Involving Students in the Co-Creation of a Complex, Evolving Learning Environment

Naemi Luckner, Peter Purgathofer, Geraldine Fitzpatrick

Human Computer Interaction Group,
TU Wien (Vienna University of Technology),
Argentinierstr. 8/193-5, Vienna, Austria
{naemi, fares, purg}@igw.tuwien.ac.at

Abstract. Technology-enhanced learning (TEL) is a promising solution for higher education settings by creating a collaborative, engaging learning experience despite high student numbers and a lack of individual feedback and support. When creating such TEL environments to fit a particular local context, co-creation methods provide a way for all stakeholders to meaningfully address and design for their own needs. In our specific university context, we are working on supporting different forms of learning within large, face-to-face university lectures. Our goal is to create a learning environment for students to learn and evolve in a self-directed and collaborative manner, using a mixture of traditional lectures and online learning activities. Throughout the creation of this innovative TEL environment, we made a point of inviting students to participate in the design and development process. We introduced multiple modes of co-creation for students to reflect on the current system, create prototypes and redesigns, and even practically implement new ideas and solutions. In this paper we reflect on these different modes of co-creation and discuss their impact on various design spaces within this project - the learning design, the learning content and the learning platform. Our findings point to the necessity of using multiple modes of co-creation simultaneously to get a better picture of the complex educational context and interconnections between design spaces.

Keywords: co-creation, TEL, design-based research, co-design

1 Introduction

Technology-enhanced learning greatly impacts current learning environments in higher education [1]. Especially in large classes with little or no opportunity for individual mentoring, students can profit from the additional means of communication and technology-enhanced collaboration provided by TEL [2]. To create a successful TEL platform, however, it is necessary to understand needs and requirements of students within a given learning context. Co-creation methods are tools to not only understand contextualised requirements, but also to include stakeholders in the

design, development and decision making process. This involvement can empower all stakeholders involved in the use of TEL and leads to a more democratic process to support a motivated and engaged learning experience [3, 4].

At our university, lectures in the first two semesters of a bachelor's program are often attended by more than 600 students. This creates an impersonal atmosphere, detains the lecture team from easily and individually connecting with our students, and presents challenges in course organisation and grading. Even so, we decided to change our course design from the traditional frontal lecture with one big exam at the end of the semester to a more student-driven, self-directed learning design. *Learning design* [5, 6] in this context describes the pedagogical model of how students are guided through the learning objectives, what the role of the lecture team (lecturers, tutors, etc) is, what kind of activities are offered for them to learn, or how they are evaluated.

We regularly offer mandatory courses in the first year of informatics bachelor programs at TU Wien and our *learning content* is mostly presented from a human-computer interaction (HCI) perspective [7]. In these lectures, students are presented with a number of challenges they have to complete in order to receive a course certificate. We offer more challenges than needed for a positive grade, so students can pick and choose those that they are more interested in, with a minimum of one challenge per chapter being mandatory. Due to time and resource constraints, the lecture team is not in the position to give elaborate feedback to the students' work, motivating the use of a double blind peer review system that is instrumental to create our rich and progressive learning environment.

When we started changing from the traditional lecture format to this new learning design, we first evaluated existing learning software such as Moodle (https://moodle.org/) with the result that they did not provide us with the functionality and versatility we wanted. Therefore we decided to develop our own learning platform geared directly at our students to better support them in their learning. We are using the term *learning platform* to describe the technological artefact that supports the learning design. This project turned out to be a long-term endeavour, and it is still being adapted and refined after more than a decade [8].

Throughout this development, co-creation played, and still plays, a vital role, enabling us to better understand the context in which we are designing, the needs of our students, and the requirements posed by the learning design. Since we are moving away from traditional learning designs towards more unconventional solutions, we repeatedly notice that not all our strategies and designs work equally well for students, and that even the smallest design decision directly influences their progress [9]. However, with our goal of creating a more fruitful, collaborative learning environment in which students learn to self-organise, critique the work of others, and value receiving feedback, we often opt for trying innovative designs rather than getting stuck with imperfect solutions only because they already exist.

Over the years we made use of various co-creation techniques, some of which we found better suited to yield results concerning the learning design, others for insight concerning the learning content or the learning platform. Redesigns in one area often influence redesigns in other areas. However, attention must be payed to all separately as well. Towards a better understanding of these interrelations, we pose two research questions:

- How can we effectively use co-creation to engage participants in the ongoing design of a TEL system in a large class setting?
- What does each of the co-creation methods contribute to improve our understanding of design challenges across different problem spaces (learning design, learning content, learning platform) within our TEL environment?

In this paper we will describe the co-creation approaches we used in the development of TEL. In the section 'Levels of Co-Creation', we'll get into details on how each level of co-creation is practically implemented, how we experienced the collaboration with students and how many students participate in each method. Subsequently, we discuss impact, differences and issues regarding their use.

2 Related Work

Co-creation [10], co-design [11] and participatory design (PD) [12] are often used as interchangeable labels for very similar processes. Sanders and Stappers define co-creation as "any act of collective creativity" [13, p.6] and position it in the realm of PD, while they define co-design as an instance of co-creation. They also contrast co-creation with user-centred design, with the distinctive feature being whether participants are seen as collaborators or as subjects. Arnstein [14] discusses degrees of co-creation on a scale from non-participation to tokenism and finally real impact, and thus cautions about the difference between pretending to involve participants versus actively co-creating.

