a framework for learning and as a specific learning event. Other perspectives in the educational domain frame the term "challenge" in association with ideas of difficulty and struggle and the need for a balanced level of "challenge" and scaffolding

to create optimal learning experiences. Educational research shows that an appropriate "challenge level" is essential for learning, while excesses trigger anxiety and impede learning. Another perspective is offered by studies in the field of adventure and outdoor education that use the concept of "challenge by choice," emphasizing participants' role in determining their own engagement while fostering growth through physical and emotional challenges. The study identifies other areas outside of the educational domain where the term/concept of challenge is relevant and articulated in different forms. In psychology, the term challenge emerges in opposition to threat and is characterized as positive stress responses. Positive psychology's concept of "challengership" integrates positive and negative aspects of challenges into a holistic well-being framework. This perspective connects with mindset theory, suggesting that how individuals perceive challenges fundamentally influences the trajectory of personal development. Organizational studies employ the "challenge-hindrance" framework, distinguishing between positive and negative stressors and emphasizing the role of challenges as positive forces in professional development. Governance and policy domains mostly use challenges to indicate complex societal issues, "wicked problems" or "grand challenges" that can only be tackled with innovative problem-solving, system thinking, and multidisciplinary approaches. The term "challenge" is also central in popular culture. Reality TV utilizes challenges as structural elements driving narrative tension. Cooking shows employ challenges to test technical skills and creativity. Social media platforms present viral challenges that spread through imitation and social belonging. The gaming industry approaches challenges as designed experiences encompassing performative, emotional, cognitive, and decision-making dimensions. A nuanced and multidimensional semantic space for "challenge" is emerging from the ongoing conceptual analysis. Challenge shares meaning and overlaps with similar or related concepts. The first set of significant similarities/differences can be found in problems, threats, goals, projects, and tasks. Unlike problems, which are typically involuntary and solution-oriented, challenges are intentional, growth-oriented, voluntary engagements focused on development. Where "problems" evoke reactive responses, challenges define a more open-ended, proactive, and strategic framing. "Threats" and "challenges" differ in how resources are perceived: threats emerge when a lack of sufficient resources to cope with the threat is felt, while challenges arise when there is a belief that enough resources to overcome obstacles are available. This distinction affects individuals both mentally and physically: threat responses trigger stress and avoidance behaviors, narrowing focus and limiting creativity. In contrast, challenge responses activate positive stress reactions, increasing motivation, cognitive flexibility, and innovative thinking. Challenges differ fundamentally from projects, goals, and tasks in their nature and function. While the latter is primarily outcome-focused with defined targets, completion-oriented, and focused on specific actions, challenges are complex, development-oriented experiences promoting sustained engagement and continuous growth. The concept of competition, often synonymous with challenge in public discourse, emphasizes achieving specific goals for rewards or titles. Competitions typically involve direct comparison against others with predetermined metrics and winners, whereas challenges focus on personal or collective growth as primary outcomes. While competitions often create pressure to outperform others, challenges encourage self-improvement, collaboration, and learning experiences. This distinction is particularly evident in educational settings, where challenge-based approaches emphasize personal development over competitive achievement. Challenges also appear to share their semantic space with another set of concepts and terms. Challenges and "opportunities" share a synergistic relationship, representing potential growth and advancement, with a forward-looking orientation that catalyzes action through a development-enabling attitude. This affinity extends to concepts like "discovery" and "exploration", where challenges serve as catalysts for expanding knowledge and capabilities. Similarly, challenges align with innovation, as both concepts involve pushing boundaries and unexplored possibilities, as well as adaptation, as both concepts emphasize flexibility, resilience, and the capacity for growth in response to changing circumstances. Starting from this preliminary conceptual mapping, the paper extends and refines the findings by synthesizing key elements and patterns identified across the explored domains with the ultimate goal of proposing a definition of "challenge" that is at the same time broad enough to take into account the relevant nuances and differences identified, and specific enough to be operational and relevant in the context of the Challenge-Based Learning framework. The proposed definition will be accompanied by a set of parameters and thresholds that could be useful in identifying and constituting a challenge. Such a definition and its entailed parameters are intended to have implications for CBL in theory, practice, and research and potentially be particularly relevant for educators, instructional designers, and researchers working to implement or study Challenge-Based Learning approaches.

JUMPing BETWEEN ISLANDS OF MODULES AND CHALLENGES – A NEW WAY OF OFFERING LEARNING OPPORTUNITIES ABROAD?

PRACTICE PAPER

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The common way of conducting studies abroad is for an exchange semester or a year abroad. However, not all students can arrange, afford, and accomplish such initiatives. In the Erasmus+ project "JUMP Europe" (Joint University challenge-based Minor Program for future generation of innovative entrepreneurs), that started during the autumn 2024, we are working to create another range of options. The universities participating in this project (University of Trento, Linköping University, Łódź University of Technology and National Institute of Applied Sciences in Toulouse) are all part of the university alliance ECIU (European Consortium of Innovative Universities), one of the oldest European university alliances.

At the CBL conference we will share our ideas of how mobility schemes can enhance students' responsible innovation and entrepreneurial (I&E) skills, emphasizing holistic cross-disciplinary learning, inter-sectoral participatory processes, and inclusivity for a sustainable Europe.

The background to the project is that since at least 2005, there has been an increased emphasis on strengthening the knowledge triangle of education, research, and innovation, but yet challenges in real life intersectorial dialogue persist (Barzman et al., 2021). Modernization in the cooperation and digitalisation is ongoing but further actions are necessary (Lassnigg et al., 2017) to fulfill the ambitions of the Lisbon strategy 2000, i.e. leveraging digital technologies to drive economic growth, foster innovation, and enhance EU competitiveness. Specifically, Carayannis at al. (2022) argues for a future university model that fosters human-centric and responsible innovation, involving all societal segments and equipping students with the essential knowledge and skills for the future.

The aim of the JUMP project is to further enhance the interconnections of higher education institutions (HEIs) through jointly designing, piloting, and evaluating flexible paths for learning packaged in pathways such as grouped modules and challenges - or a whole distributed minor co-created by the participating HEIs. In these learning pathways, students are exposed to innovation through combining Challenge-Based Learning (CBL) with innovation and entrepreneurship (I&E) education. Our vision for EU HEIs by 2030 is to evolve them as entrepreneurially minded co-creation platforms that attract talents eager to address future challenges in agile ways to strengthen the regional innovation systems and foster societal resilience.

The JUMP project aligns with two Erasmus+ key priorities: 1) fostering common values, civic engagement, and participation; and 2) supporting students' (I&E) skills via experiential learning pedagogies. These priorities are interconnected through I&E educational strategies utilizing CBL to tackle human-centric and sustainability-related problems for "21st-century" skills (Geisinger 2016; Scroccaro et al 2023). Our approach enhances learners in navigating diverse and rapidly evolving technologies and knowledge. It also ensures inclusion by introducing flexible educational paths that engage all actors of the regional quadruple helix, promoting thus civic engagement in the co-creation of societal challenges such as degrowth, circular economy, resilient communities, responsible AI and innovation. The promotion of interconnected higher education and the stimulation of innovative learning and blended teaching practices will foster HEI's digital transformation through the creation of evidence-based guidelines and toolkits drawn from the joint design, pilot and evaluation of a Distributed, Blended and Challenge-Based European Entrepreneurship Minor (CBL Minor, ca. 15+ ECTS).

The main motivation of our project aligns with the guidelines from the Council of the European Union (2021) to enable students and potentially life-long learners, to improve their I&E skills and competences to address the needs of a fast-changing society and labor market. Access to flexible, learner-centered active teaching and responsible learning is crucial and we will therefore work in the consortium to enhance EU-learners' ability to work interculturally, interdisciplinarily (over the subject borders) and multidisciplinarily (several disciplines).

This way of working is termed "cross-disciplinary" (Heikkinen et al, 2015) and has been shown to boost innovativeness. We also see the importance of an inter-sectoral setting (e.g. triple to quintuple helix, cf. Carayannis et al. 2010, 2022), where all actors in regional innovation systems become engaged in the design and execution of education pathways, increasing civic engagement and aiming to solve societal challenges in a human-centric way. In our presentation we will report from the project and share our ideas from the project as far as we have come.

HOW TO IMPLEMENT CHALLENGE-BASED LEARNING TO FOSTER ENTREPRENEURSHIP INTENTIONS OF VET STUDENTS? - AN EMPIRICAL STUDY AT THREE VOCATIONAL SCHOOLS

RESEARCH PAPER

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Theoretical Background: Societal challenges call for social entrepreneurs to be agents of change, offering new visions and business models to tackle local and global problems (Carvalho, 2019). Even though the European Union (2016) emphasises the relevance of entrepreneurial competences at all levels of education and for non-traditional entrepreneurs, there is limited evidence on the design and the outcomes that can be expected from social entrepreneurship education (SEE) in the context of vocational education and training (VET). Research suggests entrepreneurial intentions to be an important predictor of becoming an entrepreneur (Zhao et al., 2010). However, as research on entrepreneurship education showed inconsistent findings regarding change in entrepreneurial intentions, the design of entrepreneurship education needs to be critically discussed (e.g. Bae et al., 2014). Challenge-based Learning (CBL) is a promising approach for SEE as it picks of various demands from SEE and encourages learning while working on solutions to real-world challenges addressing societal and global issues (Gallagher & Savage, 2020; Martinez & Crusat, 2017). Also, in CBL, working with external stakeholders can contribute to the complexity and authenticity of the challenge (van den Beemt et al., 2023), which is a key desideratum for entrepreneurship education (Aadland, 2023). Typically, entrepreneurial methods like market research, (business) planning and modelling, prototyping and elevator pitch techniques are part of the CBL learning experience (Martinez & Crusat, 2017). In summary, CBL meets a variety of criteria relevant to SEE, but there is no study investigating CBL for social entrepreneurship in VET schools measuring the development of entrepreneurial intentions in a longitudinal approach. Therefore, this study aims to analyze the design of CBL courses for Social Entrepreneurship Education in VET and evaluate their potential to change entrepreneurial intentions by addressing two research questions: RQ1: How is CBL implemented in three SEE courses in VET considering seven dimensions characterizing CBL? RQ2: How do the entrepreneurial intentions of

vocational students in three courses with different implementations of CBL differ between the classes and before and after participation? Methods: Design and context of the study: The study was approved by the Ministry of Education. Three social entrepreneurship courses following a CBL approach were offered at two upper vocational schools (grades 10-13). All three courses worked with real-life and authentic challenges concerning SDGs raised by their school or external stakeholders. CBL implementations were mapped using standardized surveys for teachers and the vocational students were surveyed before and after their participation in the course by using standardized scales. All participants gave written consent prior to participation. Sample: Longitudinal data from N = 44 VET students participating in the social entrepreneurship courses was collected. N = 14 involved teachers provided information on CBL implementation in their course. Instruments: Differences in the implementation of the CBL approach were mapped using seven indicators from an adapted version of the CBL-Compass tool from van den Beemt et al. (2023). Entrepreneurial intentions were measured by a single item using a five-point rating scale. Data analysis: The CBL implementation was analyzed by reporting descriptive statistics in a spider graph (RQ1). For analyzing RQ2, a mixed ANOVA with two factors (course, point of measurement) and entrepreneurial intentions as a dependent variable was conducted. Results: RQ1: Differences in CBL implementation between courses mainly concern indicators for authenticity and complexity of the challenge as well as stakeholder involvement. For other indicators, courses were more comparable. RQ2: A significant.

ENTREPRENEURSHIP EDUCATION AND UNIVERSITY STUDENTS' ENTREPRENEURIAL INTENTION: A CHALLENGE-BASED LEARNING PERSPECTIVE

RESEARCH PAPER

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Introduction.

Building on the Theory of Planned Behavior, the aim of this study is to investigate the moderating effect of Entrepreneurship Education in the relationship between attributes like attitude towards the behavior, subjective norms and perceived behavioral control, and the entrepreneurial intention of university students. Specifically, it analyzes the moderating effect of entrepreneurship courses that adopt a Challenge-Based Learning approach. This is particularly relevant for educational institutions aiming to foster an entrepreneurial mindset among students. The study is based on data collected from the GUESSS (Global University Entrepreneurial Spirit Students' Survey) project in 2021, allowing for an in-depth analysis of entrepreneurial dynamics among university students.

Theoretical Framework.

The Theory of Planned Behavior is a widely recognized theoretical model that explains behavioral intention. According to this theory, intention is influenced by three main components: attitude towards the behavior, subjective norms, and perceived behavioral control. This study situates itself within this theoretical framework and seeks to address existing gaps in literature regarding the effect of Entrepreneurship Education methodologies on entrepreneurial intention. Specifically, the article explores whether the Challenge-Based Learning approach can provide a more effective educational context compared to traditional Entrepreneurship Education courses, contributing to greater awareness and intention to create entrepreneurial ventures.

Methodology.

