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Published in:
Proceedings of Nordes 2021

DOI:
[10.21606/nordes.2021.48](https://doi.org/10.21606/nordes.2021.48)

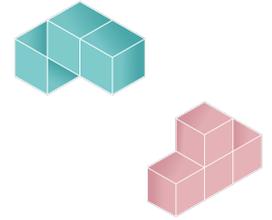
Published: 15/08/2021

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
Ylirisku, S., Jang, G., & Sawhney, N. (2021). Re-thinking Pedagogy and Dis-embodied Interaction for Online Learning and Co-Design. In *Proceedings of Nordes 2021: Matters of Scale* (Vol. 9). (Nordic Design Research Conference). Design School Kolding. <https://doi.org/10.21606/nordes.2021.48>

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NORDES 2021



RE-THINKING PEDAGOGY AND DIS-EMBODIED INTERACTION FOR ONLINE LEARNING AND CO-DESIGN

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ABSTRACT

Online courses are a key means for universities to scale up their educational offerings to wider audiences. In 2020, as the COVID-19 pandemic worsened, many such courses that were initially designed to be given in-person, were pushed online. Instructors and their respective institutions, however, had limited knowledge of processes, practices, and tools to design high-quality learning experiences. This paper collects faculty and student experiences from a Nordic university and outlines key challenges for designing high-quality live online learning sessions. It demonstrates that, given the fundamentally different contexts for learning in digital settings, teachers need to rethink their understanding of what is possible, and engage with creative tools and pedagogical practices that support enhanced learning experiences online.

INTRODUCTION

The year 2020 changed our educational landscape dramatically, as institutions were forced to move courses online due to lockdowns caused by the COVID-19 pandemic (Kimmel et al., 2020). In this situation, the reason to go online was different from the usual scaling

up and making educational offerings accessible to broader audiences. As courses that were not initially designed for remote instruction were forced to go online, unanticipated difficulties arose (Serhan, 2020). For many teachers this rendered salient the limitations and possibilities of remote instruction for the first time.

Organising great learning experiences in an online context is trickier than simply digitalising existing courses and making them available over the internet. Based on our interviews with teaching faculty and students, as well as on our own teaching practices in project-based learning, we identified three key challenges: 1) digital context is a fundamentally different setting for human interaction as compared to embodied interaction in physical space; 2) digital tools that facilitate teaching and learning evolve rapidly, and instructors need to invest time for learning such tools to accommodate those into their teaching practice; and 3) engaging pedagogical design of online learning sessions calls for attention to *appraise embodied interaction*, *promote live online pedagogy*, and *better facilitate human encounters*. Our work seeks to highlight a timely review of these phenomena during an unusual context of distance learning in the midst of a pandemic; our findings echo many aspects of earlier research in the fields of human-computer interaction (HCI) and computer supported collaborative work (CSCW).

The approach that we have adopted in this paper is qualitative and exploratory, and emerged in part through Participatory Action Research (Baum et al., 2006). The paper focusses on the design aspects of *live online learning sessions*, which may take diverse forms including lectures, tutorials, lab work, and workshops. They are constrained events with well-defined agenda,

resources, and time, while the participants are expected to be co-present during the sessions.

BACKGROUND RESEARCH

The year 2020 unexpectedly boosted existing global trends to offer university courses online. For over a decade, universities have moved part of their educational offerings online to provide more accessible education and to scale up the number of students who enrol and the study credits offered. We have witnessed the proliferation of various online platforms, such as edX (<https://www.edx.org/>), Udemy (<https://www.udemy.com/>), and Coursera (<https://www.coursera.org/>), that provide possibilities for anyone to participate in a higher education course. These online educational platforms typically provide *asynchronous* learning services, i.e. most of the materials, such as videos, texts, and questionnaires, are pre-produced and students can proceed through the course content at their own pace.

During the COVID-19 pandemic, most higher education institutions were forced to move their educational offering online. As such institutions typically have students physically present, courses are mainly organised *synchronously*, i.e. all participants of a learning session must be co-present at a specific time. Our focus is on the organisation of synchronous educational live sessions online.