There is a strong movement to use co-creation methods in education to create more active participation and engagement [15, 16], change the distribution of power between stakeholders [3, 14, 17], or give students a voice and agency [18-21]. There are various reported co-creation methods at different stages of the design process, e.g., story telling and paper prototyping [22], drama and videos [12], or discussions about design artefacts [11].

Co-creation changes the roles of researchers, designers, lecturers and students. Researchers are guiding the process by being intermediaries for negotiating ideas, fostering collaboration [19], taking responsibility to create inclusive approaches and reflect on whom they involve in co-creation [10]. Designers' roles change from

translators into facilitators of participants' creativity [8]. Lecturers take on a role as "first agent of change" [11, p.117] and provide a starting point for the co-creation processes.

Students can include their perception into the redesign [15], are profiting from closer contact to the academic and design staff [19], and might be more actively participating and engaging [23] as byproduct of the equalisation effect of digital environments [3, 24]. Their role in co-creation is described as consultant, co-researcher, pedagogical co-designer, and representative by Bovill et al. [10] or summarised as stakeholder, consumer, evaluator, informant and story-teller by Blau and Shamir-Inbal [3]. Bovill et al. [19] identify three areas where students take on the role as co-creators: curricular, course design and teaching approach.

Discussion of how co-creation can bring about changes in the power relationship are far reaching and are already mentioned by Arnstein [14] who distinguishes between actual change and pretend change. While she discusses co-creation in the context of citizen participation, her arguments can be equally applied to education, because part of co-creation is for designers, researchers or lecturers to relinquish power, be it over the final product [16], the process [11] or the pedagogy [19]. However, this sharing of power can bring about the feeling of co-ownership [16] and strengthen the sense of autonomy, competence and relatedness [25], so of self-determination [26] among students.

Potential challenges of co-creation in education involve class size [10], so called voice fatigue [3, 17, 19] where students do not see the benefits of co-creation, feel they are missing the expertise to participate or resist to change and prefer traditional structures. Additionally, there is a general cynicism about goals, either that co-creation is only used superficially without the actual intent to change structures [14] or that it is just another tool to improve student satisfaction for a higher rating of the educational institution [10].

Working with co-design in a large class, we are dealing with some of the challenges discussed in literature differently. We do not see the class size as challenge [10], but as opportunity, which introduces different and interesting design challenges, not only for the subjects of co-creation, but also for the process. In doing so, we also promote co-creation methods that might fall under a certain degree of tokenism [14], however we are using these as ways to scaffold students participation in the hope to include them in more creative and complex levels of co-creation further down the line. Last but not least, we discuss Bovill et al.'s three areas of co-creation in our educational context, teaching approaches, course design and curriculum [19] and expand them by the area of technology design.

3 Methodology

We are using a design-based research (DBR) approach [27-30], which we reflect on in detail in "Reflecting on Challenges of Conducting Design-Based Research in Large University Courses" [31]. The paper provides insights into the challenges we face in the design process, namely context challenges, research challenges, development challenges, and people challenges. Projects in DBR take place in a real-world, educational context, usually include many different stakeholders such as lecturers, students, researchers and the educational institutions as a whole, and are iterative, long-term undertakings in complex settings. Their goal is to uncover insights into pedagogical methods with the help of technological artefacts.

In our DBR project, we are working with a complex setting where the learning design, learning content and TEL platform are tightly interconnected so that changes in one area impact others. The long-term iterative nature of DBR allows for a design process where each iteration can be evaluated, their impact on other aspects of the system understood and if necessary adapted before moving on to the next design iteration. To better understand the impact on as well as the needs of all stakeholders requires close collaboration between designers, lecturers and students. Towards this, we chose a selection of co-creation methods as tools in our collaboration with students to better reflect their learning processes in our system.

To attract as many diverse student voices as possible, each method requires different levels of involvement, time expenditure and pre-existing understanding of the design process. In the next section, we describe each level of co-creation established in our design space, our experiences with the approach, and provide evaluations of participation for each.

Each co-creation mode involves a different mixture of qualitative and quantitative data both in data collection and in the evaluation of the effectiveness of that method. We examine various criteria such as the number of participants, time expenditure, relevance for problem space and limitations. An overview of the methods is given in Table 1, which shows how data was collected, how it was used and analysed, and each methods' limitations. In this paper, we do not go into depth regarding practical design outcomes for the TEL system itself, but we concentrate on participation data that contributed to these outcomes. However, our interpretation of this data is still partly informed by the outcomes of each of the co-creation modes, since they help us to better understand how to apply each level of co-creation, and what kind of design artefacts or insights we can expect from them.

We invited all students from our HCI related courses to participate in co-creation. Between 500-800 students participate in each course, but not all finish the requirements necessary to receive a positive grade. To finish a course, students have to complete activities adding up to about 60-70 points a semester, depending on the amount of ECTS (European Credit Transfer and Accumulation System) allocated to

Table 1. Each co-creation mode is differently tracked and evaluated. This graph shows what data is collected, how it is used and what the limitations of each method are.

