Students' experiences with challenge-based learning at TU/e innovation Space

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STUDENTS' EXPERIENCES WITH CHALLENGE-BASED LEARNING AT TU/E INNOVATION SPACE – OVERVIEW OF FIVE KEY CHARACTERISTICS ACROSS A BROAD RANGE OF COURSES

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ABSTRACT

Challenge-based learning (CBL) has emerged in the last decade as a response to the complexity of problems faced by modern society, new competencies needed for the workplace, and insights from cognitive sciences on knowledge acquisition and learner motivation. In CBL, students work on real-world problems which are open-ended and require interdisciplinary knowledge and entrepreneurial mindset. In the last three years, over 70 CBL experiments have been initiated at Eindhoven University of Technology (TU/e), in order to develop a broad range of CBL teaching practices. Half of these courses have taken place at TU/e innovation Space, which is a learning hub and expertise centre for CBL and entrepreneurship education. We use students' evaluation surveys to analyse the experiences of Bachelor and Masters students in these courses. In particular, we are focusing on responses to five key course design characteristics set by the teaching staff as important: how interdisciplinary and challenge-based (or linked to real-life problems) the courses are,

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how entrepreneurial and hands-on they are, and how much they contributed to students' personal development, as well as their team development. The results show that what attracts students to these CBL courses matches closely these five characteristics, and we discuss why this might be the case. Interestingly, some of the more hands-on aspects of the courses do not seem to have been affected by the COVID-19 disruption in the 2019-2020 academic year.

1 INTRODUCTION

Challenge-based learning (CBL) is a relatively new educational concept [1], which focuses on enabling learners to solve complex challenges in an increasingly volatile, uncertain, complex and ambiguous (VUCA) world. This way of learning prepares students for the future of interdisciplinarity and complex decision-making in the workplace, with emphasis on teamwork, self-awareness and entrepreneurial mindset [2]. Eindhoven University of Technology (TU/e) has placed CBL at the core of its educational vision for 2030 and aims to make CBL a substantial part of all programs at the Bachelor and Masters level. With that in mind, TU/e innovation Space was formed in 2015 (and started operating in a physical space from 2018) by a group of innovative academics who already applied various aspects of CBL in their courses. Today, TU/e innovation Space is the center of expertise for Challenge-Based Learning and student entrepreneurship. It is a learning hub for fostering connections between motivated staff, students, industry, and societal organizations to collaborate on real-life challenges. The hub facilitates courses and experiments on (interdisciplinary) CBL and student entrepreneurship; offers services and inspirational workshops for implementing CBL; and coordinates students' extra-curricular activities related to entrepreneurship. To this extent, TU/e innovation Space collaborates with and supports interested lecturers from other departments whose course objectives match the hub's objectives in terms of CBL characteristics and require hub's comprehensive facilities (including technical and other support). TU/e innovation Space monitors all the CBL experiments undertaken in the hub through educational research, in order to ultimately arrive at evidence-based teaching and learning CBL approaches.

In this paper, we present a case review of student experiences in CBL courses that were facilitated by TU/e innovation Space over the two first academic years of the hub's operation (2018-2019, 2019-2020). There were 31 courses from 7 different departments that used the hub over that time, 21 at the Bachelor level and 10 at the Master level. We are interested in investigating to what level have students perceived the key CBL characteristics attained in their courses, and provide an overview of their initial experience with CBL education. Innovation and creativity, real world challenges, collaboration across stakeholders and disciplines are at the core of CBL education worldwide [1]. Our work aims to contribute to the overall body of knowledge and support further research related to identifying best practices for implementing and facilitating CBL learning.

2 METHODOLOGY

2.2 Case review

We use a case review of CBL courses run at TU/e innovation Space during eight quartiles (four semesters) over the two academic years. A mixed-method approach was used, with a qualitative and quantitative component derived from the same instrument. Specifically, we use a course evaluation survey designed by the TU/e innovation Space Education team to monitor to what level the key CBL characteristics were met for the courses that were hosted in the learning hub. This survey, together with other forms of feedback, is collected for quality assurance, to ascertain in which form CBL is a scalable educational concept for TU/e, and what is an added value of CBL approach for all the stakeholders. Ethics approval was obtained for use of this data (ERB2021ESOE8).

