Teaching Design of Technologies for Collaborative Interaction in Physical, Digital, and Hybrid Spaces

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Abstract. There is an increasing awareness of the importance of considering and mediating human collaboration in the design of technology. There are several research approaches focused on this, such as e.g., computer supported cooperative work (CSCW) and computer supported cooperative learning (CSCL), however, less attention has been given to developing educational materials for the role that technology play in mediating human collaboration in human-computer interaction (HCI) in physical, digital and hybrid spaces, why hands-on teaching activities are insufficient. In this paper, we present an emergent pedagogical framework on teaching for collaborative interaction in HCI, consisting of a collection of eleven pedagogical patterns. The paper is based on results from applying a modified pedagogical design pattern approach in the iterative development of an open educational resource containing teaching patterns, and from pilot testing of patterns with students. Preliminary results from pilot testing indicate that teachers experience an increased capacity to teach design of technologies that mediate human collaborative interaction in relevant and innovative ways. As part of "Design Education for Hybrid Environments" special issue, we hope this emerging pedagogical framework can provide teachers with inspiration to sensitize their students and make them better prepared to become responsible designers of technologies for collaborative interaction and contribute crafting next-generation physical, digital and hybrid spaces.

Keywords: HCI, teaching, collaboration, CSCW, higher education, hybrid environments.

1 Introduction

Human collaboration is a complex phenomenon, and so is designing technologies to mediate such collaboration in physical, digital and hybrid spaces, not to say how to teach it to future designers of such technologies. The particular term 'hybrid' was used only rarely in the years up until 2019 (before COVID-19 pandemic) to characterize research described now under this notion, and there exist many definitions of 'hybrid' that are used interchangeably [38]. Hybrid in this paper refers to hybrid spaces that consist of both co-located local and remote actors, and where at least three actors are located at fewer geographical sites than the number of actors.

However, discussing teaching for design of technologies for collaborative interaction in physical, digital and hybrid spaces has been somewhat neglected within fields such as Computer Supported Collaborative Work (CSCW) [6]. In HCI, teaching have played a more prominent role, not least with the initiation of EduCHI, and textbooks (i.e. [28]) and a lively discussion on the HCI curriculum in the community (e.g. [7, 13,14]), including in various sub-fields (e.g. Child-Computer interaction [33], animal-computer interaction [36]). Teaching technology design for collaborative interaction in physical, digital and hybrid spaces involves imparting a distinctive attitude – in particular a sensitivity to social aspects and co-ordination in addition to technical aspects. In this paper, we present an emerging pedagogical framework for teaching design of technologies for collaborative interaction in physical, digital and hybrid spaces in higher education. We have applied the pedagogical pattern method [16, 22] to transform concepts, methods and practices from research into concrete in-class teaching activities with accompanying learning goals. Our hope is that this can initiate a discussion on what a HCI curriculum in designing technologies for collaborative interaction in physical, digital and hybrid spaces can be.

2 Background

The goal of technologies that mediate collaborative interaction is to assist groups in communicating, collaborating, and coordinating their activities, and can be defined as: computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment [9]. Four main areas of such technologies are presented in the classic CSCW matrix [19]: Face to face interactions focus on same time, same place in synchronous interaction, Remote interactions focus on same time, different place, Continuous task focus on different time, same place in asynchronous interactions, and Communication+coordination focus on different time, different place. In addition to this, there are also technologies that support collaboration in hybrid interaction [26] and blended interaction [8].

However, what makes designing technologies for collaborative interaction so complex to design for, is because we have come to experience that the well-defined quadrants of the CSCW matrix are difficult to apply to most systems and applications, as it is always depending on the particular use situation. Most technologies that mediate collaborative interaction in some form switch back and forth between all four quadrants of the time-space matrix when in use. There are constant transitions between co-located and remote as well as synchronous and asynchronous collaboration. Further, users typically do not rely on a single groupware application or hardware device but simultaneously use different tools and devices during collaboration. Also, the team size is greater than just two collaborators and multiple coupling styles can coexist simultaneously within a single team, effectively dividing the whole team in multiple temporary subgroups of various sizes and an individual coupling style [25]. However, while many systems can be categorized according to their primary emphasis and intent, it is more appropriate to think of a collaborative technology spectrum rather than well-defined boxes [9], something we have come to adopt in this work.

3 Method

In the development of the pedagogical framework presented in this paper, we have used a modified version of the pedagogical design pattern approach [16, 22]. In a two-year long project, a three-phased model for conducting educational design research and developing educational materials was applied. Educational design-based research is aimed at providing concrete solutions to educational practitioners in relation to practical and complex educational problems. In this work, we have focused on developing educational materials in the form of in-class activities that teachers can use to teach for collaborative interaction in technology design.