The research design is quantitative. Data were collected through questionnaires administered to university students who participated in Entrepreneurship Education courses, with a specific focus on the differences between traditional courses and those based on Challenge-Based Learning. The sample includes students from various universities and academic disciplines. Data analysis was conducted using regression models to examine the effect of independent variables—participation in Entrepreneurship Education/Challenge-Based Learning courses, attitude towards the behavior, perceived behavioral control, and subjective norms—on entrepreneurial intention.

Results.

The results from the regression models indicate a positive and statistically significant relationship between attitude towards the behavior and perceived behavioral control with entrepreneurial intention. In particular, it is found that participation in Challenge-Based Learning courses intensifies the positive effect of attitude towards the behavior on entrepreneurial intention, suggesting that a more hands-on approach may enhance students' motivation to embark on an entrepreneurial path. However, it is noteworthy that participation in Challenge-Based Learning courses reduces entrepreneurial intention. This finding suggests that Challenge-Based Learning courses provide students with a more realistic awareness of the entrepreneurial challenges, leading them to reconsider their intentions. Furthermore, the research reveals a negative relationship between subjective norms and entrepreneurial intention, a phenomenon that may be attributed to an overload of social expectations, especially among students in scientific fields. This dynamic suggests that excessive social pressure to pursue an entrepreneurial path may have a counterproductive effect, reducing students' propensity to view entrepreneurship as a viable career. These findings suggest that while attitude towards the behavior and perceived behavioral control are crucial factors influencing entrepreneurial intention, subjective norms may have a complex and not always positive effect, particularly in academic contexts characterized by strong expectations toward traditional careers. Awareness of entrepreneurial realities may thus lead to an adjustment of students' entrepreneurial intention, making them feel better prepared to face the challenges of an entrepreneurial journey.

Implications.

The findings suggest implications for educational practices. Educational institutions could further integrate experiential learning opportunities into their Entrepreneurship Education courses. The Challenge-Based Learning approach appears effective in enhancing students' awareness of real entrepreneurial dynamics, promoting a more active and engaging learning context. These courses not only provide theoretical education but also allow students to tackle real-world problems, thereby facilitating a deeper understanding of the challenges and opportunities in the entrepreneurial landscape. Moreover, the research highlights the need to design courses that not only convey theoretical knowledge but also offer direct practical experiences with real challenges, such as working on entrepreneurial projects in collaboration with companies. Such experiences can help bridge the gap between theory and practice, better preparing students to face the challenges of entrepreneurship. Creating an educational context that encourages innovation and active problem-solving could not only increase entrepreneurial intention but also enhance students' ability to apply the skills acquired.

Limitations and Future Directions.

However, the study presents some limitations. One of the main concerns is the potential presence of a self-selection bias in the sample, as students who choose to participate in Challenge-Based Learning courses may already have a higher pre-existing entrepreneurial intention. This factor could influence the results and make it difficult to uniquely attribute the impact of the Challenge-Based Learning approach on entrepreneurial intention. Additionally, conducting longitudinal studies to analyze how entrepreneurial intention translates into actual entrepreneurial behaviors over time would be beneficial. Such studies could provide deeper insights into the relationship between Challenge-Based Learning and real entrepreneurial successes, contributing to the enhancement of educational practices and support programs.

Conclusions.

In conclusion, this study provides important insights into the effectiveness of Entrepreneurship Education methodologies, particularly highlighting the potential of Challenge-Based Learning. The evidence not only contributes to a greater understanding of the dynamics influencing entrepreneurial intention but also offers practical insights for improving educational courses. By adopting more experience-oriented educational approaches, universities can strengthen their students' preparedness and stimulate a more sustainable entrepreneurial ecosystem. The ability to proactively tackle entrepreneurial challenges not only enriches students' educational experience but also helps create a generation of more aware and prepared entrepreneurs capable of navigating the complexities of the market.

HUMAN AND ETHICAL ASPECTS OF AI: A CBL CHALLENGE FOR ENGINEERING MASTERS STUDENTS

PRACTICE PAPER

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This abstract presents practice based experiences from a large course entitled "Human and Ethical Aspects of AI" in the master's program "Artificial Intelligence and Engineering Systems" at Eindhoven University of Technology. The paper explains and documents a new CBL assignment for the course that was piloted in Academic Year 2024 2025. The target group is highly extrinsically motivated to pass the course, because it is a required element in the AI&ES master program. They also show fairly strong autonomous interest and motivation to learn about ethics issues related to AI, as indicated by prior year student evaluations and instructor experience in engineering ethics education (15 years). This CBL assignment tackles two distinct but compounded problems in ethics education for engineering students. The first problem is the need to engage engineering students in interdisciplinary and transdisciplinary thinking, and in beginning to consider professional ethics as part of their own identity (Martin et al. 2021). The second problem is the increasing tendency of students to automate writing and critical thinking tasks using off the shelf Large Language Models (LLMs) such as OpenAI's ChatGPT 3.5, thereby bypassing the opportunity to acquire and improve these skills during the course (Cassinadri 2024). These problems appear as potential obstacles to some of the learning goals in the course The assignment tackles the problems using the innovative approach of asking students to automate ethics tasks using LLMs within a CBL challenge. Students are asked to choose one of the following three challenge topics:

• AI generated ethics cases.

• Chatbots for practicing clinician patient interaction

• A tool for AI supported ethics review, in groups of four, they work to customize a Chatbot or LLM tool that can perform one of these ethics tasks.

Clients were recruited from within the university, either experienced ethics teachers or people involved in ethics review. The rationale for this challenge relates to the two problems motivating the intervention. The first rationale relates to the need for engineering students to adopt an identity that relates to inter and trans disciplinarity and ethics. This problem is addressed in the intervention by requiring students to go back and forth between two roles. The first role is a first order or "subject" position in which they themselves are learning to "identify ethical issues and value conflicts at different stages of the design process" and "adopt a strategy for resolving value conflicts in a way that is convincing to multidisciplinary stakeholders." (These are two of the five learning goals in the course.) The second role is a higher order or "meta" position in

which they are the ones responsible for others to acquire comparable skills in the target context.The hypothesis of the intervention is that this role shifting is instrumental to the acquisition of an autonomous, internalized relationship to ethics and inter and trans disciplinarity. In addition, it requires students to reflect on the way that LLMs change and influence student education and learning of these tools, relating to the second problem motivating the intervention. This is grounded in the idea of the flipped classroom, although literature in that field focuses on teachers' role shifting rather than students' role shifting (Hussain et al 2020). The average size of the course is 80 students, and during the year of the intervention there were 87 students participating, in a total of 23 groups. Students followed a series of lectures in the course, as well as having time to work on the CBL assignment during tutorial sessions where the instructor is available for guidance. In addition, there were three half hour coaching meetings with each group, at which two groups (8 students), the instructor, and (at the third meeting) a client were present. Each of these coaching meetings had a different aim, with students gradually developing more concrete ideas, working toward a demo or mock up of the LLM tool that met the learning goals to a greater degree (as crystallized in an assessment matrix rubric). At the time of submission, the main part of the course has ended, but students have not yet received a grade or responded to course questionnaires. For that reason, although the implementation can be described, it is not possible to reflect on all aspects of the process and student learning. By the time of the paper presentation in April 2025, this will be added. However, there is room to note some of the key challenges and shortcomings of implementation:

• The role of ethics in the projects was somewhat less integral than expected. Students focused more on technical aspects of the project, and on deliverables, than on motivating the projects via ethical considerations.

• There was no explicit student reflection during or at the end of the course on role shifting, as part of the assignment. This was a missed opportunity to ask students to reflect on the key hypothesis of the project.

• Some student groups seemed to go off topic by focusing on versions of the challenge that did not match the assigned "clients" that I worked with during the course.

• The projects were time intensive for the instructor, alongside a series of lectures and preparation of exam materials. It is hoped that while this is a report of a limited, one off practice based intervention, the key hypothesis will prove interesting enough to inspire other researchers to investigate it further. In addition, I will be able to present some of the student outputs during the conference to inspire further discussion.

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DEVELOPING THE FIRST PARTNERSHIP OF TU EINDHOVEN WITH ENGINEERS WITHOUR BORDERS FOR THE CBL PROJECT 'FROM PLASTIC WASTE TO BRICKS'

PRACTICE PAPER

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This presentation puts forward a case study of practice set in a Challenge Based Learning course at TU Eindhoven. The course 'Decisions Under Risk and Uncertainty' was offered in the autumn of 2022 as part of the USE – User, Society, Enterprise learning line to 79 students from diverse disciplinary backgrounds. The majority of students represented second-year Chemistry and Chemical Engineering students.

The USE course 'Decisions Under Risk and Uncertainty' took place over 3 academic quartals. In this course, students worked in groups of three to five on 7 real-life sociotechnical challenges provided by external partners. For this course, the author developed the first partnership of TU Eindhoven with Engineers Without Borders Netherlands, who presented the 'From Plastic Waste to Bricks' challenge.

The motivation for this partnership was to expose students to the grand problem of plastic waste in North Africa and develop an awareness of the unequal distribution of risks and benefits based on geographical or socioeconomic context. For the challenge 'From Plastic Waste to Bricks,' students developed a risk assessment for a technology start-up seeking to convert plastic waste into plastic bricks that can be used for building the first washroom in a school in Ghana. In the first quartal students were introduced to the societal and ethical dimension of risk, via tools such as stakeholder mapping of the risk-exposed, -beneficiaries and -decision makers in the context of this novel technology that converts plastic waste into plastic bricks and participatory methods for developing community projects. In the second quartal, students gained technical knowledge of risk assessment methods such as HAZOP. In the third quartal, students developed a risk assessment to account for the societal and technical dimensions of the project. The first and third quartal were offered in the CBL format, with students having several contact moments with the educational partners. The second quartal was offered in a traditional format focused on technical and theoretical knowledge development.

The author designed and coordinated the course offered in the first quartal, and in the third quartal was the coach of the challenge 'From Plastic Waste to Bricks.' The challenge 'From Plastic Waste to Bricks' has 4 key contributions in terms of students competence development: (i) students considered the needs and power differentials of different categories of stakeholders, (ii) they gained an appreciation of the importance of using lay-expertise awareness of local communities and (iii) ensured that the perspectives and needs of different stakeholder categories are represented in the final solution; (iv) students also expressed an acknowledgment of the responsibility to reflect on the future of technological developments for the public good and energy justice. Considering the broader institutional context, the challenge 'From Plastic Waste to Bricks' marked the beginning of a collaboration between TU Eindhoven and Engineers Without Borders Netherlands. In this presentation, the author will describe the educational challenge 'From Plastic Waste to Bricks,' including the steps, challenges, and benefits of setting up a collaboration with a novel educational partner representing a community or non-governmental organisation.

The author will describe how the collaboration ran and the involvement of the educational partner in the challenge. This practice paper will provide insights into how collaborations with community or non-governmental organisations can foster student competences related to ethical awareness and responsible engineering practice.

AVANS INNOVATIVE STUDIO, AN EXAMPLE OF CBL IN PRACTICE

PRACTICE PAPER

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Abstract for CBL Conference 2025 The Avans Innovative Studio (AIS) at Avans University of Applied Sciences offers a transformative approach to challenge-based learning (CBL), immersing students in real-world problem-solving through collaborations with industry partners such as multinational corporations, healthcare organizations, and startups. AIS provides a dynamic, hands-on environment where students work in transdisciplinary teams to address authentic challenges, creating tangible outcomes like prototypes, applications, and marketing campaigns. With guidance from studio coaches and professionals, students develop important skills like problem-solving, adaptability, and transdisciplinary teamwork, preparing them for a rapidly changing job market. AIS is based on three core principles: social constructivism (Gergen, K. J. (1999). An invitation to social construction. SAGE Publications), design thinking (Brown, T. (2009). Change by Design: How Design Thinking Creates New Alternatives for Business and Society. HarperBusiness), and studio learning (Hetland, L. (2013). Studio Thinking 2: The Real Benefits of Visual Arts Education. Teachers College Press); (Schön, D. A. (1985). The Design Studio: An Exploration of Its Traditions and Potentials. RIBA Publications). Together, these principles encourage collaborative, experimental, and iterative learning within a structured yet flexible environment. Social constructivism fosters interdisciplinary knowledge-sharing, enabling students to integrate insights from various fields to approach complex problems. Design thinking promotes innovative ideation, rapid prototyping, and testing solutions within practical constraints. Studio learning offers a supportive space for students to experiment, take risks, and learn from mistakes through continuous reflection. AIS operates on two-week project cycles that push students to generate ideas quickly, make decisions under time constraints, and refine their work through rapid iteration. This action-oriented, agile approach builds confidence, enhances problem-solving skills, and develops a growth mindset essential for professional success. Each cycle incorporates continuous guidance from studio coaches and feedback from industry experts, fostering a culture of reflection and adjustment that aligns with CBL principles. By iterating on their projects in short cycles, students learn to handle real-world challenges, improving their

