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Engineering Solutions For A More Inclusive Society: A Case Study With Europe-Wide Challenge-Based Learning

Lennart OSTERHUS
Hamburg University of Technology (TUHH), Germany, l.osterhus@tuhh.de

Ulrike BULMANN
Hamburg University of Technology (TUHH), Germany, ulrike.bulmann@tuhh.de

Viktoria Constanze SCHNEIDER
Hamburg University of Technology (TUHH), Germany, vc.schneider@tuhh.de

See next page for additional authors

Authors
Lennart OSTERHUS, Ulrike BULMANN, Viktoria Constanze SCHNEIDER, and Kaline FURLAN

ENGINEERING SOLUTIONS FOR A MORE INCLUSIVE SOCIETY: A CASE STUDY WITH EUROPE-WIDE CHALLENGE-BASED LEARNING

L. Osterhus [1]
Hamburg University of Technology
Hamburg, Germany

U. Bulmann
Hamburg University of Technology
Hamburg, Germany

V. C. Schneider
Hamburg University of Technology
Hamburg, Germany

K. P. Furlan
Hamburg University of Technology
Hamburg, Germany

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ABSTRACT

Engineering practices directly impact our society and yet, traditional engineering courses often present a lack of emphasis on social and sustainable responsibility. Therefore, a course was designed to increase societal awareness and promote social-conscious engineering practices, and also interdisciplinary and intercultural

[1] L. Osterhus
l.osterhus@tuhh.de

collaboration. The course followed the concept of challenge-based learning (CBL) and was offered within the framework of the European Consortium of Innovative Universities (ECIU). In such framework, students from 13 European partner universities could join, as well as professionals and citizens as so-called continuous learners. The challenge addressed the issue of an increasingly aging European society and the physical hurdles brought by aging. In cooperation with a local senior citizens' residence, the participants of the challenge identified everyday challenges in dialogue with senior citizens, and jointly developed 3D printed solutions for such. The article deals with the conception and the accompanying reflection throughout the project. Students were asked how they evaluated the CBL course and how they reflected on the development of their social awareness. Based on the "mixed-method" approach, data were collected, analysed and evaluated with questionnaires (pre- and final survey) and student reflection questionnaires at milestones meetings. This paper emphasize on students’ experiences, obstacles and teamchers’ solutions in all three CBL phases, just despite the final event and evaluation.

1 INTRODUCTION

The population of elderly people in Germany and the EU is expected to increase significantly in the coming years (Statistiches Bundesamt 2022, European Commission 2020), leading to various challenges related to mobility, vision, hearing, and balance. While there have been efforts to develop technical aids to help seniors cope with these challenges, their widespread application has been limited due to a lack of user-centered design and affordability (Baldewijns et al. 2015) although it is known that user testing and user-centered design are critical to the success of technical systems (Czaja and Sharit 2009). There is a need for a more socially-conscious engineering environment that involves seniors in the development of customized, sustainable technical aids to promote their independence and well-being. So, to develop professional social responsibility is key in modern engineering education (see Bielefeldt 2018). Interestingly, the author found that some elements of engineers’ professional social responsibility is widely agreed upon like the protection of the environment, but others vary across countries and disciplines and may decline over time. Bielefeldt also stated that “personal motivation to help others through the application of one’s engineering skills can be fostered through a cycle of engaging in this helping behaviour.” (Bielefeldt 2018, p.51). Thus, challenge-based learning was selected as potentially appropriate participative and engaging format to foster social conscious engineering education practice.

In contrast to other high-impact engineering education practices like CDIO (Doulougeri et al. 2022), problem-based or project-based learning (Sukackė at al. 2022) or even research-based learning (Healey and Jenkins 2018), CBL is a pedagogical approach that encourages active learning and collaboration to solve real-world challenges in three phases: (1) Engage, (2) Investigate, and (3) Act (Hamburg University of Technology 2023). In the engage phase, participants are introduced to the big idea of the challenge and find essential questions. In the investigate phase, participants identify guiding questions, activities and resources and analyse its potential solutions. Finally, in the act phase, participants develop and implement their solutions and reflect on the outcomes. Various aspects have been recently detailed elsewhere like teacher-student interactions in CBL (Doulougeri et al. 2022), the role of external partners in CBL (Mayer at al. 2022), engagement beyond the classroom (Jimarkon at al. 2022), student motivation (MacLeod et al. 2022) or teamwork influencing factors (Mesutoglu and Bayram-Jacobs 2022).

Considering other CBL practices, experiences and research, this challenge-based learning course aimed at educating engineering students from different countries and disciplines on social responsibility and engage seniors in the development process of technical aids. These were 3D printed out of sustainable materials using direct writing method, thus producing and presenting customized technical aids that meet individual needs. By accompanying the course, the outcomes and training of engineers and seniors with stronger social awareness were documented.

