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ORIGINAL ARTICLE

Fostering learning with challenge-based innovation in higher education: case CERN Bootcamp

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ABSTRACT

This article presents findings on learning with challenge-based innovation (CBI) in higher education. It describes how different dimensions of Significant Learning are enhanced with challenge-based innovation among multidisciplinary students in higher education. It is based on a case study on designing and implementing a master's-level course for learning service design by solving societal challenges related to United Nations' sustainable development goals (SDG) with challenge-based innovation at CERN IdeaSquare. As a result, this article describes how the case CBI enhances Significant Learning, and what is critical for instructors and organizers of challenge-based innovation.

Keywords: CBI Challenge-based innovation, higher education, service design, design thinking, significant learning, CERN Bootcamp

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INTRODUCTION

Service design has become a popular approach for creative problem-solving, development of business and organizations, and value creation for customers (Andreassen et al., 2016; Martinkenaite et al., 2017; Stickdorn et al., 2018). Service design refers to using a designerly way of working when improving or developing people-intensive service systems through the engagement of stakeholders (Segelström, 2013). It is based on design thinking (Brown, 2008), and it can be seen as an application of design thinking in the service context (Andreassen et al., 2016; Stickdorn and Schneider, 2010; Bailey, 2012; Antons and Breidbach, 2018).

While the need for service design knowledge and skills in organizations is evident, knowledge about how to teach it or use it as a pedagogic method in higher education is very limited (Wolfe, 2020). With some exceptions (Ojasalo and Ojasalo, 2012; Ojasalo and Kaartti, 2019), empirical research literature dealing with service design education in higher education is almost nonexistent. Knowledge of what is critical to instructors and organizers in CBI-based instruction seems to almost be non-existent. Our study increases knowledge in this area. The case of this study is a course for teaching service design to a multidisciplinary group of master's students in terms of CBI. We analyse the case with Fink's Taxonomy of Significant Learning (2013a). CBI is a learning approach developed in IdeaSquare CERN for an international and multidisciplinary product development course based on design thinking and problem-based learning (Kurikka et al., 2016).

We tackle, consequently, two research questions

1. To what extent does the CBI version CERN Bootcamp effectively use Significant Learning to teach service design?
2. What is critical to instructors and organizers of CBI-based learning?

THEORETICAL BACKGROUND

Challenge-based innovation. CBI is an experimental, human-centric product development project structure hosted by CERN IdeaSquare, where multidisciplinary student teams address and develop solutions to societal problems (Hassi et al., 2016). Each university participating in CBI creates its version of the program (Faria and Fernandes, 2019).

The CBI approach, developed at CERN IdeaSquare, is a mechanism for technology transfer and knowledge sharing in society through people, such as students participating in CBI programmes (Benvenuti et al, 2017). It is similar to challenge-based learning pedagogy, which has increased its popularity in higher education institutions, fostering students' transversal competencies, knowledge of sociotechnical problems, and collaboration with industry and community actors (Gallagher and Savage, 2020). This approach enhances learning from challenges involving multidisciplinary actors, technology-enhanced learning, multi-stakeholder collaboration and authentic, real-world problems (Nichols et al., 2016). CBI is based on design thinking methods and the process is composed of three main blocks: discover, design, and deliver (Charosky et al., 2018). While online-based innovation can be combined with CBI programs (Kurikka, 2017), the physical presence in the CERN IdeaSquare innovation environment significantly motivates and inspires the students (Kurikka et al., 2016).