resilience and adaptability. Projects at AIS span diverse fields, offering students exposure to a variety of sectors—from materials science and digital marketing to public health and social issues. This transdisciplinary approach prepares students to navigate complex problems that require both specialized knowledge and cross-functional thinking. Working in cross-disciplinary teams, students integrate their own expertise with that of their peers, fostering a broader perspective that leads to more innovative solutions. AIS's mentorship model is distinctive, as studio coaches encourage students to critically reflect on their decisions, fostering ownership and accountability. External experts from various industries provide specialized insights and connect student projects to professional standards. This balance between autonomy and guidance bridges the gap between academic and industry practices, helping students explore their ideas while benefiting from professional expertise. Regular interactions with professionals deepen students' understanding of industry standards, aligning their educational experiences with real-world expectations. AIS supplements project-based learning with workshops on skills such as design thinking, prototyping, and self development, which enhance students' practical and theoretical foundation. These sessions equip students with tools for adaptability, creativity, and resilience. By engaging with complex challenges and learning to navigate uncertainty, students gain confidence and the agility required in modern work environments. The impact of AIS extends well beyond its immediate participants. Since its launch, the program has collaborated with over 250 organizations, delivering practical solutions ranging from physical prototypes to digital applications and strategic campaigns. This engagement benefits both students, who gain invaluable real-world experience, and organizations, which receive fresh and creative solutions. The iterative nature of AIS projects, supported by regular feedback loops, enables students to adapt to client needs and produce impactful results. This approach demonstrates the core principles of CBL, emphasizing real-world problem-solving, continuous reflection, and practical engagement. AIS's success has also inspired other programs at Avans UAS to adopt transdisciplinary, project-based learning. Professors from other Institutions, such as Amsterdam UAS and Fontys UAS, have participated at AIS. The adaptability of the AIS model makes it a compelling example for educators looking to implement CBL frameworks across various educational contexts. The AIS educational design is grounded in evidence-informed practices, drawing on models like the NuVu Innovation School and Stanford's d.School. AIS evolved into a model of "structured chaos," providing enough direction for a solid starting point while allowing room for creativity. This approach aligns with CBL's principles, emphasizing flexibility within structure and iterative adaptation. The iterative AIS model emphasizes regular feedback and reflection. Each project cycle of two weeks ends with an evaluation session involving clients, studio coaches, and students, encouraging critical assessment of strategies, refinement of approaches, and adaptation as needed. This feedback-focused culture develops a continuous learning mindset, where students improve their problem-solving skills and cultivate an agile approach. AIS also experiments with new technologies to enhance learning. For instance, a pilot using an AI-driven app provided personalized learning support but ultimately proved less effective than traditional coaching. This experiment highlights AIS's openness to innovation and commitment to evaluating new tools. By integrating and assessing technology thoughtfully, AIS continues to refine its educational practices. AIS has significantly impacted Avans UAS and the educational field. By aligning with CBL principles, AIS has created an environment where students learn to tackle real-world challenges through collaborative problem-solving. Emphasizing interdisciplinary teamwork, iterative learning, and professional engagement, AIS equips students with the skills needed in today's job market, such as adaptability, resilience, and critical thinking. Through its evidence-informed approach and commitment to continuous improvement, AIS enhances the educational experience for students and serves as a model for innovation in diverse contexts. In summary, AIS embodies a scalable CBL approach, emphasizing real-world problem-solving, interdisciplinary collaboration, and agile learning. By bridging academic and professional learning, AIS sets a powerful example for the future of education. Its influence extends beyond Avans, inspiring institutions to adopt similar frameworks that prepare students to face the complexities of today's workforce with confidence and creativity.

LANGUAGE AS A TOOL: A CHALLENGE-BASED SUMMER BOOTCAMP MODEL WITH SCRUM SCAFFOLDING TO DEVELOP GLOBAL COMPETENCIES

PRACTICE PAPER

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This practice paper explores a Challenge-Based Learning (CBL) approach within a summer bootcamp model aimed at building global competencies among university students. Conducted through the Ankara Yıldırım Beyazıt University (AYBU) Learning and Teaching Center (LTC), the bootcamps target essential skills through English for Specific Purposes (ESP) workshops, creating a structured, context-driven and collaborative environment to build language proficiency, employability and technical skills. This model focuses on three areas—SolidWorks Computer Aided Design, Front-End Web Development, and Level Up Your People Skills—to develop competencies for the global marketplace. Incorporating Torta et al. (2023), the model uses Scrum tools to scaffold student processes in navigating open-ended, multidisciplinary challenges. Scrum elements help guide iterative goal-setting, role definition, and peer reflection, enhancing both collaborative skills and engagement. Data collected from participant reflections reveal key themes related to skill evolution, overcoming challenges, and the role of peer mentorship or near-peer role models. Findings highlight the impact of CBL and Scrum scaffolding on fostering meaningful engagement, resilience, and peer-driven insights, with significant implications for student readiness to tackle real-world global challenges. We also discuss recommendations for improving the bootcamp structure, including extended timeframes, increased interactive elements, and added focus on mentorship and practical applications.

Keywords: CBL, ESP, bootcamps, Scrum, global competencies, mentoring, instructional technologies

Introduction:

CBL has become a prominent approach to engaging students in real-world challenges, developing critical skills for a globalized environment. This paper introduces a summer bootcamp model developed at the AYBU LTC, applying CBL principles to equip students with global competencies through ESP-focused bootcamps. This model incorporates Scrum tools to scaffold students' collaborative processes and overcome the uncertainties they face when dealing with open-ended projects, similar to engineering practices where Scrum structures tasks amid unpredictability (Torta, Thurlings, Arslan, & Alonso, 2023).

The bootcamps cover several subject areas, using English as the primary language to simulate professional contexts and foster language skills necessary for the international marketplace.

Relatively senior students serve as peer mentors, guiding teams and enriching the collaborative learning experience. CBL and ESP have both proven effective for preparing students for a globalized workforce by blending subject expertise and language skills. In CBL, students tackle complex, real-world problems, promoting in-depth learning and skill integration across disciplines (Gallagher & Savage, 2023; Leijon et al., 2021). ESP, a branch of English language teaching, focuses on the specific language skills needed for particular fields (Basturkmen, 2024; Hutchinson & Waters, 1987), helping students develop functional language skills in context. The AYBU LTC summer bootcamps were organized around three skill domains—SolidWorks Computer Aided Design, Front-End Web Development, and Level Up Your People Skills. Each bootcamp simulated real-world challenges in these fields, using collaborative projects and peer mentorship. Scrum tools, based on Torta et al. (2023), provided structural scaffolding to guide students' learning processes. Scrum principles, such as setting goals in "sprints," holding stand-ups for progress tracking, and engaging in retrospectives, allowed students to approach their projects with a clear roadmap, fostering iterative learning and collaboration. This structure encouraged students to set and evaluate goals consistently, fostering a sense of responsibility and engagement. The bootcamps used English as the primary language, supporting ESP objectives by immersing students in language-rich, context-specific environments. This integration of ESP with CBL helped build both language fluency and essential skills such as critical thinking, problem-solving, and teamwork. In the SolidWorks CAD bootcamp, for example, students tackled hands-on 3D modeling challenges, while the Level Up Your People Skills bootcamp used role-playing scenarios to simulate professional communication. To assess bootcamp effectiveness, a thematic content analysis was conducted based on participant reflections.

Structured prompts guided participants to reflect on skill development, challenges, collaboration, and the role of English immersion. Data were gathered from each bootcamp and analyzed to identify recurring themes related to global competencies. The analysis of reflections revealed several themes: Skill Development and Self-Efficacy: Students noted improvements in technical and communication skills. Increased confidence was commonly reported, with participants expressing readiness to apply these skills in future projects and professional settings.

The structured goal-setting in Scrum helped students measure their progress and recognize growth, which boosted self-efficacy. Challenge and Resilience: Many participants described the bootcamp as challenging but rewarding. The initial difficulties—such as grasping complex technical concepts or communicating in English—helped build resilience. The iterative learning cycles facilitated by Scrum tools allowed students to break down larger tasks, set short-term goals, and seek solutions iteratively, promoting resilience and adaptability.

Collaborative Learning and Mentorship: The bootcamps' collaborative structure enabled valuable peer interactions, with students helping each other troubleshoot problems and exchange knowledge. Mentorship from peers was pivotal, providing both technical guidance and emotional support. Scrum elements like stand-ups and retrospectives further enhanced collaboration, reinforcing teamwork and empathy by creating opportunities for students to reflect on and celebrate each other's progress. English Proficiency and Global Readiness: The immersive English environment played a significant role in enhancing students' language skills, especially those aspiring to work in international fields. Participants reported feeling more comfortable with technical and professional English, which they anticipated would be beneficial in future academic and professional interactions.

Recommendations for Improvement:

Participant feedback included suggestions for longer bootcamp durations, additional interactive components, and extended mentorship. Incorporating more Scrum sprints and structured reflective phases was also recommended to deepen engagement and reinforce skill development. These findings highlight the potential of CBL to prepare students for global roles by integrating ESP and field-specific content within a Scrum-based structure. The AYBU LTC bootcamp model illustrates how CBL, combined with Scrum practices, can effectively develop both technical and soft skills that align with students' career goals. Scrum tools provide structure and process for project navigation, enabling students to gain resilience and adaptability—qualities essential to global competencies. The use of immersive language learning within the bootcamp framework amplifies these effects, creating a comprehensive model that can be applied in other CBL settings to foster global competencies.

EXPLORING THE STUDENT LEARNING EXPERIENCE IN DUTCH INNOVATIVE ENGINEERING MATHEMATICS COURSES: A CHALLENGE-BASED LEARNING CASE STUDY

RESEARCH PAPER

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Background and Rationale

This study investigates the student learning experience within two distinct engineering mathematics courses: "Socio-Physics" and "Data Challenge 3", using Challenge-Based Learning (CBL) at a Dutch university. As engineering education shifts towards more dynamic and interactive methodologies, evaluating how these changes affect student learning experiences becomes essential (e.g., Banerjee & Ntaimo, 2022), in particular on the development of creativity (Wu & Wu, 2020) and problem-solving skills (Shanta & Wells, 2020). A large number of studies have concentrated on the learning experience in higher education, particularly where technology innovation and curriculum innovation have enhanced students' learning (Robledo-Rella et al., 2022). Despite general affirmations of its efficacy, detailed studies on student experiences in engineering mathematics remain limited. This work addresses this gap by exploring how CBL influences students' educational journeys through their perceptions of the learning experience in a CBL innovative engineering mathematics course to gain insight from students and instructors (both teachers and teaching assistants) in a Dutch university.

The research questions are (a) how students perceive the integration of real-world challenges into their coursework and (b) what effect the CBL approach has on students' motivation, understanding and application of mathematical concepts.

Research Methodology and Design

The research design employs a qualitative framework to investigate how Challenge-Based Learning (CBL) is experienced by students in two innovative mathematic courses: "Socio-Physics" and "Data Challenge 3." To investigate the student experiences in these two courses prior research describing the characteristics of innovative mathematic courses, proposed by Cai et al. (2024), is used to guide the inquiry and analytical processes. The characteristics of innovative mathematic courses considered here focus on various aspects of student learning experiences in Challenge-Based Learning (CBL) including the transaction of the problem, resources used for problem-solving, students' preparedness, performance, collaboration with team members and tutors, the learning environment and challenges faced during the learning process. As the intention is to understand how students experience CBL in these settings the research design integrates data from two primary collection methods: structured classroom observations and semi-structured interviews with students. Classroom observations were conducted through real-time, note-taking, capturing behavioral, verbal, and instructional aspects of the teaching and learning process. These observations provided detailed insights into the interactions and the actual delivery and flow of the course content. The focus group was organized with students from each of the courses: seven students participated in the "Socio-Physics" focus group, which was conducted in person shortly before the course ended, lasting one and a half hours. Another group participated online three months after the course concluded. The "Data Challenge 3" focus group also involved two separate sessions: the first focus group included two students and was conducted online one month after the course ended, lasting one and a half hours. The second session was conducted as an individual interview with one student two months after the course. Participation was voluntary and ethical approval was obtained from the Ethics Review board of the university.

Thematic analysis of the collected data (Braun and Clarke, 2014), processed through Atlas.ti, was guided by a coding framework based on prior research about the characteristics of innovative mathematic courses proposed by Cai et al. (2024). This framework focused on various aspects of student learning experiences in Challenge-Based Learning (CBL), including the transaction of the problem, resources used for problem-solving, students' preparedness, performance, collaboration, the learning environment, and challenges faced during the learning process.

Results and Findings

This structured approach enabled the identification of central themes and patterns, capturing both positive outcomes and challenges associated with CBL. The expected findings are anticipated to indicate whether CBL significantly enhances student engagement, learning efficacy, and disciplinary understanding by fostering a more interactive, hands-on, and application-oriented learning environment. Furthermore, differences in student experiences between the two courses are likely to provide insights into how the nature of course content, structural design, and challenge integration influence student perceptions, efficacy, and overall engagement. The qualitative focus on student perceptions in this study, while valuable, may not fully capture the complete impact of CBL.