ONLINE EDUCATION AS DISEMBODIED PRACTICE

Online education is mediated by digital technology; here the digital context is a fundamentally different setting for human interaction and learning as compared with embodied interaction in physical spaces. Physical contexts facilitate thinking, doing, and interaction in ways which are challenging to replicate in digitally mediated systems (Klemmer et al., 2006). Today's solutions, such as video calls with screen-share-presentations, rips interaction off its embodiment; this has implications for how we experience a video-mediated learning session.

For example, it is not possible to address a particular individual by simply looking at them without special equipment, see e.g. (Sellen et al., 1992; Nguyen & Canny, 2007). In a physical classroom this (the act of looking at) is often an effective and lightweight gesture for teachers to reach out to particular individuals. By reading a student's face, the teacher may seek for confirmation that one has understood what they say, or signs of possible agreement. Moreover, the direction of a student's gaze, body posture and orientation a teacher may discover if the student is attentive to teaching. Sun et al. (2019) studied a real-time facial expression tracking system to estimate students' responses to teaching during a live online lecture. The system gives

an overall rating of the response allowing the teacher to adjust the progression accordingly. Such affective AI systems can be notoriously inaccurate and their ethical use in educational settings must be carefully deliberated. However, the development of such technologies indicates the challenges being confronted by teachers in engaging with students in distributed online learning.

Physical settings afford people easily to refer to things pointing at them and using terms, such as 'this' and 'that'. Already in the 1990s the ability to orient and point at things inspired explorations into how systems could enable people to better communicate through spatial visual and aural cues (Billinghurst et al., 1998). Lee (2007) argues that spatiality may be leveraged for co-creative computer-mediated practices, as people can use their habituated ways to negotiate, persuade, manipulate and coerce by resourcing the objects available in their shared space. Achieving such computer-mediated real-time spatial collaboration, however, may be technical very challenging; as seen for example in the telecollaboration experiment by (Rhee et al., 2020).

Upon attending courses online, design students were removed from their physical project rooms. In design projects, student teams typically have a personal space, where they can work with their own project's materials, e.g., to organise hand-drawn charts and sticky notes. Klemmer et al (2006, p.144) argue that visible artefacts support situated learning and peripheral participation as well as collaboration. The physical manifestations of thoughts that the sticky notes carry on the walls of their personal spaces, are essential cognitive resources for the teams; and their visibility, ease of access through a glance, and often tactility, are important means of progressing in the process of co-learning and co-design.

Design and engineering education also involves offering courses about innovation that typically feature hands-on lab/studio work as well as real-world exploration in physical settings outside the school. Kimmel et al. (2020) list several educational settings for studio/laboratory work in an online/mixed situation, and some of these are very difficult to move online, for example, the building of physical prototypes, which is a common part of the project-based design and engineering courses.

A novel feature that follows from the disembodied character of live online education is the possibility to jump from one session into another in an instant, thus, contributing to so-called 'zoom fatigue' (Wiederhold, 2020). Video calls enable people to move from one session into another in a matter of two clicks; they simply end the previous call and join the next. Thus, they may not have any intermissions, such as walking over to others and chatting informally, to reflect on their experience between different video calls; students barely have time to reflect and recover from their

previous learning session. This may work against pedagogical aims, as debriefings and reflection either done alone or in a group have been considered beneficial for learning (Pearson & Smith, 1986).

CHALLENGES IN LIVE ONLINE PEDAGOGY

In the context of the COVID-19 pandemic instructors with limited experiences in online education were forced to move their teaching online, and they could not properly adjust their course structure or materials for this dramatic change (Clark-Wilson et al., 2020). Serhan's (2020) report illustrates how the urgent move from in-person courses into the digital realm caused resentment from many students who felt that they were receiving an inferior quality of education.

Before the pandemic, Fletcher and Bullock (2015) conducted a study to explore the effects of online teaching. They argue that moving teaching online changed the pedagogical role of the teachers, turning it into a responsive assessment and feedback role from the earlier more active and formative facilitator role. They also claim that the online setting was consequential for reducing teacher's ability to foster positive relationships with their students (ibid.).

When designing courses for an online setting, Bao (2020) recommends chunking the content into blocks of 20-25 minutes whilst adding some time for digesting the content. They argue that this helps students to better focus on the subject of study in the online context. We can identify several causes for the fatigue experienced in an online learning context: 1) *low bandwidth*, 2) *tool management*, and 3) *multi-channel communication*. These are further elaborated below.