Service design. The philosophical basis of service design is in line with design thinking (Brown, 2008). In fact, service design can be understood as an application of design thinking to service innovation. The fundamental philosophy is similar to CBI principles. Service design has several definitions. Based on the literature review, we identify the following main characteristics of service design. Service design:

- *is multidisciplinary, emphasizing particularly the theories and principles of design thinking and service innovation management* (Zhang et al., 2003; Holmlid and Evenson, 2008; Karpen et al., 2017; Sangiorgi et al. 2019)
- *uses several interactive and visual tools* (Gummesson, 1991; Norling et al. 1992; Holmlid and Evenson, 2008; Saco and Goncalves, 2008; Sangiorgi et al., 2019; Sangiorgi, 2009; Patrício et al., 2011)
- *is human-centred and experience-oriented, addressing the experience of customers and users, as well as other stakeholders* (Mager and Sung, 2011; Zomerdijk and Voss, 2010; Kimbel, 2011; Meroni and Sangiorgi, 2011; Wetter-Edman et al., 2014; Costa et al., 2018; Anderson et al., 2018; Bitner, 1990; Holmild, 2007; Goldstein et al., 2002; Teixeira et al., 2017; Holmlid and Evenson, 2008)
- *aims at developing service holistically* (Patrício et al., 2011; Teixeira et al., 2017; Trischler at al., 2018)

Taxonomy of Significant Learning. Fink's (2003a) Taxonomy of Significant Learning has been widely used in planning and analysing learning in higher education over the past 20 years. It helps in developing and understanding students' academic and personal growth (Barnes and Caprino, 2016). In this study, we use Fink's taxonomy as a framework for describing our findings and observations from the current CBI case CERN Bootcamp. We next briefly explain the main ideas of Significant Learning.

The taxonomy (Fink, 2003a,b) consists of six dimensions (Fig. 1). 1) *Foundational knowledge*. Foundational knowledge provides the basic understanding that is necessary for learning new things. This includes basic theories, perspectives, concepts, and principles. 2) *Application.* Application learning happens when students learn how to engage in new kind of action, for example, intellectual, physical or social. It includes learning how to use critical, creative, and practical thinking in learning. This involves developing certain skills, such as managing complex projects, applying and experimenting with the key content to a real-world project presented by a community partner (Albinsson et al., 2020). 3) *Integration.* This occurs when students can see and understand the connections between different things. This may include connections between specific ideas, between whole realms of ideas, between people, and/or between different realms of life. 4) *Human dimension*. This involves the students learning about themselves as well as others and their ability to reflect on their own contribution and the team contribution, the dynamics of team interaction, and the interaction with other stakeholders. They discover the personal and social impacts of what they have learned. The human dimension of learning has the potential to give students a new understanding of what they want to become. They may acquire a better understanding of others, as well as why and how others act the way they do, and how they can interact more effectively with others. 5) *Caring.* The learning experience may change how students care about something. Consequently, they may have new feelings, interests, and values. 6) *Learning how to learn*. This gives the students new capabilities for lifelong learning (Albinsson et al., 2020) This occurs when students learn about the process of learning itself. They learn how to be a better student, how to engage in a particular kind of research or development method, and how to become a self-directed learner. (Fink, 2003a,b).