Participants. The participants were the students enrolled in the 31 courses which run over the two academic years in TU/e innovation Space. There were more than 1100 students per year, of which only around 20% filled out the survey. Therefore, these results are not fully representative of the whole cohort. However, it is likely that students with the most desire to share the feedback are willing to take the time to fill out surveys such as these, and thus this information is still highly valuable as an insight in students' perception of their experience with CBL education.

Instrument. The survey was distributed electronically to the students as a part of their overall end-of-the-course evaluation. That means that the questions pertinent to the CBL characteristics would sometimes come at the end of a long string of questions, if the lecturer has agreed for the survey to be included. The survey consists of seven closed questions (Likert scales) and three open questions to gather detailed insights into the students' perceptions and experiences (see Table 1 for details).

2.2 Data analysis procedure

Quantitative data. The anonymised student responses have been provided to TU/e innovation Space as a report, one for each course, collated by the Department of Education and Student Affairs. As mentioned before, the main purpose for these reports was monitoring of quality insurance, and we performed further (secondary) analysis of these existing data. We transferred all the responses from the individual reports to an Excel spreadsheet for in-depth analysis. The seven closed questions have a 5-point ordinal scale (to rate the degree to which students agree or disagree with a statement), which is commonly used in course evaluations. In the reports that were available to us, these data have been expressed as a median value with standard deviation, which somewhat limits the depth of the analysis we were able to perform. Therefore, rather than being able to report the frequency of responses for each category, we are only able to report the median value.

Initially, we compared all the median values for all the courses across the two academic years, in order to investigate if data showed any interesting patterns

across different types of courses. The result was that most of the courses ended up sitting within a wide band of median values, with no significant pattern or outliers emerging. However, this analysis was also limited by a low number of responses per course – some courses had only 20-30 students, with 3-4 responses per course on average. We therefore decided to combine all the responses per question for each year, in order to focus analysis on each of the CBL characteristics. We present the analysis of our results via boxplots in Figure 1.

Table 1. The survey questions used in this study, and how they relate to the five key CBL characteristics (KCs).

Survey questions	**The scale**
Q1. Why did you choose this course?	Open-ended
Q2. Would you recommend this course to a fellow student? Q2a. Please explain:	No, definitely not – Yes, definitely Open-ended
Q3. To what extent do you think this course: (KC1) was interdisciplinary? (cooperating with students from different study programs, applying/integrating knowledge from different disciplines for the end result) (KC2) was challenge based? (challenging question at the start of the project, real-life problem) (KC3) was hands-on? (learning by doing; developing a prototype or minimal viable product) (KC4) had an entrepreneurial mindset? (have to deal with uncertainty, take entrepreneurial aspects into account) (KC5) contributed to personal and team development? (in terms of professional skills, like collaborating, presenting, coaching, creativity)	No, definitely not – Yes, definitely
Q4. I see the added value of the open learning spaces and prototyping facilities in innovation Space. Q4a. What is in your opinion the added value of courses in TU/e innovation Space?	Strongly Disagree – Strongly Agree Open-ended

Qualitative data. Answers to the open-ended questions were analysed to collect more detailed information on how students experienced CBL learning in the early implementation (the first two academic years). The responses were coded through exploratory thematic analysis to identify any interesting patterns and insights, based on the participants' own words. We performed inductive coding, using semantic analysis and participants' own words as "meta-themes", which were then combined into the main themes. Only the responses to the first questions provided answers that resulted in coherent codes, and we present the results in Table 2.

3 RESULTS AND DISCUSSION

3.1 Overal results

Figure 1 shows aggregated results from data analysis of the quantitative data used in this paper. Students' answers to the seven closed survey items are visualised here with the boxplots, which allow us to present the median values for each question, the interquartile range (where the middle 50% of the scores are), as well as to show the minimum and maximum score given for each item.