Low bandwidth. One of the main reasons a video-mediated live conversation is often more challenging than face-to-face interaction is its sensory quality, which is significantly lower than in-person settings. Video requires significant data bandwidth, and unless the learner's internet connection supports high data bandwidth, using video can cause significant problems in the teaching/learning experience, as the visual content may become hard to decipher, and spoken words may become incomprehensible due to cut-offs or digital stutter. Online video quality, i.e. the visual and aural resolution, is perceptually inferior to real-life interaction, which may be even worsened by sudden network issues that cause delays and signal drops, and it takes more cognitive effort to apprehend the content. This is especially problematic for international students who may participate from abroad over a poor connection. Bandwidth limitations have proven to cause fatigue even in phone-mediated conversations (Antons et al., 2012). The processing of the lower quality interaction signals requires heightened attention from participants, whereby, digitally mediated interaction is

likely to cause increased drain of what Kahneman (2011) calls 'mental energy'.

Tool management. Combined with the extra effort that teachers need to invest in managing the novelty of digital technology and online education, running a teaching session can become highly stressful and taxing for an instructor as well as for the students. A teacher needs to manage the digital instrumentation, such as microphones, audio levels, and screen sharing, to keep the session moving, which further strains their limited capacity and attention.

Multi-channel communication. The orchestration of a live online learning session requires a teacher also to handle the various peripheral channels, which are available to the students. Depending on the course, these may include such digital tools as:

- Learning Management System (LMS) such as Moodle, Canvas, and Blackboard, with possibilities to provide course information, provide assignments and feedback, facilitate discussion in forums, and share recordings and readings
- Live video call software (such as Zoom and Teams) with chat and additional features
- Presentation software (such as PowerPoint and Keynote)
- Course website or blogs
- Live discussion groups (such as Slack and Discord)

BARRIERS TO FORMING HUMAN RELATIONS

Studies have found students often experience remote instruction negatively albeit recognizing it as being more flexible than face-to-face learning (Serhan, 2020; Al Rawashdeh et al., 2020). Students have also been found to switch their cameras off during a video-mediated lecture (Bauer et al., 2020). This may be due to bandwidth reasons, i.e. the two-way video stream is too heavy for the connection, privacy reasons, i.e. students are either not comfortable for their peers to peek in their homes, or they may decide to undertake other tasks (unrelated to learning) while the educational session is running. Students have also reported feeling intimidated speaking up in a video call in front of the full class, and thus, they may have not received the assistance from teachers and peers that they desired (Bauer et al., 2020).

Students have plenty of possible sources for distractions when they participate in online education. Serhan (2020) lists one's family and one's phone as possible sources, and underlines the apparent ease with which a student, with their camera switched off, may avoid focusing on the study subject in the live online learning session. A student's attention to learning materials and active participation in an educational session can be discouraged by unnecessarily poor experiential quality (Knipe & Lee, 2002). Online learning sessions may

need to be designed with even more engagement in mind as compared with traditional classroom settings; in a physical classroom a student usually has far less distractions, and the teacher can monitor the extent to which a student is attentive and respond accordingly.

Wang et al. (2017) argue that the engagement of online students calls for a redesign of instructional activities as well as the need to promote the importance of good audio quality. They (ibid.) studied a blended synchronous learning environment known as HyFlex, i.e. hybrid class with flexible participation options (Beatty, 2007). In a HyFlex, or hybrid session, the teacher has two different groups of students participating in a single event: the embodied and the disembodied group. These two groups have dramatically different capabilities for participating in a session, including conversing, enacting, constructing, gesturing, pointing, orienting, and perceiving. Wang et al. (2017) emphasise the facilitation of *effective communication* not only between the teacher and the students, but between the different groups of students, i.e. those online and on-site.

Toor (2020) embraces the importance of investing in community building with new students, who come to the university in the midst of a pandemic. They may have never met their peers nor their teachers in person, and thus, the human relations need to be established from scratch online. The significance of connecting with peers in online learning is well-recognised for over a decade, see (Blackmon & Major, 2012). Amongst the techniques Toor (2020) employed in her practice were 1) giving strong students more responsibility to take notes and share those with the rest of the class, 2) promoting small-group interactions, and 3) peer reviewing. Bao (2020) also emphasises the role of teaching assistants to be available to offer online support for students.