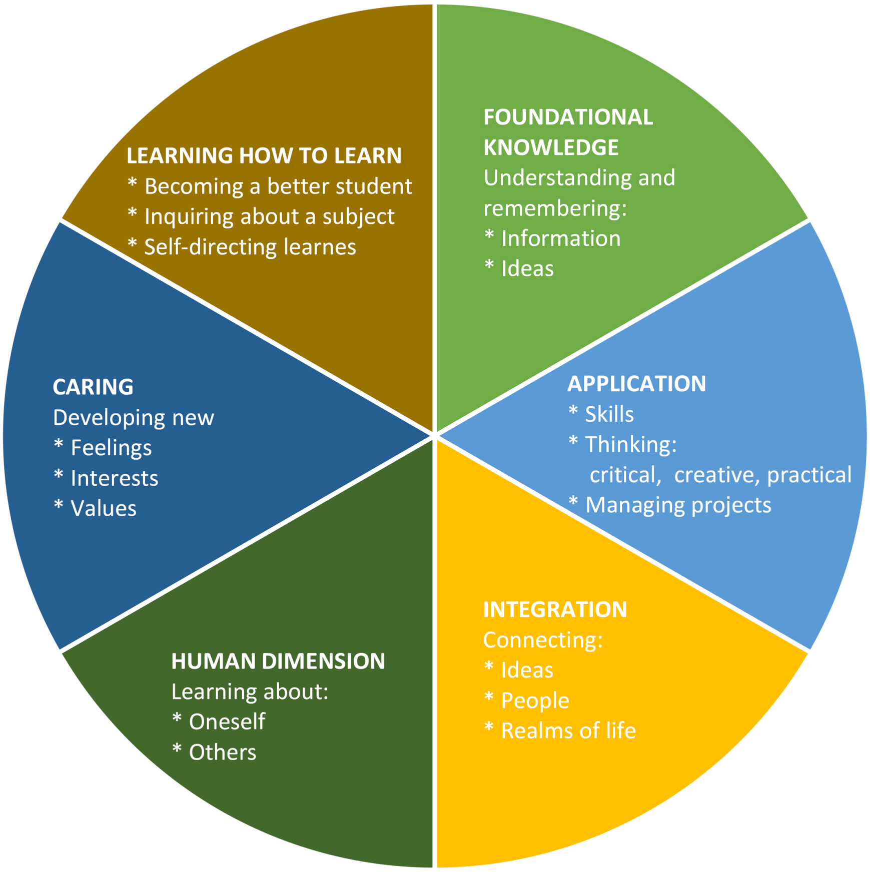

Fig. 1. Taxonomy of Significant Learning (Fink, 2003a).

METHOD AND DATA

Case study method

This study is based on a qualitative case-study method. A case study is an in-depth exploration of a particular project, policy, institution, or system in a real-life context (Simmons, 2009). It allows an investigation to retain the holistic and meaningful characteristics of real-life events (Yin, 1994). The empirical evidence of a case study may be qualitative, quantitative, or both (Eisenhardt, 1989). The evidence of a case study may be collected from the following sources: interviews, direct observation, participant-observation, documentation, archival resources, and physical artifacts (Yin, 1994). Each form of empirical data requires its own techniques for collection and analysis. A case study can be used to accomplish various aims: to offer description, to develop a theory, and to test a theory (Eisenhardt, 1989). Thus, there may be descriptive, exploratory, and explanatory case studies (Yin, 1994).

The case study in this article is descriptive and exploratory in nature. It is based on the authors' observations during the development and implementation of 2 CBI-based courses in 2018 and 2019 in CERN IdeaSquare, different documents from the course, as well as qualitative and quantitative student feedback. The summary of quantitative student feedback from two CBI implementations is shown in Table 1. The feedback was requested from all the students participating to the course 2018 and 2019. The feedback was received approximately from half of them: 12/21 in 2018 and 13/20 in 2019. The sample consists of students taking their master's degree in various fields such as Business Administration, Hospitality Management, Health Care, Social Services, Engineering, and Culture and Arts. The students work fulltime alongside their studies and they have around 2-20 years' working experience after their first degree. The data used in assessing Significant Learning dimensions in the current case are mostly based on the qualitative student feedback. Some selected quotations from the data are shown for illustration. Authors' participant-observations and quantitative student feedback were also used for complementing qualitative student feedback in making the interpretations and case descriptions of each of the dimensions of Significant Learning.

Table 1. Quantitative student feedback

Theme	Survey question	2018	2019
The content and implementation of the studies	The studies were a well-structured entity	4.00	4.15
	The study material was appropriate	4.09	4.31
	The working environment was pleasant and encouraging	4.91	4.62
	The objectives were appropriate	4.73	4.69
	The working methods were appropriate	4.36	4.31
	The working speed and schedule were appropriate	4.45	4.08
	The workload was reasonable	4.36	4.23
General evaluation of the tutors[1]	The tutors prepared themselves well	4.00	4.25
	The expertise of the tutors supported the contents	4.00	4.33
	The tutors had a positive way of working	4.55	4.73
	The process-guiding skills of the tutors were good	3.73	4.33
	The external mentors/visitors provided valuable support	4.73	4.25
The arrangements	The pre-information of the studies was good	4.30	4.33
	The practical arrangements functioned well (e.g. travel arrangements. premises, guides, technical solutions)	3.50	4.58
Students' self-evaluation	My expectations were high	4.80	4.73
	My attitude was positive	4.90	4.64
	I was well motivated to work	4.90	4.64
	I encouraged and supported other participants	4.60	4.27
	I got new knowledge	4.90	4.73
	I got new skills	4.90	4.64
	I got new networks	5.00	4.45
	I can utilize well what I have learnt	4.90	4.64