In phase 1, the focus is on Exploration and analysis. The existing domain of teaching design of collaborative technologies was explored by (i) making an inventory of existing teaching practices and research production at our own universities and (ii), by conducting a literature review on (teaching) design of collaborative technologies and through this developing the research grounding. This included e.g., searching SCOPUS for (TITLE-ABS-KEY (cscw) AND TITLE-ABS-KEY (teach*)), in which we found 135 results, but only one actually addressing teaching collaborative technologies. In this phase we also invited two experts and interviewed them on their teaching practices regarding designing collaborative technologies. We further snowballed on further research resources to include.

In phase 2, the focus is on Design and construction. Based on phase one, a number of overarching learning objectives were extrapolated and described using the SOLO taxonomy. Based on the results from the first phase, and on the learning objectives, we iteratively developed a number of concrete in-class learning activities consisting of lectures and exercises.

In phase 3, the focus is on Evaluation and reflection. Alongside the design of the stand-alone in-class teaching activities, an iterative peer-review of all activities was carried out using the pedagogical pattern evaluation method called shepherding. This method ensured multiple cycles of evaluation, reflection, and revision of the activities throughout the project. Additionally, the teaching activities were put into practice and evaluated through numerous pilots involving five universities in four different countries. After each pilot, the teacher was asked to fill out a questionnaire to collect feedback.

The method has been applied to elicit existing best practice from own research, teachers, and from related work found through desk research. It has further been applied in that we made use of the pedagogical pattern template by [22], with the modification that we used the SOLO taxonomy for defining intended learning outcomes and objectives [3]. The template is complemented with teaching materials, such as suggested literature, worksheets, exercises, and presentation slides [1]. The pattern template also consists of a number of learning cycles, as proposed by Laurillard, that we have used to develop a teacher guide for each in-class activity, see example in Table 1 below.

Table 1. Overview of the pedagogical framework in teaching design of technologies for collaborative interaction consisting of the three parts Concepts, Methods, and Practices, with corresponding teaching in-class activities.

Teacher Guidance: **User research in the Design of Technologies for Collaborative Interaction**
This teaching activity consists of two main components, a lecture and an accompanying exercise. The expected length of the lecture is 30-45 minutes. The exercise can be given varying amount of time, but a couple of hours is recommended giving a total duration of about 3 hours. In the lecture (40 min), the teacher introduces students to relevant factors for performing user research in the design of technology for collaborative interaction (distinctions from dyads to communities), and three types of methods to achieve it (ethnographic, artefact ecology, and network analysis). For the exercise (60), the students in small groups practice one out of three types of user research methods. The teacher checks what the students are doing (3 minutes / group) and advises on aspects to consider. The students share their practice outputs with peers (20 minutes), and gain access to peers' outputs as a model for their practice. The teacher chairs a class discussion (30 minutes), asking for reflections on experiences, and consolidating the lessons learned. It is recommended that students read the recommended literature before class.

The eleven pedagogical in-class activities are part of a pedagogical framework, which will be briefly introduced in the next section. For a detailed presentation of the pedagogical framework and the full collection of teaching activities see [1].

4 Pedagogical Framework: Teaching Design of Technology for Collaborative Interaction in HCI

In this section we will walk through the pedagogical framework of teaching design of technology for collaborative interaction in physical-digital spaces in HCI. The overarching learning objective of the entire pedagogical framework is: *To develop student's knowledge and skills for how to design technology that mediates collaborative interaction*. In order to strive for this learning objective, the teaching activities that the framework consists of are divided into concepts, methods, and practices (Table 2), each with its own pedagogical in-class activity and corresponding learning objectives. Each of the in-class activities are built up by teaching activities consisting of lecture, exercise, learning objectives, and recommended readings. All the in-class activities are designed to be run in either on-site or online teaching contexts.

Table 2. Overview of the pedagogical framework in teaching design of technologies for collaborative interaction consisting of the three parts Concepts, Methods, and Practices, with corresponding teaching in-class activities.

	IN-CLASS TEACHING ACTIVITY
CONCEPTS	Introduction to Collaborative Interaction Mediated by Technology. Activity theory as a lens for analysis of collaborative interaction.
METHODS	User research in the design of technologies for collaborative interaction. Requirements elicitation in the design of technologies for collaborative interaction. Evaluation of technologies for collaborative interaction.
PRACTICES	Designing for collaborative co-located multi-display environments. Designing for Mobile co-located collaborative interaction. Designing technologies for hybrid collaboration. Extended reality (XR) systems that mediate collaborative interaction. Designing for Collaborative Games. Collaborative society.