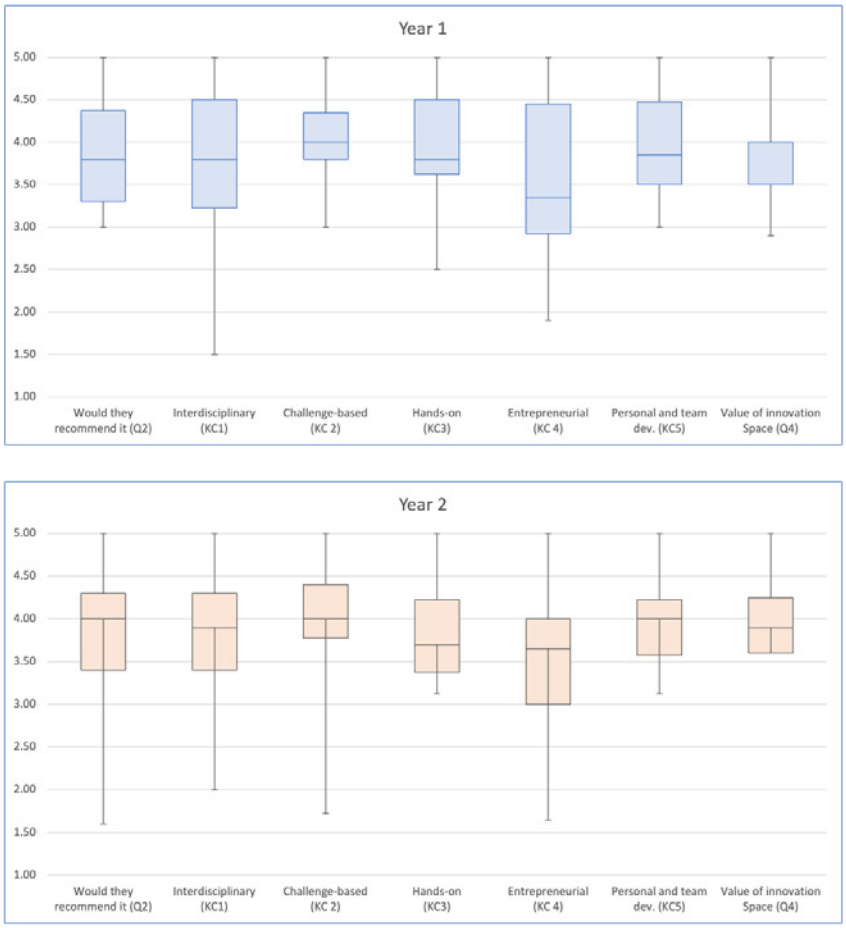

Figure 1. The two boxplots visualise each of the closed survey items (see Table 1) from the first (2018-2019) and second (2019-2020) academic year that the courses have run at the TU/e innovation Space.

In the first year, we see that most aspects of the courses have been received well by the students, with only one aspect of the course (related to how entrepreneurial the courses were) sitting under median of 3.5. In the second year, we see some improvements, despite the fact that this academic year was disrupted by COVID-19 pandemic. The range of scores decreased for most of the items, especially for the item about how interdisciplinary and entrepreneurial the courses were. All the medians improved, except for how hands-on the courses were, which is likely to do with moving some aspects of the course online in the third and fourth quartile of the year.

The answers to open-ended questions allow us to explore in more depth what students' experiences in these CBL courses were. Table 2 shows the most-frequently mentioned reasons for enrolling in the CBL courses (Q1). Besides the obvious reason that some of the courses were mandatory (which have been omitted from the table), the most frequent answer was interest in the subject matter (T1), followed by general interests (T2), and wanting to expand core knowledge and skills (T3). Wanting an interdisciplinary course has been mentioned by a relatively small number of students (T4). However, interdisciplinarity is commonly used interchangeably with similar expressions, and it's possible that some of the reasons categorized in T3 category could belong to T4.