[1] Tutor = instructors during the implementation

2018: n=12, participants 21 students/answers from 12

2019: n=13, participants 20 students/answers from 13

Scale of survey questions: 1 Completely disagree, 2 Partly disagree, 3 Neither agree nor disagree, 4 Partly agree, 5 Completely agree

Case description

Next, we briefly describe the case of this study. It is a master-level university course called "CERN Bootcamp". The following characteristics position and explain the specific version of the case CBI: the starting point for solution development is a societal challenge rather than technology, the course is based on offline interaction between students rather than online education, it is a master's level course, the students have several years of working life experience after their undergraduate studies, the students are studying alongside their full-time jobs, and the student group is multidisciplinary. Each group has 4–5 students, and the groups organize their work independently, without any predetermined roles for different students. It is coordinated by Laurea University of Applied Sciences and implemented within a consortium consisting of five partners. They are CERN IdeaSquare, Haaga-Helia University of Applied Sciences, Laurea, Metropolia University of Applied Sciences, and the University of Helsinki HIP Helsinki Institute of Physics. All the Finnish institutions are located in the Helsinki Metropolitan area in Finland. The organizing team consists of five supervisors from the Finnish consortium, around five mentors from CERN IdeaSquare, one technical coordinator from Finland and one from CERN IdeaSquare. Altogether, the core team consists of 10-12 persons. In addition, several administrative and supporting persons help in the process. The main phases of CERN Bootcamp course are described next (Fig. 2)

Altogether 20–25 students are selected to the course from the organising educational institutions. The students selected start their journey with an individual pre-assignment. In the pre-assignment, they get familiar with service design methods and how to work during a short-term intensive program. Thereafter, students get together for the kick-off event for two days in Finland (Fig. 3). This is the first time when all the parties (students and supervisors from Haaga-Helia, Laurea, Metropolia, and the University of Helsinki HIP and mentors from CERN IdeaSquare) meet each other. The main content of the kick-off days is getting to know each other, choosing the challenges and creating the student teams for each challenge (four parallel challenges), learning how CERN and its stakeholders can support the development task, finding the viewpoint from which to study the selected challenge further, preparing a plan to gather data, and planning for the expert interviews.