4.1 Part 1: Concepts

This part of the pedagogical framework cover the core concepts of collaborative technologies which are relevant for the design research and practice, and what are the strategies to link these theories and concepts to design practice. Explains the underlying conceptual and theoretical foundations that students need in order to take collaborative interaction into account, both in their methods and in their design process, as well as in taking responsibility for their end product or service.

4.1.1 Introduction to Collaborative Interaction Mediated by Technology

In response to the rising global challenges (e.g., pandemy, climate change etc.) where remote collaboration has become radically more important, the need for designing and developing technologies that efficiently support collaborative interaction has become an even higher priority. The lecture in the in-class activity “Introduction to Collaborative Interaction Mediated by Technology” aims to introduce the terms collaboration and collaborative interaction, instances of mediating technologies in space and time dimensions in which a collaborative interaction takes place along with the opportunities and challenges offered in these types of interactions.

In the exercise, the students are expected to work individually to analyse the mediating elements of an existing technology that is designed and used for human collaboration. Students will identify the elements that can be further improved in the tool and discuss further opportunities and challenges offered by the tool.

Learning goals - Students will be able to:

- identify different domains of human collaborative interaction.
- describe design principles of how human collaborative interaction is mediated by technology design.
- discuss opportunities and challenges of different types of mediating technologies for collaborative interaction.
- identify and give examples for technologies that offer collaborative interaction in different domains of space and time
- analyse different aspects of the technology design features that mediate collaborative interaction
- discuss opportunities and challenges offered by the selected tool for collaborative interaction

Recommended reading: Schmidt and Bannon [30], Briggs [5]

4.1.2 Activity theory as a lens for analysis of collaborative interaction.

In the lecture of the in-class activity "Activity theory as a lens for analysis of collaborative interaction", the students are introduced with activity theory used as a lens to understand mediation of technology as a tool in collaborative interaction. Students describe the key concepts and principles accounted for in activity theory and discuss its use in different cases in related fields that study information systems and technology design. Topics for the final discussions are on analysing the breakdown situations or contradictions in current collaborative activity systems and bring ideas to modify the system to enhance the collaborative interaction.
In the exercise, the students are expected to work in groups (max. 4 people in one group) use Activity Theory as an analytical framework to examine an existing technology mediated collaborative interaction in three levels (i.e., coordination, cooperation, reflective communication), and create a (re)conceptualization of the collaborative interaction to improve the breakdown situations or contradictions in the current mediating technology design.

Learning goals - Students will be able to:

- identify the underlying concepts and principles of activity theory,
- explain different components or aspects of a system that mediate the collaborative interaction,
- analyse different levels of a collaborative interaction by using Activity Theory as a lens to look at different components of an activity system,
- evaluate the breakdown situations or contradictions occur between different actors in different levels of collaboration.

Recommended readings: Bertelsen and Bødker [2], Kaptelinin and Nardi [20], Kuutti et al. [21].

4.2 Part 2: Methods

This part contains in-class activities with the methods and approaches for understanding, investigating, and designing technologies for collaborative interaction. They address methods for students to engage with groups and their collaborative interaction mediated by technology, and also to practically design and evaluate technologies for collaborative interaction.

4.2.1 User research in the design of technologies for collaborative interaction

In the lecture of the in-class activity "User research in the design of technologies for collaborative interaction", the students are introduced to relevant factors for performing user research when designing technology for collaborative interaction (distinctions from dyads to communities), three types of methods to achieve it (ethnographic, artefact ecology, and network analysis). In the accompanying exercise, the students are provided with the opportunity to practise these methods, present it to others while reflecting on the consequences of the methods, and revise their approach in the light of feedback.

Learning goals - Students will be able to:

- Students will be able to name three types of methods for doing user research in the design of technology for collaborative interaction.
- Students will be able to describe relevant aspects of doing user research for the design of technology for collaborative interaction in oral and visual form.
- Students will be able to apply three types of methods for doing user research in the design of technology for collaborative interaction.
- Students will be able to reflect on practical aspects of doing user research in the design of technology for collaborative interaction.

Recommended readings: Chapter 8 in Sharp et al. [32], Martin et al. [24].

4.2.2 Requirements elicitation in the design of technologies for collaborative interaction

In the lecture of the in-class activity "Requirements elicitation in the design of technologies for collaborative interaction", methods for gathering and analysing data to elicit requirements in the design of technologies for collaborative interaction will be presented. Requirements elicitation is about exploring the problem space and defining what technology for collaborative interaction will be developed. Requirements range from functional to contextual such as e.g. social, environment and user goals. In the accompanying exercise, the students can apply methods for gathering and analysing data to elicit requirements in practice.