Educational Impact

This study highlights the transformative potential of CBL within engineering mathematics, demonstrating its ability to deeply enrich student learning experiences by connecting academic theory with practical, real-world challenges. Looking ahead, we hope to see similar positive effects in other CBL courses, enhancing the overall educational experience for students. This work offers empirical evidence on the potential transformations in student engagement and comprehension, supporting a broader adoption of experiential learning practices in engineering education. Furthermore, it will pave the way for additional research into the long-term impacts of CBL on student outcomes and the effectiveness of various assessment methods in CBL environments. These findings could significantly contribute to refining course design and implementation across engineering disciplines.

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TO CBL OR NOT TO CBL? COMPARING STUDENT MOTIVATION, LEARNING STRATEGIES, AND OUTCOMES IN TWO COURSES

RESEARCH PAPER

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Challenge-Based Learning (CBL) is a relatively novel approach responding to calls for more student-centred and authentic learning environments (Graham, 2017). By working on open and real-life challenges, students are expected to take the lead in their own learning, identify adequate learning goals, acquire and apply knowledge, and develop disciplinary and transdisciplinary skills (Van den Beemt et al., 2020). Generally, students show qualitatively different ways in which students approach and deal with learning tasks which lead to qualitatively different learning outcomes. (e.g., Biggs, 1979, 2003; Richardson, 1997; Vermunt, 2005). Prior research has shown that students' application of learning strategies is sensitive to factors of the learning environment. This may specifically be true for students under an educational concept such as CBL, that advocates for student autonomy and responsibility. Accordingly, prior work has discussed CBL in relation to student motivation and self-regulation (e.g., Doulougeri et al., 2023). Nevertheless, the question of whether CBL is really able to foster student learning and yield higher student motivation and outcomes has not been systematically explored. Therefore, this research explores the effects of CBL on students' learning strategies and learning outcomes by systematically comparing a CBL-course to its non-CBL counterpart. Hypotheses Students in CBL 1. Are more motivated, 2. Show higher employment of positive learning strategies such as processing and self-regulation and engagement, 3. Acquire more knowledge than students in the original course, and 4. Gain important competencies, such as developing autonomy and self-direction; better interdisciplinary competence, and intolerance of uncertainty. Methodology Setting and Procedure This research took place at a Technical University in Western Europe. A course on Technology Entrepreneurship was re-designed to CBL. All students were invited to respond to online surveys at the beginning, during, and the end of the original and re-designed version of the course. Surveys collected data on students' background, course motivation (Kosovich et al., 2015), grit (Duckworth & Quinn, 2009), intolerance of uncertainty (Carleton, Norton, & Asmundson, 2007) as well as learning strategies, and student learning outcomes such as social engagement (Vermunt, Illie, & Vignoles, 2018), interdisciplinary competences (Lattuca, Knight, & Bergom, 2012), and entrepreneurial mindset, knowledge, and skills (ASTEE, 2014). Participants Participants were 169 students (82.2% male) in a non-CBL version of an Introduction to Technology Entrepreneurship course and 26 students (73.1% male) attending its CBL re-designed version a year later. The significant drop in student numbers resulted from a re-design of the Bachelor College's system for choosing elective courses. Results Hypothesis 1 Student motivation was captured both at timepoint 1 (beginning) and timepoint 2 (middle of the course). Students reported significantly higher motivation at the beginning of the re-design. Paired-samples t-tests were conducted to evaluate the change in motivation a few weeks into the course. In the original course, we found a significant decrease in motivation from T1 ($M = 4.52$, $SD = .56$) to T2 ($M = 4.17$, $SD = .66$, $t(62) = 5.32$, $p < .001$). An analysis of covariance (ANCOVA) comparing the two courses however showed that students' motivation at T2 did not differ between courses if motivation at T1 was controlled for. Students' course motivation was found to correlate with all aspects of the learning environment (except for differentiation, $r = .22$ - $.69$; $p < .037$). Therefore, t-tests were run and revealed significant differences between the two courses in students' perception of the learning environment as allowing for autonomy (OC: $M = 4.62$, $SD = 0.68$, RC: $M = 4.39$, $SD = 0.60$, $t(87) = 2.15$ $p = .035$) and interaction (OC: $M = 4.44$, $SD = 0.96$, RC: $M = 4.93$, $SD = 0.69$, $t(88) = 2.01$ $p = .039$). Hypothesis 2 Exploring students' reported employment of learning strategies, we found that students in the original and the CBL-redesigned course only significantly differed regarding their social engagement in the course (OC: $M = 4.06$, $SD = 0.60$, RC: $M = 4.35$, $SD = 0.43$, $t(88) = 2.00$, $p = .049$), i.e., building on other students' ideas and supporting them. No differences could be identified for the employment of other learning strategies (e.g., self-regulation). Students' reported motivation at T1 and T2 correlated with the different learning strategies and engagement scales. This suggested to conduct cluster analyses using Ward's method, which revealed two clusters of students higher and lower in motivation at T1 and T2 (Cluster 1: T1: $M = 5.26$, $SD = 0.31$; T2 $M = 5.04$, $SD = 0.33$; Cluster 2: T1: $M = 4.36$, $SD = 0.45$; T2: $M = 4.00$, $SD = 0.51$; $t(81) = 8.4$, $p < .001$). These two clusters also differed significantly regarding students' employment of all learning strategies and engagement during the course. Hypothesis 3 & 4 Data collection at the end of the re-designed course is still ongoing (until end of October 2024). Final results for hypotheses 3 and 4 will be presented at the conference. Comparing students' entrepreneurial mindset, knowledge, and skills at T1, we identified no significant differences, which means that students entered the two different courses with the same knowledge and skill background.

Discussion and Implications The findings generally support prior research that describes a close interplay of students' employment of learning strategies with aspects of the learning environment (e.g., Helker et al., 2024). Furthermore, prior work on CBL emphasising student motivation in these courses is supported by finding CBL students' motivation to be higher at T1. The question remains, whether there may be a bias given that these were elective courses and only students already curious and motivated to work in such a CBL environment may have selected the course. Nevertheless, the students high in motivation were found to employ beneficial learning strategies more, which calls for teachers' actions. One drawback of this study is the small number of students in the re-designed version of the course, which calls for further studies in the future

EVALUATING LMS FOR ENTREPRENEURSHIP CHALLENGE-BASED LEARNING COURSES

RESEARCH PAPER

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Challenge-Based Learning (CBL) is an educational approach that actively engages students in tackling real-world challenges, fostering critical thinking, collaboration, and innovation. To effectively implement CBL, a robust digital platform is essential, enabling seamless communication, resource sharing, and course management.

The Erasmus+ ENTERCBL project, which aims to develop an entrepreneurial course using the CBL methodology, requires such a platform to support its objectives. This article examines the benefits of utilizing a Learning Management System (LMS) compared to developing a new platform from the ground up. After evaluating existing LMS, Moodle emerges as the most suitable choice, aligning closely with the project's needs and the CBL framework. Moodle's flexibility, open-source nature, and extensive features make it an ideal platform to support the dynamic, interactive requirements of CBL. The study concludes that leveraging an established LMS like Moodle offers significant advantages in terms of cost-efficiency, timesaving, and functionality, ultimately ensuring the successful implementation of the ENTER-CBL entrepreneurial course.

LEARNINGS OF TWO YEARS CHALLENGE-BASED LEARNING IN THE MSC ROBOTICS PROGRAMME

PRACTICE PAPER

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In September 2022 at the University of Twente the master Robotics programme was launched in which CBL projects are integrated. This paper addresses the student evaluation of CBL in the programme. Students do four CBL projects, one per quarter. Students from different specialisations within the programme work together on their own challenge which they have defined based on a broad big idea (like health, mobility, etc.) and develop a robotics solution. The teachers of the compulsory courses of that quarter indicate which elements of the courses must come back in the CBL projects. This groupwork part, 20% of the course, is graded as part of those courses. The individual component of the CBL projects is summarized in a portfolio where students reflect on the CBL process, teamwork, personal learning goals (set at the start of each project), and the impact of their work. Formal formative feedback on the portfolios is provided after each project and after project four a pass/fail grade is given based on all four projects (van Vleuten et al.). The key elements of the individual part of CBL in MSc Robotics (related to the Learning Outcomes) are (1) CBL process, (2) teamwork, (3) reflection, and (4) impact. Students write their individual portfolio using these four elements. After 1.5 year an evaluation session with students who just completed their fourth or their second CBL project was held. The evaluation was conducted through the use of statements using Wooclap. These statements were all connected to the key elements of CBL in MSc Robotics. 51 students completed the statements, where they could choose between answers ‘not at all’, ‘a little’, and ‘very much’. Regarding the CBL process, the vast majority (49 of 51) indicated that they appreciate the CBL phases (36 votes for 'a little' and 13 for 'very much'). However, the majority also indicated that they do not appreciate the integration with the courses (29 of 50 votes for 'not at all') and this also comes back in the perceived workload, which is too high according to 60% of the students. The timing of this evaluation has probably largely influenced these latter results, because one of the courses in the quarter the students just finished, had a very high workload due to a weekly assignment, which didn't allow much time for the students to work on their CBL projects. 32 out of 50 students indicated that they really appreciate ('very much') the multidisciplinary teams in the CBL projects. And the teamwork also helped them to acquire new knowledge and skills (average of 3.1 and 3.6 on a 5-point scale respectively). Regarding the added value of defining personal learning goals, the answers were really diverse (21 votes for 'not at all', 15 for 'a little', and 12 for 'very much'). Unfortunately, we could not distinguish between answers from the group of 35 students who just finished CBL project 2 and 16 students finalizing CBL project 4. From the discussion during the evaluation session and statements made by students from CBL project 4, it became clear that they appreciated the personal learning goals much more and did not understand why someone would say that there is no added value at all. It was also asked, both for teamwork skills as for reflection skills, whether students have enough support to work on these skills. While the majority concluded that they received enough support, still 9 and 7 students (for teamwork and reflection respectively) indicated that they didn't receive enough support to work on these skills. In the free space at the end of the evaluation sessions the comment to create more hands-on experience was made by four students. Based on the results of the evaluation session, it can be concluded that the CBL process itself and especially the forming of student groups from different specialisations is appreciated, but that the connection with the compulsory courses should be improved. The first steps to work on this, is a more intensive preparation with the course teachers and some teachers already made adaptations in their course setup. What we learned from the evaluation, and especially the discussion afterwards, is that the appreciation for setting up personal learning comes with time. We have also noticed this over the years; after they have completed CBL project 4, they realize what they have learned. To make the students more aware of what the benefits are, more attention is given to this during the introduction sessions, by having older students telling what their experiences were and/or by adding quotes of these students. When setting up CBL in MSc Robotics we thought that master students should already have the skills to reflect on teamwork and personal learning goals or at least should be able to find their own resources to learn it. However, it turned out that students don't know where to start and therefore some more sessions on reflection were added to the introduction session. As students have to do four CBL projects over the year that always ends with a rough description of a robotics solution, students might lose their motivation. Therefore, different end products for the CBL projects were introduced: a presentation, overview diagram, poster, and a pitch. Furthermore, students of CBL project 3 can create a real prototype by using a mobile robot as basis, while for CBL project 4, students can extend one of the projects they already did to be able to add more detail to their solution. After two years of CBL in the master Robotics we learned that students appreciate the multi-disciplinary way of working and the structuring of the projects, but more attention should be paid to the integration with the compulsory courses and appreciation of setting personal learning goals really comes with time. From the current academic year, an extensive evaluation of CBL in MSc Robotics has started. Students complete a survey at the start of their MSc Robotics programme, at the end of CBL project 4 and at the end of their MSc-thesis project.