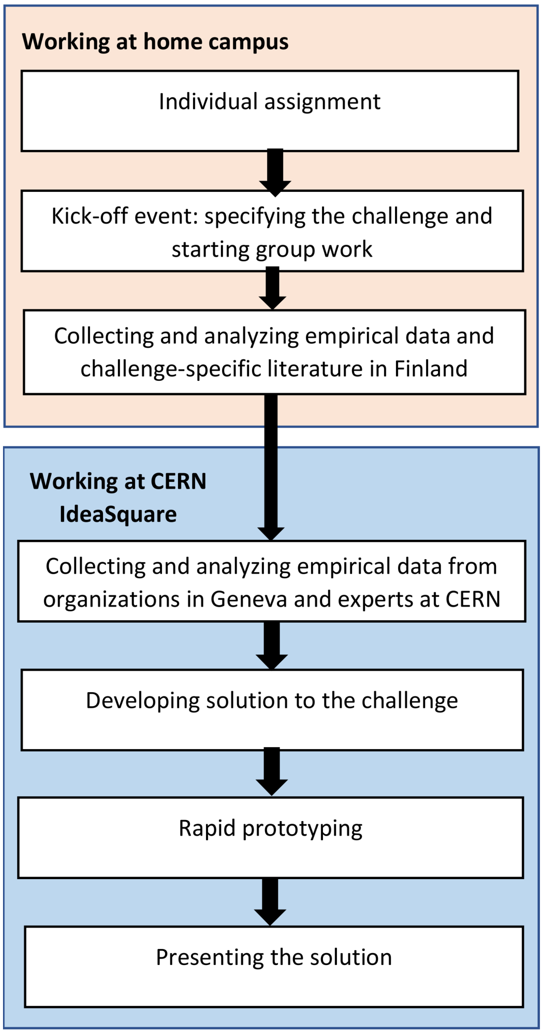

Fig. 2. Main phases of CERN Bootcamp CBI

The students collect empirical data in Finland before, as well as during, the intensive learning period at IdeaSquare. The data collection by the student teams starts right after the kick-off in Finland. The data are collected with interviews from experts and professionals who have knowledge or practical experience of the specific societal challenge or its solutions. The informants include, for example, academic researchers (e.g. professors and researchers at universities, researchers and technical experts at CERN), practitioners in companies (e.g. persons working with artificial intelligence at Microsoft), and experts in international research and collaboration organizations (e.g. a senior adviser at the World Health Organization (WHO)).

Fig. 3. Kick-off of the CBI CERN Bootcamp in Finland

Two months after the kick-off, the students come to IdeaSquare for one week (Fig. 4).

Fig. 4. Working with challenges in teams at IdeaSquare

During the week in IdeaSquare they collect more data from experts in the CERN community. They also collect data from different organizations in the Geneva area whose experts are knowledgeable concerning the challenges. They may include organizations such as the United Nations, WHO (Fig. 5), and Red Cross. The students also do rapid prototyping with their solutions and test them with persons at the CERN campus: other students, instructors, or even visitors at Idea Square.

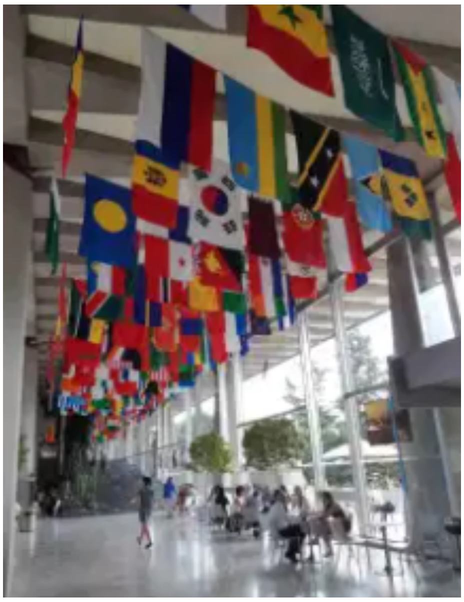

Fig. 5. Students collecting data with an expert interview at WHO

The first two days in IdeaSquare are about data gathering, analysing, learning, and creating insights on the challenges. Next, the students move to the ideation phase, which addresses the question: What kind of solutions could solve the identified problem? (Fig. 6)

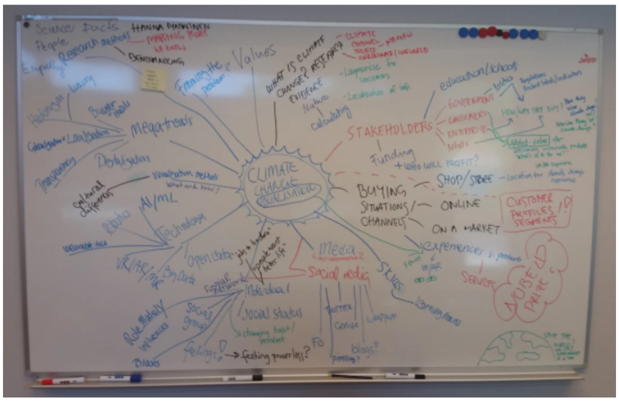

Fig. 6. Understanding the challenge and potential solution

The best ideas will be prototyped and live tested (Fig. 7). Thereafter, the ideas are finalized. At this point, societal impact is also assessed.