Learning goals - Students will be able to:

- name methods for requirements elicitation and qualitative data analysis in the design of technology for collaborative interaction.
- formulate requirements in design of technology for collaborative interaction.

- apply requirement elicitation in design of technologies for collaborative interaction.
- evaluate requirements in the design of technologies for collaborative interaction.

Recommended readings: Braun and Clarke [4], Schmidt and Rodden [31], Zowghi and Coulin [37].

4.2.3 Evaluation of technologies for collaborative interaction

In the lecture in the in-class activity "Evaluation of technologies for collaborative interaction", the students learn how to evaluate user experiences with technologies for collaborative interaction. Methods of evaluating user experience are introduced. In the accompanying exercise, students can practise by applying an evaluation framework to a new or existing technology for collaborative interaction.

Learning goals - Students will be able to:

- identify the general user experiences with technologies for collaborative interaction
- formulate proposed improvements to technologies for collaborative interaction based on its user experience
- analyse the relation between elements in the design of technologies for collaborative interaction and their user experience
- create recommendations for technologies for collaborative interaction based on user experiences

Recommended readings: Chapter 14-16 in Sharp et al. [32].

4.3 Part 3: Practices

The third part contains the practices and pedagogies, highlighting how design problems related to collaborative interaction mediated by technology are more uncertain, more nuanced, or more complex than originally assumed. This complexity will be unfolded through a number of case studies that illustrate practices in designing technology for collaborative interaction.

4.3.1 Designing for collaborative co-located multi-display environments.

In the lecture of the in-class activity "Designing for collaborative co-located multi-display environments", the students are introduced to the concept of Multi-display environments (MDE), i.e., the coupling of several displays together to form a shared interactive environment. The concept is described through a taxonomy categorising MDE:s and illustrative examples. The concept of MDE is dwelled into further through the concrete case 4in1 activities, where four tablets are combined to form one large display. In the accompanying exercise, the students are introduced to using the taxonomy for MDE: in practice.

Learning goals - Students will be able to:

- recognize multi-display environments (MDE:s)
- describe relevant factors influencing the design of MDE:s
- analyse the design of MDE:s
- reflect on the potential consequences of MDE:s for collaborative interaction
- recognize Topology, Coupling and Interaction aspects for desig of collaborative technology in MDE:s
- analyze Topology, Coupling and Interaction as aspects for design of collaborative technology in MDE contexts.
- reflect on Topology, Coupling and Interaction as aspects for design of MDE:s and the framework's potential as a tool for ideation.

Recommended readings: Garcia-Sanjuan et al. [15], Weiser [34].

4.3.2 Designing for mobile co-located collaborative interaction.

In the lecture of the in-class activity "Designing for Mobile co-located collaborative interaction", the students are introduced to the concept of designing for co-located collaborative interaction mediated by technology. This includes how technology can be a tool to enhance co-located interaction rather than something that hinders communication. A framework for designing co-located mobile interactions is presented that can be a useful tool for work in this area. The framework consists of four perspectives each outlining relevant factors for design. In the accompanying exercise, the students get to practice how the framework can be used both as an analytical and a generative tool when designing for co-located mobile interaction.

Learning goals - Students will be able to:

- recognize the need and possibilities for co-located interactions.
- describe relevant factors for mediating co-located interactions
- analyse the design of technologies for co-located interactions
- reflect on the consequences of using technology to support co-located interaction
- recognize how a design framework can be used as a generative design tool
- analyse how the use of a framework can influence the design process
- reflect on how a design tool can influence the resulting design

Recommended readings: Lundgren et al. [23], Olsson et al. [27].

4.3.3 Designing technologies for hybrid collaboration.

In the lecture of the in-class activity "Designing technologies for hybrid collaboration", the students are introduced to relevant concepts and aspects for recognizing, analysing and designing technology to support hybrid collaborative interaction, while reflecting on the consequences of the technologies. This includes understanding how hybridity matters to the tools and processes of collaboration and unpack how hybridity matters when it confers an asymmetry on the coordination that occurs within the interrelated concepts of collaboration. In the accompanying exercise, the students practice the concepts and relevant factors in designing technologies for hybrid collaboration. This involves, recognising and describe these aspects in a technology for hybrid collaboration through analysis, then re-design the technology by integrating these aspects in alternative designs, and finally reflect on the consequences of the re-design.

Learning goals - Students will be able to:

- recognize hybrid collaboration aspects in technologies.
- describe relevant hybrid collaboration aspects of technologies in oral and visual form.
- analyse and integrate hybrid collaboration aspects in the design of technologies.
- reflect on consequences of technologies on the hybrid collaboration.