Table 2. Frequency of themes from coding of the open-ended question Q1. There are 184 responses in year 1 to this question, and 234 responses in year 2. The main themes are listed in the first column and mapped to the five key CBL characteristics (KCs, see Table 1) where appropriate, and meta-themes are listed in the second column. Third and fourth columns list the frequency of the main themes for each academic year.

Main themes (T)	**Meta-themes**	**Year 1**	**Year 2**
T1: Subject-related	subject interest, fits my interests	15%	21%
T2: General interest	interesting, fun, curious about, seems challenging	9%	12%
T3: Breath of knowledge & skills	something different, not research, other than major, wanted breath of knowledge & skills, more interesting than their major	7%	5%
T4: Interdisciplinary (KC1)	interdisciplinary (multidisciplinary)	5%	3%
T5: Real-life, challenge-based (KC2)	work with companies, real life, business oriented, responsible innovation	7%	17%
T6: Hands-on (KC3)	applying knowledge, prototyping, project-based, hands on	3%	6%
T7: Entrepreneurship (KC4)	entrepreneurship, want coaching, start ups	5%	9%
T8: Team work (KC5)	group work, learn from other students, create community, like minded people	4%	4%

Reasons related to real-life experiences and work with companies (T5) have also been mentioned often, in particular in the second year. It's possible that the students became more aware of this aspect after the first run of the courses, and after the first generation of students started recommending the CBL courses (as mentioned by a small number of students). This might be also linked to the next two identified themes – wanting to do something hands-on (T6) and entrepreneurial (T7) – which have doubled in the second year. And finally, wanting to do something with like-minded people or in a team (T8) was equally frequent across the two years.

The second question (Q2a) resulted in substantial amounts of responses (124 in the first year, and 233 in the second year), but they largely coincide with the answers to the first questions (Q1). Most frequent general reasons for recommending a CBL course to other students were that it provides a different way of learning or work on projects, and that it was interesting or fun. On the negative side of things, the students also mention that there are some teething issues when establishing these kinds of courses that could be improved, mainly to do with the way assessment was structured [3]. There were not many answers to the third open-ended question (Q4a), but there were some interesting highlights, which we discuss below.

3.2 Students perception of the key CBL characteristics

Based on the answers of the participants to the open-ended question about the reasons for enrolling in one of the CBL courses, it can be inferred that the students clearly see the characteristics defined as important by TU/e innovation Space Education team – exploratory coding of their answers, grouped in themes T4 to T8 in Table 2, can be mapped directly to the five CBL characteristics (Table 1).

Interdisciplinary aspect of the courses. Interdisciplinarity refers to integration of knowledge and skills between disciplines [4]. While the students in this study are mainly from disciplines such as design, engineering and science, they are encountering diversity of approaches between different majors, and identifying benefits of interdisciplinary approach to problem solving, such as working on a project with aspects other than the major, working together with a team in order to come up with better solutions. Not surprisingly, the students see the learning hub as a conduit for such learning, as working in interdisciplinary teams isn't common or possible in faculties. The issues around interdisciplinarity were also mentioned as a negative aspect, mainly to do with students having to navigate assessment requirements between different faculties, which has been explored by Valencia et al [3]. Indeed, there is much work to be done in bridging collaborative teaching between disciplines, starting with appropriate training for lecturers to facilitate students' learning in interdisciplinary settings [2].