	# participants	time	points awarded	source of data	data use and analysis	limitations
Survey	100-300	20-30mins, up to 3 times per semester	1 point	(longitudinal) survey	qualitative (e.g., thematic analysis [34]), quantitativ (e.g., Likert scale)	anonymous, little room for more detailed questions
Bugs&Feedback	56-118	small interactions over several days	none	issue tracker	qualitative interpretation and design discourse with students	also used for more irrelevant feedback not concerning the design, such as typos. incremental, rarely new ideas
Meet & Greet	16-26	preparation time + 2-3h on site	none	researchers taking notes during discussions with students	qualitative analysis and interpretation of researcher notes	hard to give everyone equal time to talk; often determined by random group of students who participate
Challenges	~100	~8h	6-16 points	student design work	taking inspiration from design artefacts	time intensive with the addition of being graded for co-creation; many design artefacts not thought through
Tutor	9-18	multiple design sessions of ~1-2h	none	design sessions, prototyping	discussion, collaborative decision making	time used for co-creation methods takes time from supporting students
Developer	~5	multiple design sessions of ~2h	none	design sessions, prototyping, implementation	discussion, collaborative decision making. technology artefacts	time for co-creation puts additional time-investment on voluntary developers; long-term support problems
Thesis	27	3-12 months	certificate for the thesis	design sessions, prototyping, implementation, reflection	discussion, collaborative decision making. technology artefacts, real-world evaluation	long-term projects that require continuous motivation and engagement to complete; long-term support problems

the course. Each point rewarded in the system represents 50 minutes of work. The minimum number of points that can be awarded is 1 point, thus some activities which take up less than 50 minutes are still worth 1 whole point. Points are collected in challenges which are described later in detail in the section 4.4 Challenges. On average, students have to complete 6-7 challenges to complete a course, however, they can voluntarily complete more.

Participants are informed as to the research character of the project they contribute to, and that data created by their efforts might be used for evaluation and publication. Participants have the option to exclude their data from this process. This option is essential, since some modes of co-creation are awarded points towards their final grade. This makes it possible to participate in co-creation to receive a certificate, however, to exclude produced data such as challenges or surveys from being used for research. Student participation in these research-based activities was not a requirement for successful course completion. All data, no matter the source, is anonymised prior to evaluation to the best of our abilities.

4 Levels of Co-Creation

We explore different levels of participation in the design and development process of our TEL environment. Each level requires a different type of commitment from the students. Figure 1 shows the ladder of participation, starting with low-threshold on-boarding activities regarding time commitment and ease of participation, and continuing to more challenging, time-consuming levels.

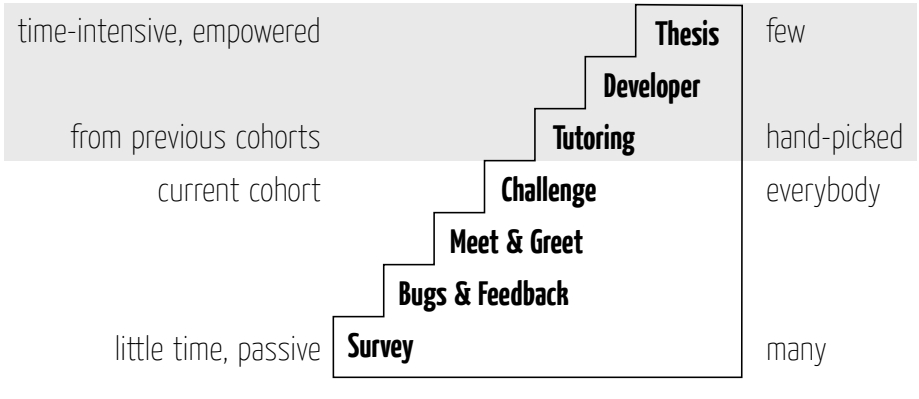

Fig. 1. This graph shows different levels of co-creation approximately ordered by ease of participation, time investment, empowerment and amount of participants. While all participants are students of computer science, the bottom 4 levels are done with students who are currently participating in the HCI lecture, while the top 3 have already progressed further in their studies.

The bottom five levels - Survey, Bugs & Feedback, Meet & Greet, Challenge and Tutoring - are not interrelated within a semester in so far as data collected in one of these methods is not immediately used in another. However, evaluated data from previous semesters can impact methods in the next semester. For example the evaluation of a survey or Meet & Greet session can impact the type of questions posed in the survey in the following semester. The top two levels are largely dependent on data collected in the other methods. These more time consuming levels of co-creation often deal with issues learned in one of the other methods. For example, developers often work on issues which came up in the Bugs & Feedback section, or students' research projects - thesis - are often dealing with challenges originating from evaluating any of the other methods where we struggle to find suitable solutions.

4.1 Survey

Each year we conduct a survey to learn about our students' needs for and experiences with the learning environment, the course design, and the organisational structure in general. Results from such surveys have already been published in conferences and journals [32, 33]. The surveys largely consist of open ended questions about the system, and often have a focus section on whichever module was recently redesigned. We want to know how students interacted with the system, where they see problems that need to be dealt with, how they would redesign or change the system to better meet their needs, and if they are missing something or have a feature request that could improve their learning.