Recommended reading: Neumayr et al. [26].

4.3.4 Extended reality (XR) systems that mediate collaborative interaction.

In the lecture of the in-class activity "Extended reality (XR) systems that mediate collaborative interaction", the students are introduced to the taxonomy for synchronous collaborative interaction in social extended reality (XR) environments. This includes understanding the main components for designing XR platforms that mediate collaboration. Opportunities and challenges of current virtual systems in mediating collaborative interaction are presented for future design considerations.
In the accompanying exercise, students are expected to work in both individually and groups (max. 4 people in one group) and envision a future case scenario for multiple people collaborating in a social Extended Reality platform, create personas, ideate possible requirements for plausible design features to be implemented in the technology.

Learning goals - Students will be able to:

- identify different components of designing XR systems that mediate collaboration,
- describe relevant mediating features for designing and evaluating XR systems for collaboration
- critically reflect on the opportunities and challenges of the XR systems that

mediate collaboration,
- create a future scenario for possible collaborative interaction possibilities and requirements.

Recommended readings: Schäfer et al. [29], Ens et al. [10].

4.3.5 Designing for collaborative games.

In the lecture of the in-class activity "Designing for Collaborative Games", The students are introduced to the concept of collaborative games and some recommendations and challenges for their design. The concept of design patterns is introduced followed by gameplay design patterns. A design space outlining the space of co-located collaborative games is used to give concrete suggestions for patterns that can be useful for design and illustrated by an example game. An exercise is used to let the student practice using gameplay design patterns as a generative source of inspiration for designing collaborative games.

Learning goals - Students will be able to:
- recognize collaborative games
- describe lessons and pitfalls when designing collaborative games
- describe the concept gameplay design patterns and its use for design and analysis of collaborative games
- recognize design space as a concept
- describe how the CoCe design space can be used for design of collaborative games
- reflect on how gameplay design patterns can influence design of collaborative games

Recommended readings: Zagal et al. [35] and Eriksson et al. [11]

4.3.6 Collaborative society.

In the lecture of the in-class activity "Collaborative Society", the students are introduced with various cases of collaborative society (e.g., sharing economy, peer production, collaborative media consumption and production, collaborative knowledge) as described in "Collaborative Society" book by Jemielniak & Przegalinska (2018). Students select one of the cases in the book and discuss the influence of the collaborative case's influence on different areas such as economy, culture, intimacy, and social relationships. Topics for the final discussions is on how students would envision the controversies and the opportunities in the future of collaborative society with respect to the current trends, the dilemma between positive and negative effects of collaborative society's advances, possible intermediating technologies on the future of collaboration.

With the exercise, the students are expected to work in groups (max. 4 people in one group) to examine how people succeed and fail to connect to each other and take action against a disastrous situation by using mediating tools. Identify mediating aspects, motivations and values of various stakeholders who are directly or indirectly

involve in the collaborative society from a critical perspective. Evaluate contradictions between different stakeholders and ideate on design for further improve the collaborative interaction between stakeholders.

Learning goals - Students will be able to:

- describe different cases of collaborative society
- critically evaluate the influence of collaborative cases on different aspects of human interactions
- elicit insight into the opportunities and challenges of the selected collaboration cases, and develop design ideas to improve current effects of collaborative society
- build knowledge that combines theories around collaborative interaction into interaction design practices.
- analyse different motivations and values of people for using a mediating tool to connect people to collaborate in a challenging situation.
- develop ideas for a reformulation/reconceptualization of a component in the current tool to improve contradictions within the collaborative society for further improvement.

Recommended readings: Jemielniak and Przegalinska [18]

5 Evaluation

Through a period of two years, we have iteratively developed, piloted, evaluated and re-iterated a total of eleven pedagogical in-class activities [1]. The teaching activities have been tested, in isolation or in combination, by a total of 40 pilot tests involving around 40 teachers and 781 students coming from various disciplines, and educational programmes, in five universities in four different countries. The students involved in the pilot tests have been enrolled in bachelor (n=19 pilots), master (n=5 pilots) and mixed PhD & master programs (n=16 pilots). The programs range from communication design (Faculty of architecture and design) to interaction design (Department of computer science), digital design (Faculty of Arts), Design, Technology and Society Program (Graduate School of Social Sciences), Design, Technology and Society Program (Department of Media and Visual Arts), and experience economy (Faculty of Arts). The pilot tests have ranged in various ways in everything from a guest lecture to a full course on designing technologies for collaborative interaction, however the full range of teaching activities have not been tested as one full program. The teaching activities have been pilot tested and formatively evaluated primarily in order to inform re-design and improvement. The formative evaluation was not systematically applied, but the teachers' constructive comments and suggestions have been implemented in iterated versions of the activities.