OUR STUDY AND DATA

During COVID-19 pandemic in 2020 (from March to December), we conducted a range of online courses to examine the challenges and opportunities for online learning among students and teachers. The data we collected and discuss here covers interviews with faculty members (Table 1) and students (Table 2), as well as our own experiences in running educational sessions in six multi-disciplinary project-based courses (Table 3). We have selected one of the educational sessions from the six courses for a closer analysis.

Table 1. Interviewed faculty members

No.	Position	Academic field	Teaching experience (years)	Interview date (d/m/y)
1	Lecturer	Electronics and Nanoengineering	>10	15.12.2020

2	Teacher	Electronics and Nanoengineering	2	16.12.2020
3	Lecturer	Management Studies	1	17.12.2020
4	Lecturer	Electronics and Nanoengineering	>10	17.12.2020
5	Associate professor	Electronics and Nanoengineering	7	22.12.2020
6	Lecturer	Electronics and Nanoengineering	>10	22.12.2020
7	Learning designer	Learning Design	6	26.11.2020
8	Coordinator	Electrical Engineering	>10	16.12.2020

Table 2. Interviewed students

No.	Degree	Major & years	Nationality	Interview date (d/m/y)
1	Bachelor's	Second year at Electrical engineering	South Korea	14.12.2020
2	Bachelor's	Second year at Electrical engineering	Vietnam	22.12.2020
3	Bachelor's	Second year at Electrical engineering	Finland	23.12.2020
4	Bachelor's	Second year at Electrical engineering	South Korea	04.01.2021

Table 3. Courses where we organised live online sessions.
*We analyse a workshop session in Course No 1 below.

No.	Context	Level	Participant count	Time
1*	Human-centred Research and Design in Crisis (project)	Master's	10	Summer, 2020
2	Multi-stakeholder IoT Innovation (project)	Master's	48	Oct-Dec, 2020
3	Human-centred Innovation (project)	Bachelor's	28	Jan-May, 2020
4	Design Thinking and Prototyping (project)	Bachelor's	24	Sep-Dec, 2020
5	Prototyping with Industry (project)	Bachelor's and Masters'	32	Jun-Aug, 2020
6	User-centred product innovation project	Master's	100	Sep-Dec, 2020

The interview sample includes both faculty members and students, and it was initiated by an internal university project to develop the quality of digitalised online education within electrical engineering. We also included one lecturer in the field of management studies, as they were using an engaging technical setup for running the online sessions. The main focus was on

faculty, as the project examines how new educational digitalisation services and online educational practices can be developed for teachers. We included a smaller sample of students to offer feedback as well. The participants were selected on the basis of their anticipated relevance to this project. Since we were restricted by the COVID-19 situation, all the 1-hour interviews were conducted using a remote mode (video calls) instead of traditional face-to-face meetings.

The plan for interview questions was divided into three different phases: before, during, and after the course. The first stage was about teaching preparation, planning courses for faculties, and about registering courses for students. The second stage was more about interaction between students and teachers during the online course. The third stage related to student feedback on the courses and improvement of future courses offered. As the profiles of the interviewees were different, we also asked individually tailored open-ended questions.

The data were analysed using a bottom-up approach with affinity diagramming, which is a designerly naming for what is originally known as the KJ method (Scupin, 1997). The method is based on a thematic clustering of individual observations and findings from field data and grouping those into wider themes relevant to the project. We have also employed our own experiences as instructors (authors 1 and 3) and students (author 2) participating in the same community as a resource when interpreting and sharing our findings.

The key findings from the *faculty* were related to the following themes:

- 1) *Interaction*. Interacting with students was experienced as much harder in online settings.
- 2) *Edu-tech knowledge*. Knowledge of educational digital tools was limited, and varied greatly across the instructors.
- 3) *Confusion*. Instructors received e-mails excessively with questions from students about practicalities.

Interaction. The interviewed faculty members largely echoed the views presented in literature about the difficulties in interacting with students online. During lectures, the students typically switched off their cameras. In some courses this was explicitly requested in order to reduce the amount of data traffic. Some of the instructors utilised questions in order to engage the students. These were typically responded by an awkward silence from students. Puzzled by the pause, the instructor then had to come up with other strategies on how to handle the situation.