The surveys take place in the end of the semester or in longitudinal form throughout the semester. For their participation, students are awarded a number of points towards their final grade, so we usually receive a significant number of answers. While we need to know who finished the complete survey to add points to their total, we evaluate the survey anonymously, deleting all identifying data beforehand. Students can also opt to only give feedback without providing identifying data, in that case, however, we cannot award them points for their participation.

Evaluation of participation. Table 2 provides an overview of survey participation in the last 5 years. Survey participation is set in context to the amount of students who ended up receiving certificate for the course, eliminating all students who dropped out before the end of the semester. A big influence on survey participation is the timing of the survey, varying from being sent out (1) after the end of the semester when all course work was done; (2) students being invited to participate in the survey in the last 2 weeks of the semester, before finishing their course work; or (3) the survey being held as longitudinal survey throughout the semester, in three stages: at the beginning, after 2 month and in the last 2 weeks of the semester.

Table 2. This table shows an overview of participants who completed the study between 2014-2018. The first column states the year, the second column the number of students who finished the course, the third column the number of participants who finished the survey(s), the fourth column the percentage of participant completing the survey(s) and the fifth column states the mode of survey used that year.

year	students who finished the course	students who participated in the survey	percentage of participation in survey	survey mode
2014	350	100	28,6 %	2
2015	390	101	25,8 %	2
2016	559	149	26,7 %	1
2017	637	482/333/301	75,7% / 52,3%/ 47,3%	3
2018	704	277	39,3 %	2

The best return was on the longitudinal study, even though the time involved was the longest and we did not offer a higher reward for taking part in this survey compared to the others. A high number of students (75.7%) participated in the first round of questions in the beginning of the semester where motivation was high and the system was new. While we had a drop in participation down to 52.3% for the second and 47.3% for the third survey, students still seemed to feel more inclined to finish what they started in comparison to previous years, where the average of returned surveys was 27.2%.

4.2 Bugs, Feedback & Feature Requests

We are constantly updating our system, adding new parts, changing parts that did not work as intended or eliminating bugs in the code. In doing so it can always happen that we introduce new bugs or design interactions that are not ideal for the students' learning environment. When this happens, it is crucial to find these bugs or failed designs early. So far, the best way we found to deal with such situations is to ask the students themselves to notify us when they stumble across one of these.

For a long time, we used an external collaborative text editor to collect such bugs and feedback. Students just had to follow a link in the system to anonymously add their grievances to a list that grew in the editor. While this system was generally working, its handling was less than ideal. To keep an overview of the recently added bugs and feedback, we created different sections within the document and invited students to add their feedback to the corresponding section. So, if they found a bug in the newsfeed area, they were supposed to write that in the 'newsfeed' subsection of section 'bugs'. Ideally, they should check what their peers wrote and not just add an already existing bug again. This system however asked too much of many students

who just went there to report an error, and we generally ended up with an unordered list of comments, some bugs, some feedback, that was really hard to work with.

Consequently, we developed a module called 'Bugs & Feedback' within our learning environment. It is modelled after standard issue trackers used in professional software development contexts. Students can quickly post a new item, which they need to characterise as 'bug', 'feature request', 'feedback' or 'security issue'. Other than that, only title and description are required to post an issue. Students post issues into an inbox, where staff can move the items to other columns reflecting their state like 'In discussion', 'Work in progress', 'Fixed, please verify' etc. In these columns, students can still comment the issues, but not change their status. Still, students can see all issues and their respective status at any time.

The module is designed to be easy and quick to use, especially to create new issues, but at the same time offers the opportunity to discuss solutions or advocate for a certain way to fix the issue, rather than just putting it into a black box. So on the one hand it is an outlet for complaints but at the same time it is an invitation to generate new ideas and solutions rather than just vent.

Table 3. The last 3 semesters of the issues tracker in numbers.

	SS'17	WS'17	WS'18
total issues	173	219	75
bugs	95	144	53
feedback	43	41	18
feature	30	33	4
security	5	1	0
# students posting issues	73	118	56
Average posting per students	2.4	1.9	1.3
Average of the Top 10 posters	9.6	7.8	2.8
students with only one posting	50	84	45

Evaluation of participation. Table 3 shows usage data of the Bugs & Feedback section from the last three semesters. It clearly shows that between 70-80% of participating students post only one issue over the course of the semester while the top 10 posters post between 35-55% of all issues. Furthermore, it must be noted that the use of the Bugs & Feedback section has significantly decreased in the last semester. While we have no clear indication as to why this happened, we attribute it to the fact that we asked students explicitly to not post trivial issues such as typos or small layout inconsistencies. An alternative explanation would be that our system has

become more stable over the last year, and we changed the learning design rigorously [9], which might have had an impact on the satisfaction with the system as a whole.

4.3 Meet & Greet

In the end of each semester, we organise a so called 'Meet & Greet'. We invite students to our library - a small but comfortable room with space for around 30 participants - and provide coffee, tea and cakes. In this more familiar face-to-face setting, we moderate an open discussion about the learning environment established in our course. The essential difference of the Meet & Greet to the survey is that it provides the opportunity to discuss students' experience of the lecture on their term - bringing up topics and issues we might have overlooked and which are not included in the survey. Additionally, we get a lot of hearsay and rumours from the participants who are typically more motivated, eager students.