Working in the project was a valuable experience and learning opportunity for the participants, which contributed to strengthening the relations between the partner universities. It also contributed to providing contents to several university courses, most notably in Istanbul, where 2 courses at 2 different universities were largely based on

this material. The collection of teaching activities presented in the pedagogical framework is meant as an inspirational educational resource, where it is possible to pick and choose what is needed, and what fits into the existing curriculum. They are not designed for a specific curriculum or meant to be taught together as a course. This was helpful both for the application of the material in Istanbul, mentioned above, and when it was used for pilot studies at Özyeğin University, Koç University, Aarhus University, Eindhoven University of Technology, and Chalmers University of Technology.

The teaching materials were iteratively developed based on the peer-review process, but were also evaluated based on a questionnaire by the teacher after pilots. The teachers state that the added value of the piloted teaching material was: 1.) professional development within technology design for collaborative interaction, 2.) a qualitative update of the design curriculum of collaborative technologies, 3.) increased capacity to teach technology design for collaborative interaction in relevant and innovative ways. The activities for evaluating collaborative interaction mediated by a technology ranging from being fully analogue (e.g., a collaborative board game) to being fully immersive (e.g., a collaborative virtual environment in VR) (see Figure 1).

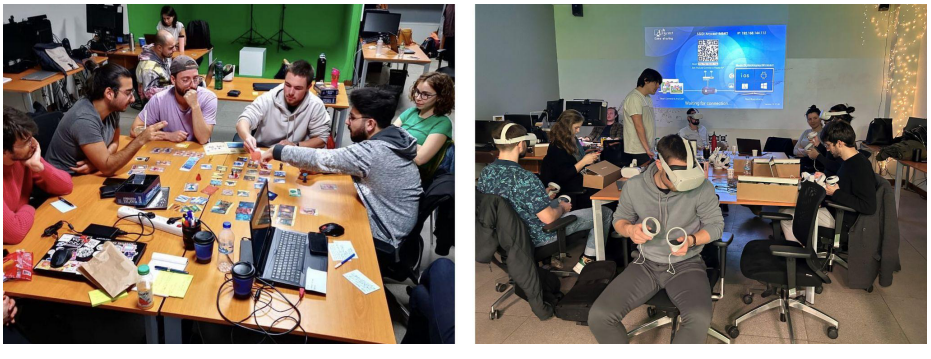

Figure 1. Students discuss collaborative interaction mediated across different technologies: on the left, one group play *Forbidden Island* board game and another group observe and analyze the mechanics, dynamics, and aesthetics of the game that mediate the collaboration in the gameplay; on the right, students design a VR social platform together in *Spatial.io* to make a desired collaboration happen between students and professionals, and implement tools that mediate synchronous and asynchronous communication between them.

The student response to the piloted materials is visible in the final course evaluations from the courses in Istanbul. These courses were largely based on contents from the TEDCO project, and the respondents were overall positive with scores above 4 out 5 on most items. In summary, the quality of the results was scrutinized in several ways: through several rounds of peer reviews and revisions, in an expert review session where 3 invited experts provided feedback on the results, and the developed teaching materials were tested in a number of pilot sessions. All-in-all 40 sessions were carried out involving 781 (non-unique) students. The sessions were taught by 55 (non-unique) teachers. Feedback was collected from students and teachers through online questionnaires. The teaching materials are available for download at https://www.tedco.se.

The materials were found to be useful In general. One of the most challenging topics was incorporating conceptual knowledge into the design to mediate collaborative interaction. For instance, explaining the nuance and the close relation between terms coordination, cooperation, collaboration, and reflective communication is not easy, let alone knowing how to design for it. Activity theory was used as a lens to analyze the dynamics of the elements that a collaborative system consists of. With all its complexity, identifying the terms separately and defining the components of a collaborative system was reported to be a challenging but useful exercise for students which help them to make an elaborate analysis of a complex system (see Figure 2).