TRANSDISCIPLINARY CHALLENGE-BASED LEARNING: A CASE STUDY OF INTERCULTURAL, INTERUNIVERSITY COLLABORATIVE LEARNING DESIGN

RESEARCH PAPER

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The goal of transdisciplinarity is to initiate and support interactions between higher education institutions (HEIs) and societal actors to integrate expertise, experience, tools, and methods from multiple perspectives to tackle problems of societal importance (Gibbs, 2015; Klein, 2014; LERU, 2016; O'Sullivan, 2023; Vienni Baptista and Rojas-Castro, 2020). Within the European tradition, transdisciplinarity is a normative and societally-oriented educational approach (O'Sullivan, 2023). Transdisciplinary challenge-based learning (T-CBL) brings students, academic and extra-academic actors together in a learning process that both frames complex societal problems and creates action pathways to potential solutions. Extra-academic actors are defined as actors who are connected to transdisciplinary work on challenges but who are external to the academy (O'Sullivan, 2023). In transdisciplinary learning and research, the aim is to bring disciplines, multiple actors and students together in an exercise of knowledge integration to collectively examine, understand and attempt to solve complex societal challenges. This presents challenges and opportunities for HEIs to design learning experiences that recognise the needs of different actors in the learning process and provide transparency on the goals and outcomes of the learning. In CBL, students develop skills to engage with complex societal and environmental challenges (Malmqvist, Rådberg & Lundqvist, 2015; Membrillo-Hernández et al. 2018; van den Beemt, van de Watering & Bots, 2023), however, the complex nature of global societal challenges means that all actors need to think globally in transdisciplinary problem analysis and solution design. This means that all actors in research and education on global challenges need to develop an awareness of how cultural differences impact on problem analysis and solution development. However, in literature to-date the role of intercultural learning and the design of learning experiences that integrate knowledge from different geographical epistemologies has not been explored. Most research on CBL to date focuses on challenges where student groups are predominantly mono-disciplinary, and students undertake challenges within their own discipline (particularly within engineering education) (Helker et al. 2024; Leijon et al. 2022). While there is emerging research exploring design principles in CBL (Doulougeri et al., 2022), missing from the research to-date on both T-CBL and CBL is an exploration of what factors influence the choice of learning design, who is empowered in learning design and how learning design may differ in differing global contexts. In T-CBL, it can be argued that the learning design is synonymous with the curriculum. The process of learning influences what knowledge, theories and methodologies are introduced to students and what are excluded. The idea of what is included or excluded from the curriculum has been referred to as curricular justice (Connell, 1993). Curricula are informed by curriculum ideologies, which can be perceived not only as belief systems that provide the value premises from which decisions about practical educational matters are made (Eisner, 1994), but principles, ideas, beliefs and epistemologies about curricula (Lyall et al., 2015b). In T-CBL, where multiple viewpoints are integrated to analyse problems of societal importance, it is necessary to have transparency on why certain perspectives – disciplinary, geographical, cultural and political – are included and/or excluded from learning design. This case study describes how an alliance of three Dutch HEIs collaborated with a South African university to redesign a ten-week hybrid transdisciplinary, inter-university undergraduate course on sustainability education that would both allow for geographical and cultural differences to influence learning design and create areas of commonality for students and extra-academic actors to engage in mutually supportive work. The goal was to redesign the T-CBL course, originally designed for students at a Dutch alliance of HEIs, to provide an inclusive environment for different global and cultural perspectives on sustainability in urban environments. Realist evaluation (Pawson, 2013; Pawson & Tilley, 2004; Pawson & Manzano-Santaella, 2012) was used as a methodology to redesign the course. Realist evaluation explores the idea of 'how things change' and is an inherently theory-driven process that is both a research strategy and design (Pawson and Tilley, 1997; Pawson & Manzano-Santaella, 2012). Its key aim is to unpack programs to explain how and why programs work (or fail to work) in different contexts and for different program stakeholders (Astbury and Leeuw, 2010). Realist evaluation in this case supported course coordinators from multiple institutions to develop a shared language to make transparent the choices in course design that supported students to participate in a learning journey that consciously sought to decolonise spaces of teaching and learning (Costandius et al., 2018). The learning design was viewed as a posited program theory about how students would learn and what the boundaries of their learning would be. A program theory is visualised as a holistic endeavour designed to affect change. This enabled academic actors to visualise the course design as providing resources to actors engaged in learning and create a program theory about how actors would respond to these resources. The findings demonstrate how realist evaluation can be employed by transdisciplinary teams seeking to both create a common language around learning design and to increase transparency on how and why choices are made regarding learning goals and desired outcomes in T-CBL. Findings also demonstrate how realist evaluation, when used as course design, can provide a mechanism to iteratively evaluate and continuously develop programs of learning.

TRAINING THE TRAINERS: HOW TO TRANSFORM MORE TEACHERS INTO CBL TEAMCHERS – THE ECIU@LiU WAY

RESEARCH PAPER

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Within the university alliance ECIU (European Consortium of Innovative Universities), Challenge-Based Learning (CBL) has been chosen as the main pedagogy, especially for the challenge modules offered in the ECIU joint offering of learning opportunities. The pedagogy within the ECIU sphere runs in a loop of three phases: Engage, Investigate, and Act. It starts with a wicked real-life challenge given by an external stakeholder, which the students, during the first phase, have to narrow down and make their own. As multidisciplinary teams are preferred, students need to learn about each other and about what competences and skills are represented in the group.

Based on these and upon information gathered, the group then develops a solution which is presented in an open forum. This approach gives great opportunities for the students to train cognitive skills (e.g., problem-solving and critical thinking), intrapersonal skills (e.g., self-management and self-development), interpersonal skills (e.g., communication and teamwork), and technical skills (i.e., what we label disciplinary knowledge; for this division of skills, see Geisinger 2016). However, digging through the research on CBL shows that although the area is rather well researched, most contributions focus on the students and their views and benefits, while only a few contributions focus on the teachers (Eldebo et al., 2022; Norrman et al., 2022). What we know from previous research, though, is that skills and theoretical knowledge are interlinked (Kereluik et al., 2013; John Dewey, 1986). Rotherham and Willingham (2010) argue the same way and call for a better curriculum, better teaching, and better tests to also take the skills into account. In ECIU, the role of the teacher is put forward, and to underline that there are differences between the traditional teacher role and the teacher roles needed for CBL, the label "teacher" in the ECIU has been renamed to "teamcher." This is due to the fact that the CBL pedagogy requires not only the traditional teacher role (e.g., course plan, learning goals, lecturing, and examination) but also the role of the organizer (e.g., arranging the challenges and setting the scene for learning) and the role of the coach (e.g., skills-oriented support) (Eldebo et al., 2022).

In the CBL process, the "teamchers" by Eldebo et al. (2022) are defined as individuals that "either on their own or as part of a team, arranges, leads, and supports CBL activities. Furthermore, teamchers take, and often also slide between, the roles of being teacher, coach, and organizer of CBL activities" (p.804). Using the label "teamcher" hence highlights the collaborative bonds between teacher, student, and challenge provider that are the essence of CBL. Among the challenges inherent in the CBL pedagogy is not only how to set up the course and find suitable challenges but also designing the course in a way that enables the development and assessment of both knowledge and skills. Regarding the latter, there is a lot of experience within areas such as healthcare and medicine, while social sciences and engineering—despite the CDIO framework (cf. Crawley et al 2007) and all its efforts related to "create engineers that are able to engineer"—traditionally focus on measuring knowledge. To remedy this and also to follow the prompts of Rotherham and Willingham (2010), ECIU organizes support for their teamchers at all member universities, both at central and national levels. At ECIU@LiU, we arrange meetings, workshops, and CBL courses, and we share material and experience. To understand and meet the interests, needs, and challenges of teachers, we have recently sent out a questionnaire.

To date, we have obtained about 34 respondents from the Faculty of Engineering (18), the Philosophical Faculty (14), and the Faculty of Medicine (2). Our preliminary analysis shows that while there is enthusiasm for adopting CBL, challenges related to resources, collaboration, and institutional flexibility need to be addressed for successful implementation. Respondents value shared experiences, peer support, and structural changes that encourage innovation and experimentation in teaching. The teachers seek both concrete resources (time, idea banks, example portfolios) and intangible support (collegial acceptance, flexibility in processes, moral backing). We have also received indications that there is a desire to build a community around CBL implementation through networking, shared knowledge, and cross-departmental or cross-institutional support. Finally, there seems to be a demand for training focusing on giving practical tools and confidence to apply CBL effectively, especially in large classes. Also, the pedagogical alignment was highlighted. Risks, such as losing personal legitimacy in the eyes of external partners if students were underperforming, were noted. In our presentation at the conference, we hope to have a larger sample and more robust findings to share. We also aim to share how we work at ECIU@LiU to support both newcomers to CBL and experienced teachers.

SUSTAINABLE FUTURES: EMPOWERING EDUCATORS WITH CHALLENGE-BASED LEARNING STRATEGIES

PRACTICE PAPER

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With the growing urgency of sustainability challenges, higher education institutions have a responsibility to prepare students to meet complex global demands. Challenge-Based Learning (CBL), an experiential and interdisciplinary pedagogical framework, is ideally suited to empower educators in developing sustainability competencies across diverse student populations. This presentation introduces a comprehensive, research-backed CBL model designed for educators in both formal and informal educational contexts. Through a structured approach encompassing theory, practical implementation, and innovative case studies, I will demonstrate how CBL can cultivate the skills, knowledge, and agency needed to foster sustainable futures. Introduction: As the global sustainability agenda accelerates, educational institutions are tasked with equipping students with skills that transcend traditional academic learning. Education for sustainability emphasizes systems thinking, ethical responsibility, and real-world problem-solving, aligning with UNESCO's Sustainable Development Goals (SDGs) that encourage "quality education" and "sustainable cities and communities" (UNESCO, 2017). Challenge-Based Learning (CBL), which integrates problem-solving with active learning, has emerged as a transformative approach for teaching sustainability. CBL's experiential format aligns student engagement with sustainability principles, allowing for exploration, critical thinking, and solution generation in response to real-world challenges (Gallagher & Savage, 2020). This presentation will highlight findings from a recent handbook developed for educators across formal and informal settings, emphasizing CBL as a model to embed sustainability in education. The handbook outlines a research-based framework that equips educators with the strategies needed to facilitate impactful, interdisciplinary learning that resonates beyond the classroom. This approach prepares students to engage with complex environmental, social, and economic challenges, thus contributing directly to global sustainability goals. Objectives: This work seeks to achieve the following: 1. Empower educators with practical, evidence-based strategies for implementing CBL in sustainability-focused education. 2. Promote interdisciplinary learning by integrating environmental, social, and economic dimensions into classroom challenges. 3 Provide replicable CBL scenarios and tools for diverse educational contexts, including international perspectives, to foster collaborative and critical skills. 4. Encourage real-world application through case studies that demonstrate CBL's effectiveness in driving sustainable behaviors and community involvement. Methodology: Our approach draws on an extensive CBL framework designed to enhance educator training, curriculum design, and student engagement. This methodology is grounded in established CBL cycles of engagement, investigation, and action, adapted specifically to

promote sustainability goals (Vilalta-Perdomo et al., 2020). Key aspects of the framework include:

- Teacher Training and Professional Development: Structured training programs for educators to develop competencies in guiding students through sustainability challenges.
- Curriculum Design for CBL: Development of interdisciplinary challenges that require students to research, hypothesize, and generate solutions to real-world sustainability issues.
- Digital and Community-Based Integration: Utilizing digital collaboration platforms for virtual CBL and partnerships with local organizations to provide community-focused learning opportunities.

By equipping educators with these tools, the framework not only builds capacity for teaching sustainability but also enhances educators' ability to foster collaborative and critical thinking skills among students. Implementation and Case Studies: The handbook includes various case studies that illustrate the application of CBL in different educational settings. Prominent examples are ENNEPlus and GreenoVET Projects, that include an international competition focused on green innovation and sustainability (Christersson et al., 2022). In this initiative, students work with real business challenges from the green energy sector, collaborating in interdisciplinary, cross-cultural teams. Each team develops a solution addressing a specific sustainability challenge, such as renewable energy systems or sustainable product design. Another key case study involves Sustainable Living Labs (SLL), which promotes experiential learning by taking students out of traditional classroom settings to work on sustainability challenges within their communities (Leijon et al., 2021). Through SLL, students engage directly with sustainability in their own cities, applying their learning to create measurable impact. These hands-on experiences foster long-term engagement with sustainability concepts and provide students with the agency to make impactful changes in their communities. Conclusion: This framework illustrates how CBL can drive meaningful educational outcomes in sustainability, providing educators with a structured yet flexible model that adapts to various educational contexts. By focusing on real-world challenges and community-based solutions, CBL empowers students to connect classroom knowledge with global sustainability goals, thereby fostering the next generation of leaders who are equipped to address pressing environmental and societal issues. Our findings underscore that CBL is not merely an educational model but a transformative approach that instills critical competencies for the future. By adopting CBL, educators contribute directly to the development of sustainable communities and prepare students for lifelong engagement in sustainability efforts. This presentation advocates for the scalability of CBL frameworks within university curricula worldwide, highlighting its potential to reshape how sustainability is taught and practiced in higher education.