We start by asking all students who attend the session for a short overall feedback to get them talking. Then we go through a list of topics and discuss advantages and disadvantages of the current iteration along with suggestions of improvements. This takes on the character of co-design sessions, where design artefacts such as sketches are created to express and advance ideas. We end the session with another round of feedback from the students to see if any important topics were not raised in the discussion.

Within such sessions we, the organisers, divide up our roles. One person will take over mainly guiding the discussion, another will mainly take notes. We consciously decided not to electronically record the discussion for later use, since we think that students will speak more constrained and cautious when they know they are being recorded. This too adds to the feeling of being able to comfortably and openly talk with us as organisers, lecturers and designers on a face-to-face basis.

Directly after the 'Meet & Greet' we discuss the outcomes in a debriefing session amongst ourselves. We want to make sure we documented all the important inputs, understood them comparably, and then go to prioritise all recorded issues depending on the urgency, in which they were discussed, as well as their necessities to our development process.

Evaluation of participation. Session are attended by a varying number of 16-26 students each semester. We observed that students who attend these sessions often come prepared with a list of issues they want to talk about. To give everyone room to address their issues, session sometimes take up to 3h and need to be well-moderated so that every student finds equal opportunity to participate.

We also found that students who take the time to participate in the Meet & Greet session seem to be more well-disposed towards us and the system compared to survey data and comments in the Bugs & Feedback section. They genuinely want to help to

improve the system, not only complain about things that did not work as desired or intended. This observation could, however, be misconstrued since in face-to-face communication it is easier to understand underlying intentions and motivations that get lost in digital communication.

4.4 Challenges

Challenges are used as two co-creation instances: as ideation tools for the platform and learning design, and as a means to crowd-source and create new challenges, so the learning content.

As we teach courses in the area of HCI, we have the unique situation to be able to create assignments dealing with the evaluation and redesign of the system used in the course. Students do not have to complete any particular challenge, since they have a pool of challenges in each chapter of the course to choose from, and they can opt for another one. However, many students are open to the idea of reflecting on our system on a design level, even though they usually just interact with it.

Challenges in the system are organised into sub-tasks which are building upon each other. So, in the first task of a challenge, students evaluate one or more components of the current system, describing what works well for them and what does not. In a second task, they choose a specific area they think could be improved by a redesign and go into depth in their analysis. A third task might see them propose a redesign that could address the issues they raised.

The second type of assignment challenges the students to propose a new challenge, consisting of multiple tasks that deal with a topic discussed in the course so far. To complete this challenge, students first create a description of what has to be done in each task along with the reasoning and intended learning objectives. They continue the challenge by completing their own specifications, and conclude with a reflection of what their takeaway was after doing the challenge.

Evaluation of participation. We posed such challenges in two different courses, one with a focus on societal impact of technology, the other one a basics of HCI course. Due to the different specialisations in the courses, the tasks differ in that one course focuses more on concepts and their impact on the community of learners, whereas the other tasks focus on the interaction design within the system and how it influences the students' work-flow.

Since we had an interest in receiving as much feedback on the system as possible, students had the choice to complete only the reflective tasks building up to the final task, or to complete the challenge as a whole. Students received 6 points just for handing in the tasks in which they had to analyse and critique modules and concepts of the system, worth about 5 hours of work. If they also worked on the more time-consuming final task of creating a redesign they could request up to 16 points for the

whole challenge, depending on how much work they put into the redesign. Each point is equivalent to 50 minutes of work, so an additional 10 points represented a bit over 8 hours of work.

Exemplary data of two courses show the following participation patterns: The course on societal impact of technology was attended by 557 students, 105 started the design challenge, 98 completed the analysis tasks and 43 even did the final redesign challenge. 677 students attended the basics of HCI course, 119 started the design challenge, 111 completed the analysis tasks and 52 even did the final redesign challenge. The work students handed in for the final task ranged from conceptional redesigns to low and high fidelity prototypes of different modules of the system, some of which were actually implemented in the current version of the learning platform.

4.5 Tutor

We offer between six to 25 tutor positions each year, which are publicly announced and we additionally advertise them to students who have completed the course in previous semesters and who attracted our attention either by exceptionally good work in the course or by participating actively in co-creation activities. On paper, each position consists of six to ten hours of work weekly, however, since students in our courses are not working persistently throughout the semester, these weekly hours vary. Tutors are informed about these trends beforehand and are ready to work less in the beginning of the semester, more towards the end.

Weekly sessions with all tutors along with a concluding design session at the end of the semester gives us insights into the design of a different part of the system, the lecture staff's back-end. Since all tutors have previously completed a course as students, using the same learning platform, and now see how we, the lecture staff, interact with it, it gives them a unique view on the interconnections between these two perspectives. Hence, their input is vital to improve the system.

Evaluation of participation. In the last five years we had between nine to 18 tutors per semester depending on student numbers. More than half of the tutors who work with us come back to continue their work in the following semester, some coming back up to five times.

We do not require tutors to work at a designated time or place, so weekly meetings establish a shared rhythm and sense of community. This is also important for co-creation activities in that we observed an imbalance of participation in the beginning of each semester: Tutors who have worked with us before are more willing to offer opinions and re-design propositions, while the inexperienced crowd mostly attends silently. Over the semester, there is a shift towards a more equal participation of all attendees, and hence more space for a diverse set of inputs.