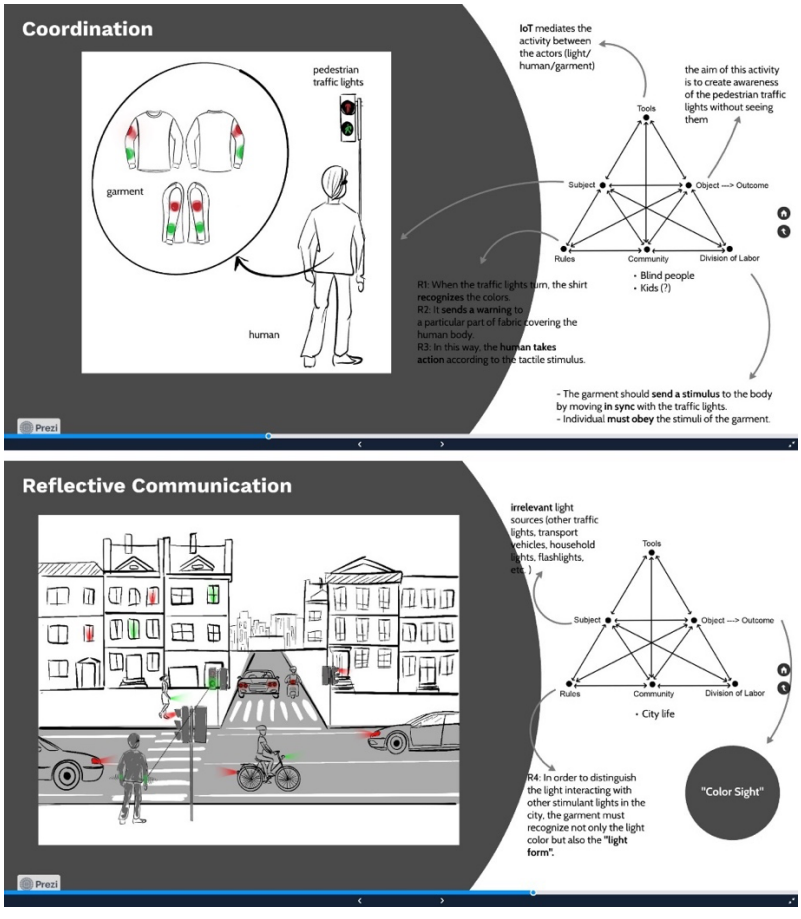

Figure 2a. A student work using the conceptual components of collaborative systems defined in *activity theory* and the three levels of collaborative interaction (i.e., coordination, cooperation, and reflective communication) as a lens to ideate on a prospective design of a wearable technology as a mediator of a future collaboration between blind people and other residents in a prospective smart city. Photo credit: Zeynep Güngör, Ph.D. candidate at Design, Technology & Society Graduate Program, Özyeğin University.

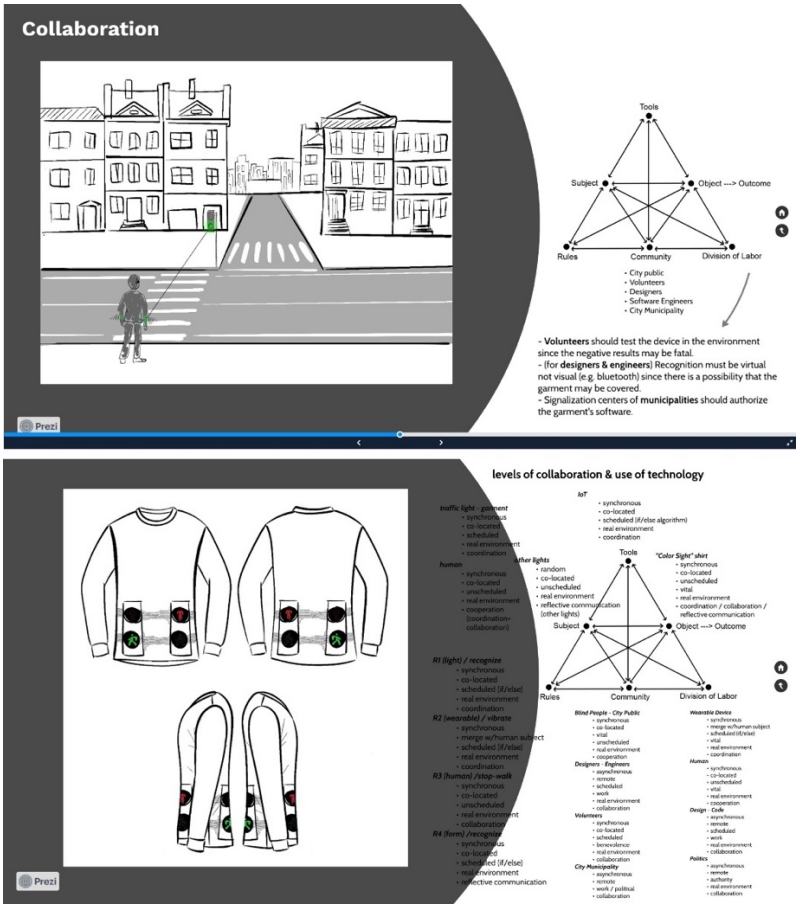

Figure 2b. The student uses the activity theory model to identify and further elaborate on the speculative design components of the envisioned collaborative interaction by describing the possible (in)direct stakeholders, related objectives, and tools within a smart city. Photo credit: Zeynep Güngör, Ph.D. candidate at Design, Technology & Society Graduate Program, Özyeğin University.