So, this paper initially emphasizes the presented challenge regarding socially-conscious engineering practices. Subsequently, the methodology for evaluating the challenge based on participant responses is introduced. Following this, the results section encompasses the evaluation outcomes, along with the obstacles and solutions encountered in implementing CBL throughout all phases. In conclusion, the findings are summarised and clear directions for future investigations are provided.

2 METHODOLOGY

2.1 This Challenge

This challenge took place over the period of one semester (3,5 months) and covered a workload of 3 ECTS (approx. 90 hours). Thus, this challenge was referred to the type mini-challenge.

In this CBL course, the challenge provider was a locally-based senior citizen's residence together with the challenge hosting university, the Hamburg University of Technology (TUHH). The 14 participants were international and interdisciplinary students and one continuous learner from four European universities collaborating with seniors and the two so-called "teamchers" from TUHH. Teamchers are here researchers and teachers in the discipline of materials engineering and natural sciences. Importantly, teamchers act in their role of facilitating a working team, providing the general structure, supporting in organizational and communication matters rather than providing continuous disciplinary expert support (see Imanbayeva 2021). Due to the large distances between the different universities, the course was designed as a hybrid course. In average, 7 participants joined on-campus of the hosting university and 7 attendees participated online only.

The challenge focused on developing engineering solutions to enhance the quality of life of seniors in the residence. The learning goals of the CBL course included: (a) identifying and analysing societal challenges related to ageing, (b) developing and testing engineering solutions to address these challenges, (c) enhancing critical thinking and problem-solving abilities through a human-centered design approach, (d) gaining experience in collaboration and teamwork, (e) strengthening confidence and communication skills through presentations and discussions, and (f) understanding and reflecting on concepts of inclusivity in engineering solutions and their impact on society through participatory engagement.

Throughout the CBL course, participants have been responsible for developing their own challenge tackling approach and solutions while being supported by the teamchers. The teamchers primarily attended the challenge meetings on campus, i.e. in person, while also providing online access to facilitate a hybrid learning experience. Fig. 1 depicts the time schedule of the challenge. The preliminary meeting took place April 07, 2023 and the closing event on July 11, 2023.

Fig. 1. The time schedule of the CBL course.

In TUHH's WorkING Lab's maker space, hybrid milestone meetings were held (see Fig. 2). The course began with a preliminary meeting for introductions and initial organisational issues. A week later, the senior residence staff introduced themselves at a kick-off meeting, and participants were divided into teams for brainstorming and team building. The next week involved an input meeting, providing teams with key information about 3D printing capabilities (see Fig. 3), project management, user-centered design, and ethical collaboration with seniors.

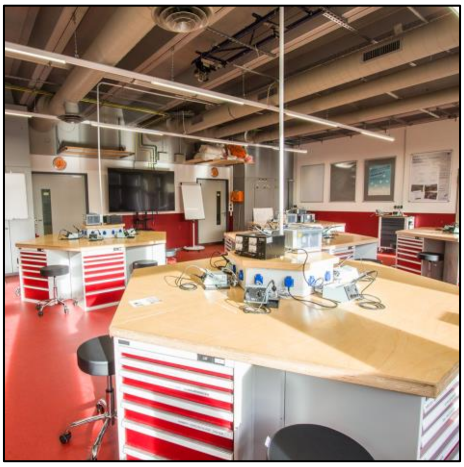

Fig. 2. Maker space for hybrid sessions

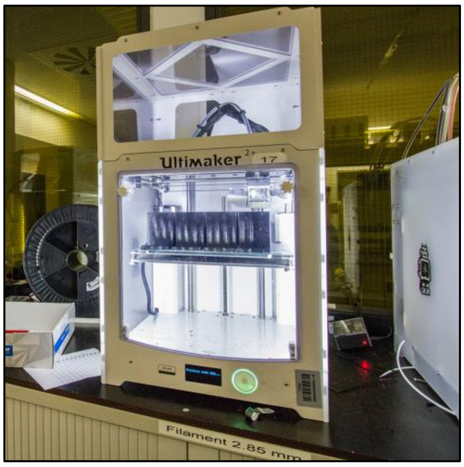

Fig. 3. 3D printer used in this challenge

In addition to these meetings, presentation meetings were held where the teams presented their project plans and later on their interim results. A feedback discussion was held at the end of the work period, followed by a public closing event where prototypes of aids for seniors were presented and demonstrated. Surveys were conducted at the end of each milestone meeting to provide insights into group dynamics and working progress. In addition to the milestone meetings, teams also held self-organised team meetings and meetings with seniors, with the latter being supported by senior residence and university staff. During these meetings, teams engaged in dialogue with different seniors about their challenges and potential aids to improve their daily lives.