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CHALLENGE-BASED LEARNING TEACHERS AS CATALYSTS OF SUSTAINABILITY EDUCATION: PERCEPTIONS AND REFLECTIONS FROM TWO EUROPEAN UNIVERSITIES

RESEARCH PAPER

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In an era defined by grand societal challenges, educators are called to equip students with key competencies to contribute to a sustainable future. This sustainability education paradigm can be supported through pedagogies that empower students to construct knowledge through authentic problems (Guerra, 2017; Sandri, 2022), with challenge based learning (CBL) being one of such approaches. Our study examines CBL teacher's experiences with sustainability education by exploring teacher perceptions from two European institutions. Theoretical background CBL is an increasingly practiced experiential learning approach characterized by open ended challenges that teachers often present in collaboration with academic and external stakeholders (Leijon et al., 2022; van den Beemt et al., 2023). In CBL, students learn through multidisciplinary teams by developing solutions to authentic sociotechnical problems (Malmqvist et al., 2015). CBL is unique in that teachers often act as coaches and co creators in the learning process (Doulougeri et al., 2024). Therefore, both the solution and competencies developed through shared learning experiences are important outcomes of CBL (Kohn Rådberg et al., 2020; Rosén et al., 2022). Transforming educational practices for sustainability requires agency from educators (Barth & Rieckmann, 2012; Guerra et al., 2024). The understanding of how this agency is exercised through CBL remains limited for two reasons. Firstly, most literature on teachers' views focuses on teacher education context (Brandt et al., 2019; Cebrián & Junyent, 2015), leaving out the experiences of practicing teachers. Secondly, a specific view to how teachers design courses for sustainability education is lacking from recent reviews on CBL in engineering education (Doulougeri et al., 2024; Sukackė et al., 2022). To bridge these gaps, our study aims to create a connection between how teachers conceptualize sustainability and operationalize it in their CBL teaching practices through two research questions: How do CBL teachers conceptualize sustainability within their teaching practices? Which elements of CBL course design do teachers identify as contributing to sustainability education? Methodology Our study employs a qualitative research design, where we will conduct semi structured interviews with eight teachers, four each from two European universities. The participants are selected using purposive sampling to ensure diverse experience levels with CBL (Patton, 2002). We will use thematic analysis and inductive coding to identify and interpret patterns in meaning within our data. This approach enables us to generate new insights through an iterative process of coding, categorizing, and refining of themes (Braun & Clarke, 2006; Saldaña, 2009). The key limitations of our study lie in CBL teachers' potential bias towards sustainability education, and the cross sectional and qualitative nature of our study, which may not fully capture the complexity of CBL course designs across diverse contexts. Expected contributions Our study provides a nuanced understanding on how teachers integrate sustainability into their teaching and supports the advancement of more rigorous theoretical underpinnings for CBL. By exploring teacher perceptions and their influence on teaching, we identify specific elements of CBL that teachers associate with fostering key competencies for sustainability. Additionally, we contribute to the scholarly discourse on sustainability education by offering empirical evidence on the link between teachers' conceptualizations of sustainability and their instructional methods. Based on our findings, future studies can investigate teacher training needs to inform institutional policies and explore factors that enable teachers to enact professional agency for sustainability education.

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RETROSPECTIVE MAPPING: A BUMPY JOURNEY TO CAPTURE SELF-REGULATED LEARNING IN A CBL MINOR

RESEARCH PAPER

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Retrospective mapping: a bumpy journey to capture self-regulated learning experiences in a CBL minor Introduction in Challenge Based Learning (CBL), students are encouraged to transition from traditional teacher dependent learners to self-regulated learners, responsible for their own learning processes (Gallagher & Savage, 2023). Self-regulated learning (SRL) is essential for navigating CBL environments, which are inherently less structured and demand high levels of autonomy, critical thinking, and problem-solving skills (Zimmerman & Schunk, 2013).

However, SRL development is rarely straightforward; it is a complex, iterative process that includes both progression and setbacks as students adapt to various challenges (Vermunt & Donche, 2017). Although current research typically assesses SRL through surveys and reflection reports conducted at different stages of the course (Doulougeri, Vermunt, et al., 2022), these cross-sectional methods limit our understanding of students' continuous and evolving SRL trajectories over time. To address these gaps, this study investigates two research questions: (1) How do students retrospectively map their SRL journeys in a CBL minor program? (2) What are the critical phases that define students' SRL journeys? By focusing on students' retrospective accounts, this research aims to reveal pivotal moments that impact SRL development, offering a more comprehensive view of how self-regulation unfolds and adapts in real time within CBL contexts.

Methodology

This research uses narrative-oriented inquiry and journey mapping through drawings to reveal the unique paths students follow to develop SRL. A 5-point scale is integrated into journey maps, enabling students to rate their SRL at various stages. Additionally, narrative interviews allow students to reflect on their SRL experiences over time. By combining these methods, the study provides insights into students' perceptions and introduces a visual, retrospective mapping tool to quantify SRL development.

Participants

The research sample consisted of 19 (over 90% response rate) students from a CBL minor program in one Dutch university. Informed consent was obtained from all participants. Data collection After introducing SRL (Zimmerman & Schunk, 2013), students drew lines to map SRL levels from 1 (very low) to 5 (very high) on the y axis for each stage. This exercise encouraged reflection on SRL changes over time. In narrative interviews, students further discussed their learning experiences, focusing on how they navigated key phases and moments illustrated in their SRL journey maps.

Data Analysis

The first phase of analysis focused on journey maps. Student drawings were scanned and resized using Python and the OpenCV library to ensure uniform image quality, size, and format for automated data extraction. By analysing each line's coordinates at each program stage, SRL ratings were derived. An average SRL path was calculated across six learning stages, with students ranked by proximity to this average, with Student 1 being the closest. For the ongoing qualitative data analysis, we started from Student 1 to explore student's specific SRL phases in their journey. This analysis provides a detailed example of how SRL develops in alignment with the average trajectory. Results A bumpy but positive SRL journey characterized from all students' drawings The SRL journey of students shows a clear positive trend, beginning with an SRL mean (M) of 3.22 and a standard deviation (SD) of 0.10 in Week 1, and progressing to a higher mean of 4.00 with a notably low SD of 0.06 by the last stage. In Figure 1, the blue line shows the average SRL path across all participating students in the study. The red line represents the unique SRL progression of Student 1. It captures the "ups and downs" specific to this student, showing moments of both challenge and growth as they navigate through different phases. Figure 1 A bumpy but positive SRL journey in a CBL minor Three phases underscore the developmental nature of SRL Aligned with the average SRL path, another main finding from our preliminary interview data analysis is the identification of three stages in students' SRL journey, including phases we've termed initial struggle, adapting to autonomy, and self-regulation mastery. In the initial struggle phase, students frequently experience uncertainty and low motivation. As Student 1 noted, "At first, I didn't know anyone...and I had no clue what this minor actually involved...so that made myself regulation level a bit low, below average." As students' progress, many begin adapting to autonomy, where they internalize SRL strategies and gain confidence. For example, Student 1 said: "I got positive feedback that I was very good in communicating with the clients...and that was encouraging. I started thinking about myself like, OK, how can I do better?" In the self-regulation mastery stage, students achieve higher SRL levels, characterized by increased self-confidence and resilience. In the final stages, Student 1 demonstrated "Once we came to the last two weeks... I felt really good about it, not only for myself but also because we learned to support each other, think about other people as well, and do a little extra to help someone else thrive."

Conclusion

This research contributes to our understanding of SRL development in CBL settings by highlighting the nonlinear nature of students' SRL journeys.

The implications of these findings are twofold. First, they underscore the need for educators to provide flexible and responsive support that addresses students' evolving SRL needs at different stages. By recognizing that SRL development is a journey marked by both progress and setbacks, educators can create learning environments that are more attuned to the challenges students face. Second, the use of journey mapping and narrative inquiry demonstrates the value of creative and introspective methodologies in educational research, offering new ways to explore and document SRL in CBL settings.

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ENGAGING STUDENTS INTO HIGHER-ORDER THINKING WITHIN A CHALLENGE-BASED LEARNING CONTEXT: INTEGRATING CBL WITH 360 DEGREE PEER FEEDBACK

PRACTICE PAPER

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Introduction

Today's students need to gather 21st century skills to prepare for their future career. 21st century skills can be measured by higher-order thinking skills (HOTS), which is a process in which students develop higher cognitive levels, such as problem-solving, critical and creative thinking, analytical skills and the ability to make decisions guided by ideas and information (Saputra, 2016).

By involving students in the learning process, they can develop HOTS with which they are capable of analyzing and synthesizing ideas, making judgements and applying theory (Barak & Dori, 2009; Barak & Levenberg, 2016; Marra & Palmer, 2004). Engaging students is key to developing HOTS and thus can be done by e.g. inviting students to peer review their fellow students' work and provide constructive feedback. Recent research by Lu, Yang, Shi and Wang (2021) has provided evidence for a positive relationship between peer interaction and HOTS. The reason for this is that when students are actively involved in the learning process, they actively communicate, collaborate and learn from each other as well as apply and improve their critical thinking, problem-solving and creative skills (Jones, 2007; Utecht, 2003).

Although we know of the positive effects of peer feedback on student learning, feedback from multiple peers and multiple perspectives, 360-degree peer feedback, has even higher effects on students' writing performance (Huisman et al., 2019; Nicol et al., 2014) and student learning (McGourty et al., 2000). Knowing that interdisciplinary learning is an important approach to link core cognitive skills across disciplines to enhance students' higher-order thinking competences (Carr et al., 2018; Peppler & Wohlwend, 2018), and that problem solving, collaboration and creative thinking are core parts of HOTS, we propose that challenge-based learning (CBL; Beemt et al., 2022; Gallagher, 2020; Radberg et al., 2020) approaches help to improve HOTS among students. Based on quasi-experimental research among junior high school students, Yulianto et al. (2019) suggest that CBL approaches help to develop HOTS among students. CBL is specifically designed to strengthen the 21st century skills of students (Williams, 2024) and develops creative thinking (Yang et al., 2018).

CBL is an active, collaborative, self-regulated, multidisciplinary group. reflective and creative learning approach (Castro, and Gómez Zermeno, 2020; Van den Beemt et al., 2023) in which students work on real-life challenges together with stakeholders and peers to design solutions for practice. Learning happens through the identification, analysis, and design of a solution to a sociotechnical problem (Malmquist et al., 2015). Teachers who aim to improve HOTS among their students can thus make use of 360-degree peer feedback and CBL techniques to engage their students in problem-solving, critical thinking, collaboration, and meta-cognition. However, the question is how to combine these two techniques and design a course in which 360-degree peer feedback and CBL are integrated to improve HOTS.

We fail to understand how peer feedback can be applied to make use of the multidisciplinary background of students, stakeholders and teachers in CBL approaches and when to employ peer feedback in a CBL journey to best enhance the learning process. This is why in this paper, I will demonstrate how to design a course in a higher-education context in which students work on a complex challenge in a multidisciplinary team and apply 360-degree peer feedback to improve their HOTS. I will aim to answer the following research question: How to integrate CBL and 360-degree peer feedback in a master course in a higher education setting to improve the HOTS of students?

Methodology

CBL and 360-degree peer feedback are integrated in a 5 EC master course in the Business Administration programme at the University of Twente. Based on a single case study in a higher education setting, I will show how to design a course that integrates CBL and 360-degree peer feedback for the development of HOTS among students. The course is a 10-week course with a focus on innovation in the field of human resource management. The course is open for master students from various programmes (BA and EST), from various specializations and from a Double Degree programme with the University of L'Aquila, Italy. Master students have gained various pre-educational programmes in business-related bachelor programmes of the University of Twente, other Universities in the Netherlands or Universities of Applied Scienced. Students are divided among multidisciplinary teams of students, including three or four students. The course is set up around a CBL project assignment in which students work on a sociotechnical innovation challenge and is structured around the three phases of CBL: Engage, Investigate and Act.

Course Design

The students and the teacher co-create the rubric of the CBL assignment together. While students work on the CBL assignment, they receive feedback from four sources - teacher, stakeholders, peers and self-assessment – three times. The first feedback is provided after the ENGAGE phase when students are asked to submit a proposal of their assignment. At this point, they receive oral feedback from stakeholders and written feedback from their peers and teachers. They are asked to reflect on the feedback provided and self-assess their own work based on the co-created rubric. The second feedback round is provided after the INVESTIGATE phase. In this phase, they receive feedback from their peers and are based on self-assessment. After the ACT phase, a poster presentation is organized with the stakeholders in which the students pitch and present their designed solution. At this point, they receive oral feedback from the stakeholders and written feedback from their peers. In this phase they also reflect on the feedback provided and self-assess their own work with the help of the rubric. After three rounds of 360-degree feedback, the students submit their final CBL assignment, and the teacher assesses the work and provides feedback based on the co-created rubric.