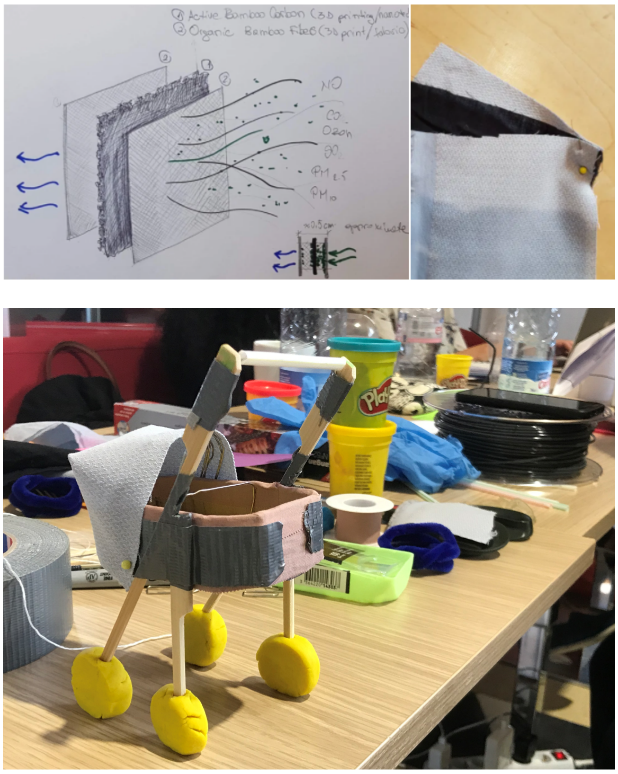

Fig. 7. Prototyping the solution

The solution and the impact are presented on the last afternoon of the stay in IdeaSquare (Fig. 8). Then, the students go back home. Afterwards, they write a learning diary individually.

Fig. 8. Presenting the solution to the challenge

RESULTS

Next, we describe how the dimensions of Significant Learning are enhanced with CBI in the current case. For each dimension, we describe the learning goals and activities. We also show examples from qualitative student feedback. This covers RQ1: To what extent does the CBI version CERN Bootcamp effectively use Significant Learning to teach service design?

Foundational knowledge

Learning goals related to foundational knowledge in the case of CBI include understanding the basics of service design process, co-creation, and most commonly used methods. Also, the concept of wicked problems and sustainable development goals (SDG) are part of foundational knowledge of the CBI. Moreover, knowledge of the challenge addressed by the students' team also belongs to learning goals.

Learning activities of foundational knowledge consist of pre-assignment. In the assignment, the students read a compulsory literature package related to the required basic knowledge, analyse it according to instructions, and prepare a report. Specific additional literature and lectures are recommended to students. Also, students do desk research by collecting research literature and other material dealing with their specific challenges. Moreover, they start empirical data collection by conducting expert interviews before coming to IdeaSquare.

The following examples of student feedback illustrate this learning dimension:

> "Students should all read the service design book to be on the same page."

> "The lectures were a valuable help."

> "Course was overall fantastic and learning was superb in the end. Would just have needed more guidance and maybe even help to understand the process before doing it."

Application

Learning goals of the application dimension include the capability to apply the service design process and basic tools to design solutions and innovations related to SDG goals. Also, the use of sprint methodology within the design process belongs to the learning goals of the application dimension. Moreover, acting as a developer in open innovation networks and environments and managing complex co-creative projects involving multiple stakeholders are included in the goals.

Learning activities of the application dimension consist of carrying out the CBI project in teams. The teamwork is accomplished in the open and collaborative environment (IdeaSquare). Various guidance and mentoring is included in the learning activities.

Examples of student feedback:

> "This is something new and a definite added-value to my skills and experience."

> "I really learned during the study trip, from tools and methods till attitude to the challenges."

Integration

Learning goals of the integration dimension cover the recognition of opportunities to solve societal problems with novel solutions applying technologies developed in CERN, as well as understanding the societal impact of the solution. Moreover, learning to conceptualize and commercialize services is focused on.

Learning activities of integration are achieved with multidisciplinary perspective and student teams. The data collection from several experts with varying societal and global perspectives on the students' challenge also contributes to the integration dimension of learning.