Challenge-based aspect of the courses. There are different approaches to setting challenges in CBL courses [1] and at TU/e innovation Space, it is preferred for challenges to be open-ended and defined by students. They need to have societal relevance and, therefore, students get to collaborate with challenge owners (companies, organisations, researchers, student start-ups). Working with companies and on real-life (rather than theoretical) problems was a significant reason for some of the students to join CBL courses. A few students commented on liking the freedom of choices within a project available in their courses. Some students found extra motivation to succeed in their study when working with companies, because it gave them a better idea what is possible with their degrees. Interacting with companies and working on real-life problems contextualises for students how what they are learning is relevant for their future. Context-based learning can take many shapes, but all have been found to have a positive effect on student learning [5]. The main negative comments regarding the challenges were that the projects are

somewhat vague. Indeed, some students would have preferred to work on predefined questions, usually provided in more traditional courses where project questions have been offered by a lecturer. The main difference in the two approaches is that in traditional project-based learning the outcome of the research tends to be the final goal to be assessed. In open-ended CBL projects at TU/e innovation Space, the emphasis is on the process of learning through the projects. Learning through discovery and self-development of a learner are the ultimate goals.

Hands-on aspect of the courses. Practical or applied side of learning was mentioned as a motivation to join CBL courses, often contrasted with "theory" learned in other courses. An opportunity to experience the commercial side of innovation is also mentioned. In the early 1990s, there was a call for a more hands-on, "learning by doing" approach to engineering education [6]. However, hands-on education has been gradually reducing rather than increasing since that time, due to many factors, one of which is massification of post-secondary education which led to increasing students-to-teacher ratios. However, in the last few years there were global changes across higher education to move to more active and hands-on approaches to learning, which have shown many times over to increase engagement and learning outcomes for the students [7]. Learning by doing is the teaching philosophy of TU/e innovation Space. The students taking courses at the learning hub have an added benefit of having teaching spaces next to prototyping facilities (as mentioned in the students' responses to Q4a), as well as support from the technical staff at the hub, to facilitate the process of creating their own concept and product. Interestingly enough, there was almost no mention on how educational modifications introduced due to COVID-19 pandemic have affected hands-on learning, probably because the students, who were able to do so, were allowed to continue using prototyping facilities to some extent and under the strict health guidelines.

Entrepreneurial aspect of the courses. This is one of the items in the evaluation surveys with the widest range of answers. This could potentially stem from a narrow interpretation of what entrepreneurship is, focusing just on start-ups or running your own business, as expressed by the students. Entrepreneurship is not a necessary part of CBL education, but it forms a strong focus at TU/e innovation Space, which also hosts and facilitates related entrepreneurial extra-curricular events. The students expressed significant curiosity about wanting to learn more about the entrepreneurial side of things, often in the context of working with other students. Developing wider enterprising abilities in university graduates has been encouraged since the 1980s, but has not progressed as hoped [8]. However, recent reports indicate that there are significant benefits in embedding entrepreneurship education at undergraduate level across all disciplines, which impact on both students' learning outcomes, as well as provide benefits for the society and economy [9].

Personal and team development aspects of the courses. This is one of the strongest aspects of the courses, as rated by the students. As a motivation to join

the CBL course, or reason why they would recommend the CBL course, the students list wanting to learn *from* other students or *with* other students, and wanting to work in groups. This links to known benefits of collaborative learning approaches, which are found to improve students' knowledge and skills through the co-creation process [10]. Some students mention that this is the most fun part of the courses. However, a small number of comments refer to increased responsibility for such learning, especially if some of the team members are perceived not to contribute equally or are not "developed enough" to persist in courses such as these. As a benefit of the learning hub (Q4a), the open learning spaces that enable group work are welcomed by the students, providing opportunities to mingle and exchange ideas, as well as create a "motivating atmosphere". The fact that these spaces can be noisy is sometimes mentioned as one of the negative aspects. From the third quartile of the 2019-2020 academic year, a large fraction of collaborative learning was moved to an online setting due to COVID-19 pandemic, but that warranted only a very small number of comments from the participants.

4 SUMMARY

This paper presented a case review of student experiences in a variety of CBL courses delivered at TU/e innovation Space during the first two years of implementation. The overall experiences are very positive, and interestingly enough, the students highlighted the course design characteristics that closely match those set by the Education team as important. Our future work will focus on conducting more in-depth focus groups and interviews with both the students and the staff to examine how these particular CBL characteristics can be used as design principles to support CBL learning in a variety of courses and settings.

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