Teachers experience professional development within technology design for collaborative interaction, a qualitative update of the design curriculum and increased capacity to teach technology design for collaborative interaction in relevant and innovative ways.

6 Discussion

In this paper, we have shared our pedagogical framework for teaching students in higher education how to design for collaborative interaction in next-generation physical,

digital and hybrid spaces. The framework consists of concrete in-class teaching activities originally stemming from our own and our colleagues' research. As such, this framework can only be seen as a first steppingstone towards developing students' knowledge and skills for how to design technology that mediates collaborative interaction and comes with a number of limitations and concerns.

First of all, it is important to point out that the pedagogical framework as presented in its initial form here, is not meant to cover a whole course, or all that is needed to become an HCI practitioner specializing in designing technologies for mediating collaborative interaction in physical, digital and hybrid spaces. Also, there are many topics that are not covered, as we have used an inductive approach and started with our own research and teaching practice and developed in-class activities based on that. This means that there is huge potential for further development. Secondly, the learning goals are mostly in the lower parts of the SOLO taxonomy, why we are not aiming for educating experts in the field, rather make students in HCI become aware of and include aspects of collaborative interaction in a more responsible way. Thirdly, there are many aspects of the general HCI curriculum that are not included in the framework, as a limitation has been to aim for the specific of designing technologies for collaborative interaction rather than the general HCI. This provides both freedom and a constraint to the individual teacher, who at some point might need additional teaching activities, such as e.g., an introduction to HCI theory. Fourthly, the pedagogical in-class activities do not cover the full design process. This means that there are gaps such as e.g., prototyping and implementation.

Finally, we acknowledge that there is an unequal balance in the framework, e.g., that the number of in-class activities for concepts is much lower than that for practices. But there is also an imbalance in that the in-class activities belonging to methods are much more general in their nature compared to practices, which is more specific to collaborative interaction. We have removed some in-class activities that ended up being too general (e.g., on prototyping). For the remaining in-class activities, we have tried to compensate for the more general type of lecture by having examples and exercises more specific to technologies that mediate collaborative interaction, however this remains a topic for discussion.

Given that the number of activities related to concepts are lower than practices, it is important to point out the related challenges that we believe require further efforts to deal with. The intermingling use of terms coordination, cooperation, collaboration both in research and practice leads to difficulty in teaching how to design for these nuanced concepts. Thus, offering students with the related activities and materials that encourage them to discuss the underlying components may still be challenging but also helpful to unpack the complexity within and the relation between these phenomena. Moreover, based on our informal observations, analyzing a collaborative interaction as a complex phenomenon with respect to its different subjects or actors by identifying direct and indirect stakeholders was also a new and mind opening exercise for students. It was informative for the students to acknowledge the fact that one design solution for a collaborative interaction may have different results for diverse stakeholders (human/nonhuman actors being affected indirectly by the artefacts) in the collaborative society [18]. Thus, constant evaluation of collaborative interaction from the perspective of various subjects within the mediated environment, however not only with a focus on

the shared goal but also on the possible value tensions is an important point in teaching activities as it also aligns with [13].

Similar to [12], the materials are designed for appropriation by the teacher, to fit their specific educational context, curriculum, and student group. We have chosen this open-ended approach, as we are interested in seeing how the materials are adopted and developed over time and in various context, as we ourselves are limited to our own educational traditions and contexts and are always eager to learn from the community.

7 Conclusion

In this paper, we have responded to the IxD&A journal special issue call for educators to share their pedagogies, frameworks, and tools for crafting next-generation physical-digital spaces. We did so by presenting an emerging pedagogical framework on teaching for collaborative interaction in physical, digital and hybrid spaces in a higher education context. We believe that this work has two contributions. First of all, to propose a concrete idea for what a pedagogical framework for higher education in teaching design of technologies for collaborative interaction can be and open it up for critique and further development and extensions. Secondly, students display through their learning process, aspects that would perhaps have been hidden if we studied experienced fieldworkers, or only reflected on our own research practices [6, 17]. That is why we believe that a discussion on teaching practices is important also to develop the research field, especially with teaching materials tested in real educational contexts. A limitation of this work is that the field of designing technologies for collaborative interaction in physical, digital and hybrid spaces is wide and in a fast-paced development, so we have only covered a small portion of it. In that sense, we believe that the framework is a valuable starting point, but that more work is needed. It is the hope of the authors that the HCI and interaction design community will engage in revising and further developing this framework for future.

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