Examples of student feedback:

> "The models of study, cross-disciplinary approach and environmental motivating methods are amazing and rewarding."

> "Working together around an interesting challenge with others who were keen on finding a solution. It was so great that we were from different backgrounds in many ways."

Human dimension

Learning goals of the human dimension include the ability to reflect on one's own role and contribution to the service design process and outcome of the student team. This includes new interaction skills for working on a multidisciplinary team and facilitating collaboration under time pressure in the CBI.

Learning activities of the human dimension cover collaboration with people from diverse backgrounds, disciplines and cultures in teams. Peer evaluation of the project results, self-evaluation as a part of the feedback form, and the learning diary assignment are also part of the learning activities of the human dimension.

Examples of student feedback:

> "It would be good to encourage the future teams to have a few face2face meetings before the bootcamp. You will become familiar with your team members and organize the work better."

> "I learnt a lot about the service design process and about myself working in one"

> "The collaboration was a bit challenging. Even when we had different attitudes on doing things we had to do, all to work towards the common goal of the project which we actually succeeded to do."

> "At the end of every working day should be a group evaluation (just a short review of what went well, what could have done better → continuous improvement). At the end should be a retrospective."

Caring

Learning goals of the caring dimension include the ability to be conscious of and sensitive to another person's feelings and thoughts without having the same experience. By using various service design methods in the CBI, they learn to empathize with the beneficiaries of the solution to the challenge. The goal is to increase caring through the student's better understanding of the seriousness of the challenge as well as the potential impact of the solution.

Learning activities of caring cover the firsthand experience of how it is to feel and use empathy in the design process. Also, working with non-profits, inspiring and challenging innovation projects, and focus on SDGs enhance the development of new feelings, interests and values.

Examples of student feedback:

> "Meeting great new people and being in this inspirational environment of science and innovations."

> "The model of study, cross-disciplinary approach and environmental motivating methods are amazing and rewarding."

> "CERN is the most inspiring environment I've ever been in. I loved the atmosphere, the idea of sharing knowledge and working together."

Learning how to learn

Learning goals related to learning how to learn include discovering how to be more productive during the learning process. Enhanced co-creation and facilitation skills practiced in the CBI aim at improving the student's capacity to effectively learn from and with others. Moreover, the personal and external learning interests in the process create not only knowledge, but also deeper understanding.

Learning activities entail observing and participating in teamwork, constantly asking questions, receiving instant feedback from instructors and other students, which develop new and different ways of learning. The student finally makes a reflection of their learning process in the form of a learning diary.

Examples of student feedback:

> "Maybe the participants could be encouraged to share their ideas and get support/feedback from the other teams."

Critical issues to instructors and organizers

Next, we cover the RQ2: What is critical to instructors and organizers of CBI-based learning? The critical issues to instructors and organizers are categorized into four areas: process, learning environment, staff, and students (Tab. 2). The results are based on the instructors' and organizers' reflections on their experiences and feedback on the learning camps organized in 2018 and 2019.

Table 2. Critical issues to instructors and organizers

Focus area	Critical issues
Process	• enough emphasis on data gathering • selection of challenges • guidance • retrospectives • flexible timing • modifications to the sprint working model and service design process model
Learning environment	• enabling co-creation and serendipity
Staff	• multidisciplinarity • adaptability • coaching skills
Students	• collaboration • motivation • full attention to the joint project • guidelines for the teamwork

The process in the case CBI is based on design thinking applied to service innovation, which follows double-diamond design process model (Design Council, 2019) and intensive co-creation during the week in IdeaSquare in terms of a sprint model (Knapp et al., 2016). As the challenges are very broad in the beginning, we find that the students need enough time to gather and analyse the data to understand the problem area. After the first camp, the need to position the challenges within the broader framework was identified. Thus, SDGs should be emphasized and clarified at the starting point. Students' chance to influence the challenges they work with increases their motivation and commitment to the projects and enhances learning about sustainability issues on a global scale.