4.6 Developer

Developing the learning environment is a long-term project we have been conducting for many years, unfortunately without any funding. Hence, we depend on student volunteers to support us in developing the system. We have the advantage of teaching HCI in a computer science curriculum, so there are usually motivated and able students that want to work with us. Many of the students come to us via our courses and seminars and can also earn credits towards their studies by helping us develop the system.

We offer them the possibility to work in a real-life project rather than made up scenarios that they usually deal with in their studies. They get a first-hand experience of our user-centred design and development process. They experience the highs when designs succeed as well as the lows when designs fail or students do not react favourably to the latest iterations. They are included in our design sessions, can get involved as deeply as they want, and get to design their own ideas into the system. Overall, we entertain a symbiotic relationship with our developers where both sides profit greatly.

Evaluation of participation. We are organised on principles of agile software development, so we develop the learning platform in small, manageable, iterative and flexible chunks. The software is divided into different modules or components, i.e., parts of the system that interact with each other, but that cater to different goals. One module, for example, is a communication and chat platform used to publish organisational news and discuss current topics; another module is the peer review system that organises around 50.000 reviews each semester. All design concepts in these modules are evaluated regularly, re-designed and adapted by updating the code.

Agile software development requires tight collaboration within the design and development team, so co-creation becomes a core part in this type of development. While the number of developers who concurrently work on the system varies, we feel comfortable supervising and working with four to five students at the same time. We observed that especially groups of developers who are already tightly interconnected, either through work on this project or on other projects within their studies, have a vivid discourse culture and create and inspire each other constantly, which in turn leads to better results in design as well as implementation. On the other hand we observed that leaving students to develop on their own for too long without regular meetings and design sessions usually leads to them failing to meet their development goals, or to the creation of modules that are not well-embedded within the system.

4.7 Thesis

Last but not least, we offer students the chance to write their bachelor, master or PhD thesis about topics within our learning environment. In this co-creation mode, students are actively driving the development of a module or subtopic within the system, and they collect and evaluate data needed to research the impact of their design. They become not only co-creators, but co-researcher who come up with their own research questions in addition to design objectives.

There are multiple ways we attract students for this ultimate level of co-creation. On the one hand, we advertise topics we are interested in and which we think constitute self-contained work for students to finish their degrees. On the other hand, students can also approach us with their own ideas. Mostly students will come up with ideas during one of the other levels of co-creation and want to continue their work in the context of a thesis. Every now and then however we encounter students who randomly come up with ideas and approach us on their own accord.

Evaluation of participation. This last group of students within the co-creation process, while the smallest in numbers, is usually highly motivated to collaborate with us in the co-creation of a new iteration or a new part of the learning design, learning content or learning platform. The collaboration can last from six months to a couple of years, depending on the type of thesis. Therefore, some are deeply invested after having spent so much time and effort to improve the system. Over a time span of 13 years, we have supervised 16 bachelor thesis and seminar papers on related topics, 7 finished and 3 work-in-progress master thesis and 1 PhD in progress.

5 Discussion

In this paper we have been exploring the effectiveness, value and time investment of different modes of co-creation to involve students and other stakeholders in the ongoing development of a bespoke TEL environment made to support teaching of a large university class. Our approach to co-creation is less structured than others such as Barbera et al. [11], who have seven phases and involve students in the last phase for feedback. However, it gives us opportunities to adapt our process constantly to better fit our and our participants needs. We work with a very large number of potential participants, and in doing so we had to create ways to scaffold their participation, invite diverse groups with different perspectives and inputs, make their time worthwhile, and deal with the data produced in the different modes of co-creation.

We are moving on a spectrum between more user-centred modes of information gathering to modes that allow for more active co-creation as discussed by Sanders and Stappers [13] and Arnstein [14]. We use this sliding scale to scaffold the change of

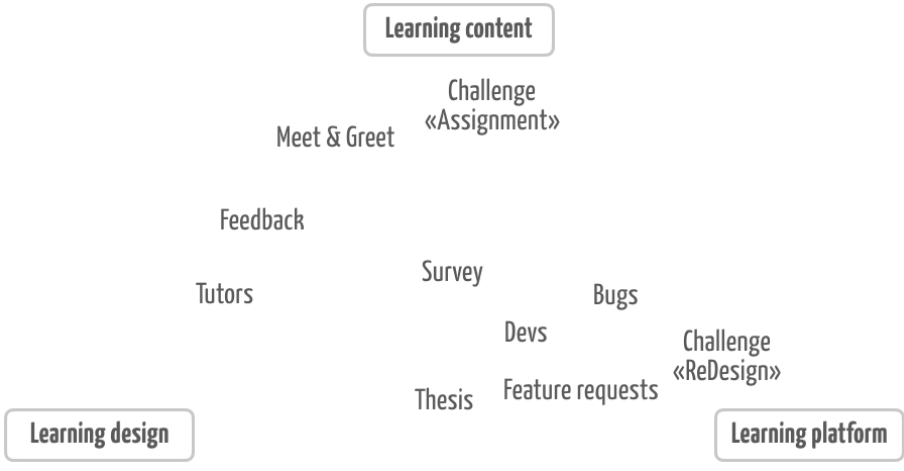

Fig. 2. The graph shows which areas profit from which type of co-creation. The proximity of a co-creation mode to one of the three problem spaces shows how much it contributes to its design.

students' roles from passive participants in a lecture to being active co-creators with whom we aim to collaborate further [23]. This collaboration is employed in different areas - learning design, learning content, and learning platform. Here, we build on Bovill et al. [19] and their three areas of co-creation, extending their approach by subsuming teaching approaches and course design under learning design, and adding the area of 'learning platform' to shift the focus away from the purely pedagogical approach to our TEL perspective.