STUDENTS' LEARNING GAINS AND LEARNING EXPERIENCES IN TRANSDISCIPLINARY CHALLENGE-BASED LEARNING

RESEARCH PAPER

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Global policymakers and academia are recognising the need for transdisciplinary collaboration among professionals, to work on grand societal challenges (GSCs), such climate change, natural resource management and global pandemics. To prepare graduates for this task, universities currently offer challenge-based learning (CBL) experiences. In CBL, students are stimulated to take charge of their own learning, and be able to apply, acquire and learning knowledge to work

on a real-life authentic challenge (Helker et al., 2024). In CBL, students work in multidisciplinary groups and collaborate with societal stakeholders (i.e. professionals in a relevant field) on authentic and open-ended challenges (Gallagher & Savage, 2023; Membrillo-Hernández et al., 2019). However, there are variations of how CBL is applied, and most current research focuses on CBL that work with predominantly mono-disciplinary student groups, on challenge topics within their own disciplines (Leijon et al., 2022). Therefore, in the context of this study, we adopt the term transdisciplinary CBL (T-CBL), where students from multiple disciplines work with a broad network of actors, both in and outside of academia, on real-life, open-ended challenges (O'Sullivan et al., in preparation). T-CBL is a relatively new approach and is a student-centred approach. Due to its nascency and student-centeredness, we are still unaware of how and what students actually learn from this type of education, and if T-CBL is working as intended. Vermunt et al. (2018) defined learning gains as changes in knowledge, skills, values, and attitude that may occur during higher education across disciplines. Additionally, Vermunt et al. (2018) distinguished four distinct components (cognitive, metacognitive, affective, and socio-communicative) and three cross-cutting dimensions (view of knowledge and learning dimension, research dimension and moral dimension) in which learning gains can be brought out during higher education in general. However, this learning gains framework was derived based on higher education in general, and not specifically for T-CBL contexts. With this study, we intend to use the learning gains framework as a lens for looking at the learning gains of students in T-CBL contexts. In addition to that, we can compare our results with recent findings by Bravo et al. (2024) on students' learning gains in extra-curricular CBL teams that was conducted in engineering contexts, as well as Van Uum and Pepin's (2023) findings on students learning gains in engineering contexts. Furthermore, since T-CBL is a relatively new educational approach, it is unclear which learning experiences (e.g. learning activities, moments of uncertainty, failure etc) contribute to which learning gains. Therefore, besides studying the learning gains, we also study which learning experiences students engaged in that contributed to their learning. Therefore, with this study we aim to answer the following research question: What are students' perceived learning gains while participating in T-CBL and which learning experiences impact those learning gains? Methodology To investigate students' perceived learning gains from their participation in T-CBL and the learning experiences that contribute to the learning gains, we conducted semi-structured interviews with 19 students who participated in inter-university challenges. These inter-university challenges were organised within an alliance of four higher education institutions in The Netherlands. Students from three different challenges were approached at the start of the challenges with information about our study. Informed consent was obtained for those who wished to participate. The semi-structured interviews were conducted towards the end of the challenge, depending on each students' availability. The interviews were conducted individually to consider the individual perspective of students when determining students' learning gains (Baume, 2018). During the interview, students were invited to tell us about the challenge they participated in, what they learned from participating in the challenge and which learning experiences contributed to each of the learning they mentioned. Towards the end of each interview, students were asked to summarise and visualize their learning gains in a pie-chart diagram. The interviews were then transcribed verbatim, followed by coding and analysis using thematic analysis (Attride-Stirling, 2001) which was done in conjunction with members of the research team. The thematic analysis of the data was conducted utilizing the combined frameworks of van Uum and Pepin (2023) and Vermunt et al. (2018). Findings The preliminary results currently show that (1) students report a variety of learning gains from their participation in T-CBL, with most of the learning gains in the socio-communicative domain; (2) students gain ‘perspective-taking’ and ‘interdisciplinary learning’ under the socio-communicative dimension, which are two learning gains that are applicable in T-CBL contexts; (3) affective and meta-cognitive learning gains, while not as frequently mentioned as socio-communicative learning gains, are still very much present and should be taken into consideration when designing and teaching CBL; and (4) that single learning experiences can trigger different learning gains (for example, being in contact with stakeholders can trigger both affective and socio-communicative learning). It is also interesting to note that students differed in the way they expressed their learning gains – some as a reflection of what was done, others as a reflection of what was not done, or what they observed from others. More fine-grained results will be presented and discussed at the conference. Theoretical & Educational Significance As T-CBL is a nascent and innovative learning approach with limited research on its impact, it is crucial to gain insight into how and what students learn from T-CBL. By mapping students’ perception of their learning gains, and how these are related to specific learning experiences, we contribute both scientifically and practically, towards informing the design of future CBL within higher education, in aspects such as curriculum development, course design, as well as support for student learning. Additionally, this research will also investigate if the learning gains framework (Vermunt et al., 2018) can be applied in the T-CBL contexts of this study.

FROM CLASSROOM TO WORKPLACE: TRANSFORMING HIGHER EDUCATION THROUGH OPEN INNOVATION

PRACTICE PAPER

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The evolving demands of modern industries highlight a persistent gap between university education and professional requirements. Students, as vital conduits of knowledge into industry (Plewa et al., 2015), often encounter real-world applications late in their academic journey—typically during internships, final projects, or when they enter the workforce (Berbegal-Mirabent et al., 2020). Traditional educational models, which prioritize theoretical instruction, introduce practical exposure too late to fully prepare students for professional environments. This delay limits the application of academic knowledge to real-world contexts, hindering both immediate productivity and long-term career readiness. Addressing this gap requires rethinking university education to better align with contemporary professional demands. This shift involves blending discipline-specific knowledge with its practical application, enriching education with professional and personal experiences (Bayuo et al., 2020). Such approaches also foster critical soft skills, including teamwork, communication, and problem-solving, alongside technical expertise. This paradigm reflects broader efforts to strengthen ties between academia and industry, enabling students to engage earlier and more meaningfully with professional challenges. This study presents InnoCrowd, an innovative program that bridges academia and industry through challenge-based learning (CBL). Grounded in open innovation principles, InnoCrowd creates an ecosystem where students, faculty, and companies collaborate to address real-world problems. The program embeds industry challenges directly into university courses, equipping students with essential technical and soft skills while providing hands-on experience. Students gain early exposure to professional contexts, enhancing their readiness for internships and careers. Simultaneously, companies benefit from innovative solutions, access to emerging talent, and strengthened collaboration with academia. By fostering mutual benefits, InnoCrowd supports knowledge transfer and regional innovation ecosystems, addressing both educational and industry needs comprehensively. At the heart of InnoCrowd lies a crowdsourcing platform that connects academic and industry stakeholders. Companies submit challenges, which are matched with appropriate courses and disciplines. This integration redefines traditional educational paradigms, embedding professional challenges earlier in the curriculum to align academic training with contemporary industry demands. The initiative also contributes to debates about universities' roles in innovation, demonstrating how education can drive economic and societal advancement (Compagnucci & Spigarelli, 2020). The pilot program, implemented at the Polytechnic School of Engineering of Vilanova i la Geltrú (Universitat Politècnica de Catalunya), ran from October 2024 to July 2025. It encompassed undergraduate and master's programs, including Bachelor's Degrees in Industrial Design and Product Development Engineering, Informatics, and Industrial Engineering (specializing in mechanical, electrical, and industrial electronics and automatic control). The Master's Degree in Railway System and Electrical Drive also participated. Between October and January, the program focused on designing the crowdsourcing platform, disseminating the initiative, gathering industry challenges, and matching them with relevant courses and faculty. The implementation phase ran from February to June 2025, during which 164 students, coordinated by six faculty members, engaged with eight challenges developed in collaboration with seven companies. Outcomes were documented and evaluated during an assessment phase from July to October 2025. To evaluate the program, an ad hoc questionnaire gathered student feedback on satisfaction and perceived utility. Of 164 participants, 117 responded (71%), rating aspects of the program on a 5-point Likert scale: utility of the activity (4.51), satisfaction with implementation (4.53), willingness to engage in future business challenges (4.51), improved understanding of course material through CBL (4.34), and comprehension of real-world business problems (4.43). Students also provided qualitative feedback, highlighting direct interaction with companies, practical application of theoretical knowledge, and a stronger connection between their studies and professional realities. Many noted a sense of purpose beyond academic grading, as their work addressed tangible problems, which enhanced motivation and engagement. Additional benefits included collaboration with peers from diverse programs, exposure to multidisciplinary teamwork, and alignment with professional environments. Areas for improvement included more time to develop solutions, greater involvement of company representatives in the classroom, and clearer challenge definitions. Feedback from participating companies reinforced the program's success. A tailored questionnaire assessed their expectations and experience. Companies rated their overall involvement at 4.9, the quality of student solutions at 4.6, alignment of solutions with expectations at 4.5, student commitment at 4.8, and faculty engagement at 4.9. The initiative's value to companies was rated at 4.8, with 100% of respondents indicating willingness to participate again. Companies emphasized the program's practical approach to applying academic knowledge, its role in fostering creativity and innovation, and its ability to build collaborative networks with the university. They also appreciated staying connected to emerging knowledge and new generations of professionals. From this experience, it can be concluded that InnoCrowd provides a compelling model for reimagining engineering education. It bridges the gap between academia and industry, equipping students with essential skills and experiences while fostering meaningful collaborations with industry partners. The findings from this initiative offer a blueprint for other universities to adopt similar approaches, strengthening ties between education and regional economic stakeholders. This project underscores the transformative potential of CBL (Gallagher & Savage, 2023) and open innovation in higher education, ensuring its relevance in an ever-evolving world.

ASSESSMENT IN CHALLENGE BASED LEARNING PRACTICES: A CALL FOR MORE STUDENT INVOLVEMENT

RESEARCH PAPER

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Introduction Society is faced with many challenges like the need for more circularity and sustainability, climate change, energy transition, and the rise of disruptive technologies like Artificial Intelligence. These societal challenges have in common that they are complex, cross boundaries of time, geography and discipline, and are increasingly IT driven. To cope with these challenges, engineers need to be able to deal with uncertainty, rapid change, interconnected systems and able to collaborate in interdisciplinary teams [1 2]. Challenge Based Learning (CBL) is seen as a promising educational framework to equip engineering students with the knowledge, skills and competences needed. CBL can be characterized by working on real life open ended problems, interdisciplinary teams, stakeholder involvement, sharing of and reflection on results and process and group and individual learning [3 5]. CBL and assessment Although good overviews what is currently known about CBL exist [4 5], only limited attention has been given so far to assessment in CBL [6 7]. Therefore, to find out how teachers actually assess when teaching a CBL course, we set up this research. The main research questions were: how do teachers assess in their CBL course, how does that correspond with literature on CBL, which recommendations can be formulated for theory and practice? Based on the limited literature on assessment in CBL, we distilled five characteristics to be included: • Disciplinary content and skills [8 9] • Groups and individuals: multidisciplinary collaboration [8 9] • Formative and summative assessment, said to be intertwined for challenge based education. [7 11] • Reflection as a meta cognitive skill important for effective learning in CBL [12] • Active role of the students, eg formulating criteria or co assessment [12] • Active role of other stakeholders [4] Method We used semi structured interviews with 9 questions with pre coded answers and 10 open questions. Additional information was collected from the online learning environment of the courses. Teachers were selected based on existing networks, additional names were collected in the interviews. The results of the interviews were summarized in an Excel file, using the questions as categories and additional categories identified from the literature. The results were further analysed across courses and within courses. Results The results showed that all assessment characteristics from CBL literature were present across the courses: skills and content were tested, formative and summative assessments were used, reflection was included, individual and group aspects were addressed, and others besides the teacher had a role in assessment. Thus, practice corresponds with literature. However, when analysing each individual course, it appeared that only one course met all characteristics. This course was from a programme with an educational philosophy that aligns very well with the CBL philosophy. In addition, three courses met all but one criterium. Of those three courses, two did not involve stakeholders in assessment, and in one course the active role for students was limited, as this course missed students' individual learning objectives. We also noticed a large variety in the assessment methods itself, in line with CBL theory [8, 9]. Teachers used posters, essays, reports, oral presentations, websites etc. Furthermore, the weight given to content goals, skill goals and reflection varied much across courses. Finally, timing and scheduling of assessment varied. For example, feedback was given at many different moments throughout the course. Despite these differences, all but one courses used clear assessment criteria (a rubric or a single point rubric). Almost 2/3 of the courses used a rubric. What stood out was the limited role of students in assessment. In only seven of the 17 courses studied, students had an active role in assessment. In four courses students could co define assessment criteria, in five courses students were co assessors and in only two courses students could both co define criteria and co assess. Almost all teachers acknowledged that they could design and execute the assessment more in line with CBL theory, but in practice they didn't do that. Although we did not explicitly ask for reasons for this, possible explanations are that the current system of university education focusses teachers on assessing at the end, teachers might have the conviction that it is their responsibility to assess or teachers might fear additional workload when redesigning the assessment. Recommendations for practice From the findings, we derived the following recommendations for practice. * Teachers could not only focus on the more common assessment methods, but could take a wider view and consider less common assessment methods like blogs, vlogs, posters etc. * Teachers could give students a greater role in both designing the assessment criteria and assessment itself, with different forms of peer and self assessment and reflection. * Teachers could pay even more attention to formative assessment (feedback) throughout the course and integrate it more with summative testing. In doing so, they can continuously track the students' progress and learning in more detail. This may eventually reduce the need for summative testing at the end. Recommendations for future studies Based on our findings, further research could investigate more in depth * why teachers do not give students a larger role in assessment in a CBL context. Promising directions for this are given by [6]. * what currently keeps teachers from including all aspects of CBL in their course. * why teachers currently do not use formative assessment more as input for summative assessment. Research indicates that formative assessment could and should have a more important role [13]. Limitations In our research we only analysed courses at one institute; in other institutes the results could be different. Moreover, the teacher themselves indicated their course as CBL. We did not check whether each course met every aspect of CBL, because CBL can have many forms and one can even distinguish a level of CBL [14]. As we only wanted to focus on assessment, it did not make sense to also analyse the CBL level of the course. This, however, means that we cannot indicate whether in 'intense CBL' courses the assessment is done differently from 'mild CBL'.