2.2 The Evaluation

We aimed here to explore how challenge participants engaged in the challenge, reflected on their experience, and evaluated their development of social awareness in their engineering practices. To address these questions, we adopted a mixed-method approach. Data were collected using three self-designed questionnaires on Limesurvey: a pre-survey (7 items, mostly free text boxes). Four reflection surveys along the project progress, i.e. at the end of the milestone meetings, i.e. kick-off, input, project plan and interims presentation (9 items with 6 on a 4-point scale and 3 free text boxes), and a final evaluation after participants completed the course (17 items across three levels of evaluation according to Kirkpatrick and Kirkpatrick (2006): reaction, learning, and future perspectives, as well as recommendations). Especially the reflection surveys offered to submit the responses to the teamchers, but allowed to disagree on publication which decreases the number of responses. We analysed the data using descriptive statistics. Additionally, just one week before the closing event, we held an oral feedback discussion meeting where the two project teams used a flinga board and were asked separately to reflect on their work within the teams, the teamchers and collaboration with the seniors in terms of what they appreciated, which obstacles have been tackled in which way and which hurdles are still open to be solved.

3 RESULTS

3.1 Evaluation Results

The first evaluation results presented here include results of the pre-survey, all four reflection questionnaires and the feedback meeting. These highlight students' experiences in all three CBL phases, despite the closing event combined with the final evaluation.

Pre-survey: The results of the pre-survey indicate that the six respondents were motivated and had realistic expectations upon entering the challenge. Most respondents found out about the challenge through the E-learning platform of TUHH among other sources. Respondents joined the challenge with the aim of contributing to society and practicing 3D printing. They identified losing team members, a tight study schedule, and the hybrid format as hindering aspects, and dedication to the challenge as a facilitating factor for achieving the challenge goals. Finally, they expressed their excitement and appreciation for joining the challenge.

First reflection: At the first reflection, collected at the end of the kick-off meeting, nine respondents found the meeting to be very positive, feeling well accepted in the project team and motivated. Respondents were satisfied with the first results so far, confident in developing great prototypes, and knew what was expected of them. Their personal "Highs" included teamwork and brainstorming sessions, while their personal "Lows" related to technical issues and adapting to the hybrid format. They highlighted the need for organisational and communication support and clear expectations on the goal, product, and specified tasks to start working in their teams.

Second reflection: The second reflection was collected at the end of the input meeting, where seven respondents reported a positive experience in the meeting. Their main feedback did not change significantly, but only three respondents felt well accepted in the team. Their “Highs” included understanding various input topics within a short time, controlling enthusiasm and expressing their opinions in the group. Their “Lows” related to becoming familiar with digital tools and staying focused, particularly when discussing topics of which they had prior experience. They stated that they have learned about 3D printing, understanding the right problem statement, planning team meetings, sorting out their own schedules, helping the elderly, and studying hard to achieve success. They mentioned that the next steps are to work in their teams.

Third reflection: In the third reflection, collected at the end of the project planning meeting, ten respondents reported a positive meeting experience. Especially, the team acceptance, satisfaction and motivation was detected as very positive while participants’ confidence was positive and the expectations have been clear, but not completely. Their “Highs” related predominantly to meeting, talking and listening to the seniors and building a relationship and experience seniors’ interest as well as to conducting the project better within time and using management tools, to present the project and getting feedback and to conveying all ideas. The respondents identified their "Lows" as deficiencies in certain communication skills (with seniors, presenting their projects, and giving feedback), articulating the problem statement, and using the design software. To move forward, respondents described to need a clearer understanding of the seniors’ problem, a selection of one problem to be focused on, a vision of a prototype that can be produced in the available 3D printer, team work and collaboration with the second team, feedback and motivation.

Fourth reflection: In the fourth reflection, only 4 participants responded at the end of the interims presentation. Interestingly, for the first in this challenge, one respondent mentioned lower satisfaction and confidence. The reported “Highs” in this phase relate to making prototypes and talking to the seniors and care takers to gather more information. “Lows” that have been stated relate to not being able to make 3D prints yet and time management. To move forward they stated to need more communication with seniors, expert input on 3D drawing and dedicated time to work on this challenge by all team members.

The reflection meeting: 12 participants joined the reflection meeting which was held one week before the closing event, i.e. at the very productive finishing phase of the challenge. The participants appreciated the access to the input resources via padlet, used media in the meetings and the WorkING Lab facility, the availability, clarity in expectations and organisational support by the teamchers, the enthusiastic and sharing team atmosphere and productive work within their teams as well as the relationship with the seniors. They stated that their learning relates to a structured project work including manufacturing techniques/ 3D printing, management roles, tools and the opportunity to get in contact with product end-users as well as helping the society. Finally, they shared that they experienced obstacles related to arranging team apointments, decision-making process in their teams, expert knowledge on 3D printing, 3D printing limitations. In that last week, their challenges relate still to communicate with all and make fast and democratic decisions on key prototype design aspects or shortly test the prototypes with the seniors for modifications for the final printing - all while participants are busy with other projects at the end of the semester.