Each of these three areas profits differently from our co-creation methods, as shown in Figure 2. While some levels of co-creation bring about insights into students' experiences and desires for the applied learning design, others are more deeply concerned with the learning content or the technical representation of the learning design. If we had used only a subset of these co-creation modes, we would have had an even more incomplete picture, leading us to creating designs that fail to fit our educational context.

The Importance of Co-Creation. We experience the co-creation process as very fruitful and important to create a modern, functioning educational environment. For years, we have been developing technology for educational purposes. However, moving further away from being students ourselves, we sometimes find that learning designs that we thought to be engaging were not being adopted with the enthusiasm we had hoped for.

Technology changes the way people interact and communicate with each other, and it also changes the way people learn or deal with information. Such changes practically show in documented cases where students focus on speed over accuracy in

knowledge retrieval [28] or where they tend to use technology as a means of communication rather than creation [29]. For us, these changes become visible in the students' daily interaction with our system, in the adoption of or discontent with changed or even with well established modules and course designs.

We can try to translate our understanding of these changes into innovative learning designs and software development, but we will not manage to fully immerse ourselves into our students' points of view. Without including the students' voices [3, 17-19] into the design and creation process, we cannot alter our system to be accepted and satisfying for students to use as well as enabling them to reach their learning goals. We need them to tell us what works for them, and what does not.

However, while co-creation is a way to bridge such a gap, we are constantly struggling to balance our students' needs and wants for the system with our own understanding of what they should take away when using the system. For example, while some of them might only want to participate and complete the course with minimal effort, our desire as educators is to encourage them to learn how to critique a design and give productive and helpful feedback [33]. One of our main challenges is to find compromises that include both perspectives, sometimes relinquishing designs and ideas about learning that we hold dear, at other times overruling students' inputs and upholding what we find pedagogically necessary for their education.

Promoting Diversity in Co-Creation. Participation in different levels of co-creation is not exclusive, and students are invited to participate in as many ways as possible. What we observe is a few students who continue to engage in different levels of co-creation and a long tail of students who just participate in one activity, mostly one they receive points for. However, we do see a trend that students who have already engaged on a lower-level are more likely to engage on a higher level of co-design as well. This suggests the importance of including students in modes of co-creation as early in the process as possible so that they want to come back for the more time consuming tasks. Therefore, we are working on ways to lower the threshold for involvement in co-creation processes in the first place.

To some extent, a low threshold to participation is part of an on-boarding strategy to change the role of students from passive consumers to domain designers [23]. Using Fischer's proposed scale to describe the transformation of our students, passive consumers are students who just participate in the lecture; active consumers are the ones taking the opportunity to critique and contribute to learning design, learning content or learning platform; power users and local developers are the students who move up the ladder to become tutors or developers in the system; and students who take on research in the area for their thesis become domain designers.

We therefore aim to create an environment that is inviting, where students feel their feedback is valued and leads to improvements of the system, if not for their own course experience, then hopefully for future students. Dent-Spargo [25] argues that co-creation processes increase the chances of designs being accepted by users and that

being part to the process changes their view on the system. However, since here the system in question is only used in a few courses, changes in its design may not directly affect the students who get involved in the co-creation processes. This can lead to some students being reluctant to spend their time working on and redesigning a system they will not be using again in the future, and creates a challenge for how we can reward and appreciate their collaboration and give them a sense of ownership.

One obvious strategy is to award them points towards their final grade within a course. However, keeping them involved in more long-term co-creation processes asks for a different kind of reward. Here we adopt strategies on a more individual basis: we create opportunities for face-to-face interactions; we supervise and mentor thesis work; we organise regular meetings where we openly share the current status of our project, our immediate goals, and our visions for the future; we have explicit design sessions where we deal with one or two particular parts of the system to be able to attract interested co-creators; and we organise social events from time to time, such as gaming nights, picnics etc.

Creating off-topic situations such as these social events have proven particularly important for creating a feeling of belonging, conveying an openness to communicate as well as the notion that co-creators are valued as individuals, not only as work force. Interestingly, contrary to the findings that students are more prone to talk in online spaces [3, 24] we have experienced a more open critique and discussion culture in our face-to-face co-creation sessions. This might also reinforce the work of Dent-Spargo [25], who mentions a relaxed atmosphere and feeling as part of a group to create a desired feeling of relatedness to the project.

Distributing Power in Co-Creation. Because our course is part of the first year of a degree program, we are mainly dealing with students who have come directly from an educational system where there is a clear hierarchy and they are used to being told what to do, when to do it and how to do it. This can create an exaggerated power imbalance when they come expecting that this format will persist throughout their education.

By asking the students to engage in co-creation activities from the beginning, we may be underestimating long-formed habits and sometimes might need to move more lightly as agents of change [11]. Abrupt change sometimes leads to resistance to participate among the students [10] who might be overwhelmed and are projecting their insecurities within this new educational situation, finding sudden new opportunities in autonomy and responsibility overwhelming. We struggle with questions of how we can better create a feeling of empowerment among the students, especially since there is a disconnect of feeling the impact of co-creation, which serves their successors more than themselves.