PRACTICING SOCIOTECHNICAL CHALLENGES IN TECHNOLOGY, DESIGN, AND ENTREPRENEURSHIP: A MODEL FOR CROSS-DISCIPLINARY INNOVATION

PRACTICE PAPER

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With new technological advancements, students will enter jobs that currently do not exist (Word Bank Group, 2019). Learners need to develop combinatorial and cross-disciplinary skillsets to tackle complex real-world challenges. This paper presents a model for engaging students in innovation at the intersection of technology, design, and entrepreneurship. These problems cannot be addressed from a single technology, design, or business perspective; rather, they require examining multiple approaches to create practical solutions (e.g., creating a platform-based business to physically bring together local artists for impact). Cross-disciplinary challenges may prompt students to pivot unexpectedly across different disciplinary boundaries. For instance, a student designing a sustainable self-driving car might need to explore supportive road infrastructure, necessitating knowledge in transportation, civil engineering, and Geographic Information Systems (GIS). However, rigid learning objectives often limit students' ability to scope their projects beyond familiar areas. This gap stems from focusing on domain-specific knowledge and control over project completion, making it difficult for students to shift perspectives. This study addresses: What pedagogical model helps students practice real-world sociotechnical challenges, leading to innovation and diverse cross-domain solutions at the intersection of technology, design, and business? This paper introduces a four-stage model based on an innovative school at a North American research university. It outlines the four phases involving discerning, prompting, identifying, and iterating/pivoting. RELATED WORK Cross-domain reflective practice Sociotechnical research is crucial for addressing the interplay between technological and societal aspects of real-world problems. Baxter and Sommerville (2011) highlight the emergence, non-determinism, and complexity inherent in sociotechnical research. To navigate, learners must adapt across different learning stages, identifying and deconstructing unknown domains without relying too much on predetermined knowledge. Facilitating reflective practice—learners moving across a cycle of reflective thinking to use generalize knowledge across diverse areas to inform their understanding of specific experiences (Schön, 1983)—across multiple disciplinary domains can enable students to develop innovative solutions. This process requires building reflective thinking skills to explore authentic problems (Dewey, 1933), integrating diverse domains within and outside one's specialties. Challenge based reflective learning (CBRL) Challenge-based learning (CBL) is a systematic approach wherein students acquire the skills necessary to address complex real-world challenges through collaborative efforts (Gallagher & Savage, 2020; Leijon et al., 2022). CBL has been expanded into multi- and trans-disciplinary environments (Leijon et al., 2022; Nicols & Cater, 2008). CBL highlights several key elements necessary for facilitating students' real-world explorations: multidisciplinary, technology-enabled, real-world problems- and solutions- oriented, and collaborative, hands-on, and inquiry-based approach to learning (Nicols & Cator, 2008; Leijon et al., 2022). Yet, CBL often serves as a broad term rather than a practical model. A more actionable framwork is needed to implement CBL in sociotechnical design and innovation. Recent research explores CBRL (Challenge-Based Reflective Learning), utilizing the ethos of CBL to apply reflective practice in cross-disciplinary challenges (Sung et al., 2024) particularly at the intersection of design, technology, and human-centered innovation. Further investigation is needed to understand how this model facilitates students' navigation across diverse perspectives and domains within complex challenge spaces.

CONTEXT This paper develops a pedagogical model for CBRL through a case study. Findings are based on 1) archival data involving internally and publicly available materials related to the case school's the 4-year curriculum, pedagogical frameworks, and 2) interviews with faculty involved in creating CBRL. More data collection is planned to analyze activities and strategies of the identified four stages.

FINDINGS CBRL's cross-domain model follows four key phases where students identify, test, and deliver their chosen projects (See Figure 1). Discern. Students begin with broader challenge areas, either generated by faculty members, industry or community stakeholders, or the students themselves. Examples include: "the future of mobility/walking" and "future of government modernization." Students deconstruct and redefine a given challenge before diving into domain-specific areas or potential solutions. Faculty encourage students to deconstruct assumptions and perspectives related to the challenge area to foster contextualizing domain-specific skills and knowledge. They practice the associative questions, "What does with what?" and "What would happen if…?" rather than a discipline-focused, linear question, "What follows from what?" Exploring such questions plays a pivotal role in nurturing students' unique dispositions for discernment because emphasizing the ability to formulate meaningful questions precedes the ability to provide insightful answers (Brown & Thomas, 2008). Prompt. Students identify perspectives and knowledge areas for their challenge. Students work with faculty to determine the appropriate domains and levels of knowledge, access relevant courses, and find needed experts for collaboration. For example, a student took an advanced Optics course from the Engineering school to design an affordable AR headset. Prototype. Students experiment with viable solutions by creating digital and physical artifacts, moving beyond traditional ideation. They transform ideas into concrete representations using rapid prototyping. It highlights the importance of sociomateriality in knowledge practices, revealing insights through material forms, artifacts, and infrastructures (Orlikowski, 2006). Iterate or Pivot. Students incorporate feedback and iterate, innovating or pivoting to new challenge spaces. While pivoting, they continue to apply the core competencies built through associative practices. For example, a student who founded an AR headset company later pivoted to exploring smart city planning for housing crisis. CBRL supports students' repeated cross-domain experiences without prescriptive resources to solve sociotechnical challenges. Over time, students develop fluency in identifying known and unknown information as it relates to sociotechnical complexities.

EDUCATIONAL IMPACT AND FUTURE WORK This study explores how to facilitate students' cross-cutting innovation through a process of discernment, prompt, prototype, and feedback. Ongoing research examines diverse domains in senior projects and students' navigation of iterative cycles to understand sociotechnical complexities across ill-defined areas.

These findings aim to reveal how students translate domain-relevant skills and expertise to fostering cross-disciplinary, sociotechnical innovation.

LIKE STREAMS FEEDING THE RIVER: RE-OWNING THE CONCEPT OF COLLABORATION IN A LEARNING COMMUNITY

PRACTICE PAPER

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Challenge based learning matches social-constructivist pedagogies, specifically problem-based learning, inquiry-based learning, project-based learning and experiential learning. Recent research into the use of CBL in HIE shows that CBL is applied as a frame for educational innovation towards active authentic learning environments with effects on student motivation and the development of professional and transversal competencies. A similar approach to address real world problems is the learning community. This practice paper describes a recent exploration of the concept of collaboration in a learning community working on international water technology at a Dutch institute of higher education. This LC brings together four teams of students, their tutors, a research group and its client companies, in weekly sessions. Students join the LC from different bachelor programs and international partner institutes. Tutors have affinity with water technologies but act as coaches rather than specialist teachers. Students get assignments and expert feedback from researchers. In this LC, research and design activities are aimed at building or improving so-called demonstrator technologies in relation to the central mission: "providing the right quantity of water, with the right quality in the right place at the right time". The exploration is part of a practice-based study into an educational innovation, building and integrating learning communities in the ecosystem of the university. Learning communities fit into the triple helix model of innovation in the knowledge economy, where universities, policy makers and industry interact equally to promote social and economic development. Representatives from practice, education and research work, learn and innovate together. Ideally, everyone learns in a learning community, not only students. Challenge-based learning occurs as the participants convene around a central challenge or question. These questions typically derive from open-ended, complex societal issues and practical questions around sustainable development, often in a local context. Participants work on knowledge sharing, production of knowledge and application of knowledge. Closely engaging with changing realities, LC's generate authentic collective learning experiences for life long and self-directed learning, with outcomes at different levels: for individuals, teams, organizations and society. Mechanisms for successful LC's are 1)promoting team reflection and team activity, 2) boundary crossing, 3)integration of learning, working and innovating, 4) promoting self-directed learning and 5) the support of a facilitator. Typically, there is a constant alignment of interests, goals, domains and world views. Thus, LC's are social learning systems that increase the capacity to learn, work and innovate and enable people and organizations to accelerate sustainable development. Collaboration is one of the cornerstones. It is also one of the five dimensions of the IDG framework, set up to help people and organizations to accelerate progress toward the UN Sustainable Development Goals. Collaboration is specified in skills: communication, co-creation, inclusive mindset, intercultural competence, and mobilization. For this learning community, we set out to develop a fresh understanding of collaboration. It seemed to have become a threadbare idea, something out of a management textbook which was not owned by participants of the learning communities we had seen. We also expected that the IDG dimension of collaboration could be meaningful in relation to sustainability efforts by the LC. Methods for the exploration were derived from participative action based research, using mixed methods. The main researcher was involved in the community as a tutor. Data collection took place through structured reflection during LC sessions, and by keeping logbooks. A photovoice method was used in which students, tutors and clients reflected on photos that they took during their work as a team and during sessions with the learning community. Results include metaphors for collaboration, photo captions and concept maps. They were discussed with participants and compared to theoretical concepts of collaboration. Findings may be used to 1)achieve a shared understanding of relevant conditions, mechanisms for and effects of collaboration in learning communities and 2) design a practical assessment tool to evaluate collaboration in learning communities. Limitations of this practice-based study are the pragmatic use of literature, and a potentially limited use for other communities, who might benefit more from actively regenerating the forces of collaboration in their own local context.

LEARNING GAINS OF INTERDISCIPLINARY AND TRANSDISCIPLINARY LEARNING IN CBL

RESEARCH PAPER

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Learning Gains of interdisciplinary and transdisciplinary learning in CBL Overall relevance to the CBL domain: Challenge based learning (CBL) got increasing attention over the last decade as CBL is a promising and innovative approach to flexible and creative education in which the focus lies on addressing real world problems in education often related to global themes (Leijon et al., 2022).

Two important elements of CBL are interdisciplinary learning and transdisciplinary learning (Gallagher & Savage, 2023). Interdisciplinary learning happens when students work in a multidisciplinary team on a complex issue which necessitates knowledge and academic perspective taking and therefore integration (van den Beemt, van de Watering & Bots, 2023). Transdisciplinary learning means that students interact with real life actors (often non-university) stakeholders, forcing students out of their comfort zone and again necessitating the students to expand their horizons with new perspectives, this time also outside the academic context (Mayer, Ellinger & Simon, 2022).

Theoretical background and rationale for the study:

Interdisciplinary and transdisciplinary learning is strongly connected with the core and aim of the CBL educational approach. However, we do not know what the actual result on the performance level of the student is of these collaborations and interactions (Gallagher & Savage, 2023). This is problematic, as while CBL grows attention, also the need for clear best-practice guidelines for the approach is growing. Recent work of Bravo et al. (2024) has lifted the veil a bit, as they studied the learning outcomes of CBL students at Eindhoven University in two project groups. We hope to open up the black box more, by including a broader sample of respondents from multiple universities and participating in various challenges and zoom in specifically on the interdisciplinary and transdisciplinary learning. In this study we use the learning gains perspective of Vermunt, Ilie & Vignoles (2018) to qualitatively dive into the learning gains of students who participated in CBL and experienced interdisciplinary and transdisciplinary learning. Vermunt, Ilie & Vignoles (2018) identify four areas of learning: cognitive learning, related to developing knowledge and understanding, meta-cognitive relating to developing learning strategies and reflection competences, affective learning relating to personality development and attitudes, and socio-communicative learning relating to teamwork competences and communicative abilities.

In this study we aim to provide insights in the learning outcomes of CBL, specifically in relation to interdisciplinary and transdisciplinary learning. We therefore focus on the following research question: What learning gains do students experience from interdisciplinary and transdisciplinary learning in challenge-based learning?

Research methodology and design: About thirty interviews are organized with students of four universities of the EWUU alliance (Utrecht University, University Medical Centre Utrecht, Wageningen University and Research and Eindhoven University) in the Netherlands focusing on their learning gains. They will be asked to describe their experiences relating to working in interdisciplinary teams, what they learned from interactions with stakeholders, and what they picked up from the increased autonomy and uncertainty often involved in CBL. These interviews will be coded using the four categories of learning gains.

Results and Findings: At this stage, fourteen interviews are completed and analysed. The preliminary results seem to indicate learning in all four areas:

- Cognitively: students develop understanding of their own discipline in relation to other disciplines; they pick up knowledge of other disciplines.
- Meta-cognitively: students become more aware of their own disciplinary boundaries and abilities.
- Affectively: students widen their perspective on epistemology; they learn about their preferences in collaborations.
- Socio-communicatively: students learn how to overcome jargon, they learn how to adjust their questioning to non-academic stakeholders, and they develop socially from interacting for longer periods with the same team in a challenge.

Deeper discussion, comprehensive conclusions and clear contributions are expected to be finished before the conference. Educational Impact: the preliminary results show the richness and variety of interdisciplinary and transdisciplinary learning gains in CBL. The results contribute to understanding the learning processes happening in CBL and can be used to facilitate more informed educational design, as educators would be able to predict learning outcomes better.

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