Students work in their teams in a self-guiding manner. This is supported by suitable pre-readings dealing with service design methods and co-creative problem-solving in intensive sprints. It is also supported by the active guidance of supervisors. Each team has a dedicated supervisor, and students can also consult any other supervisor related to their specific expertise when needed. Retrospectives support students' agile teamwork during the intensive week. A retrospective refers to the team's joint reflections on what happened in the past and identified actions for improvements when going forward.

In the sprint working models, timing is often planned in detail and is strictly followed. In the case of wicked problems and for serendipity, the schedule should be flexible, however. In general, the sprint and service design process models need to be modifiable and flexible enough to suit a CBI.

Learning environment. The physical learning environment at IdeaSquare enables smooth collaboration and co-creation within and between the student teams, and with the visitors of CERN. The environment leaves room for serendipity, as unplanned meetings are allowed to happen. External visitors and experts who come to meet and talk with students as they work in teams give valuable input to them.

Staff. Due to the nature of the challenges and diverse possibilities to approach them, a multidisciplinary group of instructors is an advantage. Instructors should also be ready to adapt themselves and their guidance to changing situations. Even though there is a plan, some adjustments to the process and methodology are always needed. Different teams need different tools and frameworks to carry out their projects. Coaching skills make it easier to support student teams to find suitable ways of working and improving their learning experience.

Students write a motivation letter as they apply to the course. Applicants are also evaluated with a multi-hour goal-oriented group work exercise in the admission process. Hence, their teamwork skills are already assessed. The ability to collaborate with others is paramount in the intensive CBI studies. Furthermore, the motivation towards the course content and commitment to the challenge chosen by the student team are essential. To support students' team-building efforts, they are asked to organise meetings on their own. In these meetings, they plan the approach for developing a solution to their challenge before the intensive week. They also get to know each other and build team spirit. For these meetings, they collect and analyse material related to their challenge. The role of instructors is to observe the teams, be available for questions, and stimulate and intervene in the teamwork if necessary.

The skillsets of the students vary: some have the substance knowledge of the challenge, while others have facilitation skills. The students who take the role of a facilitator on their team should not use their position to guide the content of the work in the direction that they prefer, at least not too strongly. A facilitator should be more neutral. Thus, the guidelines for teamwork need to include this aspect.

DISCUSSION AND CONCLUSIONS

This case study shows that the CBI-based course is effective for learning service design in higher education. It shows that CBI enhances all areas of Significant Learning Taxonomy. Thus, the students learn, not just service design process and methods, but also several more general skills. It shows that the CBI has potential to develop the student's way to interact with other people, acquire and apply knowledge, combine theory and practice, understand and develop solutions for global and societal wicked problems, work constructively under time pressure, and communicate with various methods and audiences. It also shows that learning can be fun.

Our case study also finds certain issues that are critical to instructors and organizers of CBI courses. They include sufficient degrees of flexibility and adaptability with the schedule and program and enabling serendipity, multidisciplinarity, and students' ability to collaborate and commit themselves to the challenge. Based on the student feedback, it is important to plan and communicate the practical arrangements carefully and well in advance to them.

In order to support new universities willing to join CBI, we highlight the following conclusions. Leaving the premises of one's own university enhances innovativeness and enables different and inspiring learning experiences. As organizers and instructors are flexible and prepared to make changes to the pre-planned process, they enable serendipity and use of the most suitable working methods for students. Also, as students feel pressure due to the intensity and limited time of CBI, they are likely to achieve the learning goals in due time. Dropouts are highly unlikely in CBIs. Moreover, both students and instructors can more easily contribute to positive group dynamics in an innovation environment designed specifically for co-creation.

We suggest the following opportunities for further research and development. Firstly, collaboration between different CBI courses from different universities could be explored and developed. This should be examined from the students' learning as well as instructor and organization perspectives. Secondly, indicators and metrics for understanding the impact of CBI should be developed. The impact could be addressed at least at the levels of the individual student, educational organization, and society. The time aspect, as well as direct and indirect impact, should be considered. Thirdly, the methods for introducing technologies developed in CERN for CBI students should be researched and developed further. The students could more effectively use this knowledge when developing solutions to their challenges.

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