We also reflect on our own actions and values, and the need to balance out how and when we re-distribute power [14]. We need to better understand whom we attract with co-creation opportunities and whose voices we inadvertently drown out and we need

to develop better inclusion mechanisms [10]. Such reflections on the challenges of giving up power are a step in the right direction, however, we still often stumble across our own preexisting expectations of where we want the system to go or how much power our students actually want [17].

Data Evaluation in Co-Creation. Due to diverse ways of involving students in co-creation, we end up with a lot of input, ideas, contributions and data that needs to be evaluated. Some processes lend themselves better to timely data analysis than others. For example, the notes taken during a Meet & Greet session demand immediate analysis right thereafter. This is because they are usually only taken from the perspective of one researcher and there are also many details around the discussions that are not directly captured in the notes but that we remember when reviewing the notes. If we do this review too long after the session, the notes become less meaningful and our experience is that we have struggled to remember the context. Timely analysis of notes makes it easier to negotiate the perceived priorities while still remembering details from the discussion. A survey, on the other hand, demands a very different process of analysis, taking up more time and effort in the preparation, e.g., execution, screening, coding and clustering the data, and only then being able to interpret the outcome and design iterations based on these inputs. Overall, surveys sometimes take months of processing and still more time to directly affect a redesign of the system while other design sessions have a more immediate impact.

To be able to draw on as many perspectives and inputs as possible, we need to be constantly thinking about how we can use and include what we learned from different co-creation modes. One way we deal with this challenge is that we have different people responsible for different parts of the system within a clearly defined platform design concept. For example, when we designed the new Bugs & Feedback tracker, we had one student responsible for developing this module. Hence, all feedback, design propositions and development ideas were collected and discussed with them in person. In this way, we divide responsibilities not only for the development but also for the required data analysis. Students who are interested in writing a thesis in the area get the chance to collect data in one or more fashion, analyse their data with our guidance and turn their interpretations into graspable considerations for the learning environment.

Using so many different co-creation methods gives students multiple diverse options to report from their perspectives, however, it comes at the price of creating additional work and effort for the team of researchers and designers involved in the project. We have to decide, which data to analyse more rigorously and which data to use more as a set of impressions that influences the ongoing decision making. We see this as an unavoidable side effect of offering co-creation opportunities diverse enough to attract as many different viewpoints as possible. While varying the intensity of data analysis is less than ideal, we argue that this way every co-creation opportunity has an effect on the design of the system. We have to be very careful to not create a situation

of non-participatory co-creation, as argued by Arnstein [14] where we just pretend to employ modes of co-creation but are actually not listening to our collaborators voices.

Co-creation as education and research. We have the unique situation in which what we do and how we design and develop our system mirrors the content of what we teach. Coming from an HCI background and educating the next generation of computer scientists and developers creates countless possibilities for us as well as our students to learn from our experiences, an advantage also mentioned by Bovill et al. [19].

Co-creation in this setting can be looked at from a multitude of perspectives. It is an experiential teaching tool that can be adapted and cater to diverse interests of our students. It is a way for our students to better understand the subject matter, trade-offs and consequences, and reflect on design processes as a whole. It is in itself our preferred design process and helps us to improve our specific teaching and learning context for university students. And it is a research tool, with which we can investigate novel teaching and learning designs on the one hand and better understand the process of co-creation as a whole on the other hand. Therefore, adopting co-creation into our HCI education bridges the gap to our HCI research and brings students closer to HCI work in general.

6 Conclusion

The ongoing development of a TEL system is a never ending endeavour without a clearly defined final condition. It is a moving target that is influenced by changes in policies, changes in curricula, changes in pedagogical approaches, changes in technology and most importantly changes in the way students learn. Co-creation helps us to better understand, react to, bring about and guide these changes.

In this paper, we have documented our diverse means of co-creating a TEL environment used in HCI education for computer science students. We found that using a diverse set of co-creation modes provides opportunities to involve a diverse set of participants even in a large class setting. While there is no compulsion to get involved in co-creation at all, the majority of students take advantage of the possibility to offer feedback or re-designs. When they see their propositions having an impact on the design or our understanding of their needs, they get invested in the project and are more likely to follow up by working on more time-consuming modes of co-creation.

When analysing the contributions drawn from each co-creation method we saw a clear distinction of areas they improved concerning learning design, learning content and learning platform. Some methods could also be more valuable for other problem spaces if adapted from current practices. However, a balanced use of different

methods creates valuable insights across all problem spaces and is a more diverse and effective way to invite a broad array of students to participate.

Our learnings about the combination of co-creation methods - to include a broader array of perspectives into our development process - can also be adapted to other contexts in and outside of higher education. In particular, methods such as surveys, issue trackers, or challenges are not location or content dependent and can easily be adapted to any learning context. We hypothesise however that other methods, such as design sessions with tutors or students, might work better in co-located contexts because the face-to-face setting might enable participants to feel more comfortable working together as a group and also, more practically, enable co-sketching of design solutions. However, modern online platforms show much promise in facilitating even such design sessions through remote collaboration tools, making them more location independent.

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