3.2 Obstacles and Solutions in Conducting the Challenge

During the planning of the course, the authors have brainstormed the potential obstacles for the successful development of the ECIU course (such as obstacles 1, 2 and 5), but also collected further information from the surveys' results detailed in section 3.1., which allowed the identification of further obstacles, as well as confirmation of expected ones. A detailed description of each obstacle and their solutions is provided below.

Obstacle 1: Hybrid format - Solution 1: The challenge-based learning course faced the challenge of organising teams comprising participants from the challenge hosting university (TUHH) and students from other European universities, as well as conducting meetings in a hybrid format. To overcome this obstacle, teams were mixed. So, each team included students that participated online as well as in-person at TUHH's campus. Information and updates were shared on a Padlet, and email communication was encouraged. Nevertheless, the student teams themselves had the freedom to decide on the communication channels to be used. Additionally, presence meetings were planned, involving online and on-campus participants. For such events, students could apply for financial support from their home institution for personal traveling.

Obstacle 2: Different scales of pre-knowledge, especially on 3D printing - Solution 2: To tackle the varying scales of knowledge and experience, especially with 3D printing, team building was integrated in the kick-off meeting to mix the teams accordingly to their previous knowledge. Moreover, broad impulses were given in the input meeting (3D printing, project management tools, user-centered design, partnering with seniors), as a mean to level the knowledge and bring the ones without previous knowledge to be able to interact and contribute. Also the teamchers referred to 3D experts within the hosting university when advanced technical competencies where needed.

Obstacle 3: Desire for clear expectations - Solution 3: The participants expressed the need for clear expectations in terms of decision making and the role of the teamchers in the CBL course. To address this, the teamchers explained their own and the participants' role and the teams' autonomy in decision-making processes in the course, while also providing clear expectations for the students throughout the challenge.

Obstacle 4: Making team decisions – Solution 4: To handle a lot of ideas that came up in various project phases, the teams used voting in meetings and messenger services as a democratic, inclusive and effective decision-making method. Especially, the feedback meeting in the last week with the teamchers helped that the teams reflected their options on finalising the prototype and go with one decision that meets the expectations and increased confidence in the final prototyping.

Obstacle 5: Language restrictions - Solution 5: Language capabilities are a key in this challenge, so that participants could properly communicate with the elderlies. The CBL course involved participants from different countries, with language knowledge differing from that of the elderlies. To overcome this, participants were distributed so that each team contained at least one person, whom would speak the same language as the elderlies. Additionally, the teamchers offered to assist with translation in meetings with the elderlies which turned out not to be necessary.

Obstacle 6: Arranging appointments for team meetings – Solution 6: Teams decided to arrange a couple of hybrid meetings in advance and take detailed notes to enable that participants who could not join are still up to date.

Obstacle 7: Limited prototype design with 3D printing technology – Solution 7: To overcome design restrictions that are related to the 3D print technology, one team decided to modify the prototype and thus, buy one part of their assistive technology and design only the other part by using 3D printing. The other team decided to design a simple, but effective assistive technology that can be completely printed.

4 SUMMARY AND ACKNOWLEDGMENTS

This study introduced a CBL course designed to foster intergenerational cooperation and to confront aging-related challenges through engineering solutions. Our CBL approach elevated social awareness in engineering students by incorporating seniors' experiences and promoting the use of 3D printing with sustainable filament. Evaluation results suggested that the course successfully facilitated collaboration and the development of a socially conscious perspective.

In accordance with the literature (Jimarkon at al. 2022, MacLeod et al. 2022), our study demonstrated that CBL allowed participants to navigate various experiences, from "Highs" to "Lows", fostering complex learning and increased awareness of daily aging issues. This is a crucial outcome as it motivates students to contribute socially and professionally to societal challenges (Bielefeldt 2018). While our findings are limited by methodological factors and the number of participants, they indicate that our approach was effective. However, we are unable to definitively state if our method was superior to other potential approaches.

Moving forward, we propose several steps: (1) gathering final evaluations from student participants, (2) procuring feedback from the partnering senior residency, (3) drawing a comprehensive conclusion from this challenge, and (4) creating practice guidelines for future collaborations with seniors within a CBL framework. These steps will shed light on the potential of such practices and contribute to a database of CBL implementations, inspiring future similar challenges. By sharing our experiences, we hope to encourage the use of CBL in addressing societal challenges across generations. Furthermore, our experience may provide useful insights for other institutions looking to integrate similar strategies into their curriculum.

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