There are many potential reasons for the silence: 1) the question was not audible due to technical issues, 2) the students were not properly attending to the presentation, 3) a student may have talked with their microphone muted, and 4) the question might have been too easy or

hard, which might make some students feel either stupid or intimidated. Instructors had no means of getting cues about these. The strategy that was chosen by some of the instructors was to persistently wait for someone to respond, meanwhile reminding the students to ensure their mic was unmuted when talking. Typically, the answers came from a few of the more active students.

Based on the first author's experience in teaching a first-year bachelor course, the difficulties in interacting with the students during online sessions also led to less personal connections with the students. After running a full semester-long course, there were still a number of students, whose face the instructor had never seen before, and thus, would not be able to recognise them when encountered later, e.g., in the hallway or lab.

Edu-tech knowledge. The transition to online teaching happened suddenly in March 2020. The instructors complained that they did not have knowledge of the proper tools to use in their course online, nor had they prepared their course to be offered online. Furthermore, their host institution had not provided ready-made instructions or tutorials on how to move existing courses online. Thus, the instructors were forced to improvise, and most of the instructors interviewed simply used their existing course structure and content, transposing their existing lectures into online video presentations. Most also utilised the live recording features of the video call platform, and offered the recorded videos to students through the local LMS for later review.

The interviewed instructors complained about a lack of information on what tools and methods were needed to prepare for high-quality online courses. All of the interviewed instructors said that they do not know what tools and methods were best suited to enhance their courses. The university provided broad guidelines, but the instructors did not consider them of practical value. In addition to moving courses online, new teachers also need to understand what kinds of pedagogical techniques and strategies work for online learning. The teachers acknowledge that sharing ideas on teaching approaches would be really helpful for each other.

Confusion. During online teaching several faculty members reported receiving a large number of e-mails from students asking for course assistance. The situation for online learning was novel for both the instructors as well as students, which required the teachers to anticipate possible problems that would arise in the online context upfront. The instructors complained that due to the quick transition from in-person to online teaching, they simply did not have sufficient time to prepare properly:

"In an ideal world, I was ready before the course would begin, but in the real world, I will always have many things underway." – Faculty member (No 4)

Moreover, to transition to online teaching and achieve well-working processes, the instructors would have needed to update the structure, content and pedagogical approach for their courses, for which they had very limited prior experience. Their experience transitioning to online learning was a journey into a new territory.

The key findings from the *students* supported those of the instructors interviewed, about challenges in interactivity and engagement:

- 1) *Boredom*. Students experienced many of the online lectures as dull and boring, and they had difficulties maintaining their attention on the lecture content.
- 2) *Disengagement*. The lack of participants keeping their video cameras open created a 'desolated atmosphere' in the virtual classroom and students felt their peers are not really attentive to the course content or to each other.
- 3) *Confusion*. Poorly documented changes to courses as well as the delivery of course content through multiple digital platforms caused confusion among students.

Boredom. All of the students interviewed mentioned that they lost their focus on the lecture more easily as compared to face-to-face teaching. The sessions were experienced as being too long. A 45-minute session without a break often made students lose their sense of attention. When courses, which were originally designed to be given face-to-face, were simply moved into the online context, their duration and structure did not appear to be effective as intended by the teachers. The students started to feel fatigue quicker. They mentioned that a lengthy online session with a monotone voice explaining course content had far less dynamic to maintain students' attention effectively. They also mentioned feeling annoyed with some lectures that were delivered over a low-bandwidth network connection or with too low-quality audio/video. Students wished for more concise and to-the-point sessions, and technically higher quality materials.

"Listening to the monotone voice makes me lose my concentration while sitting on a chair for three hours."
- Student (No. 3)

Disengagement. Students commented that interaction between students is important, especially, for first year students, as it helps to make the classroom atmosphere more engaging and they get to know each other better, in addition to learning about the subject. Since they could not get a chance to do school activities with classmates physically together, they did not feel a sense of belonging, as they did not get to know their peers during the course. Some teachers had required brief introductions from all students in the class, but this was considered too short and superficial to contribute to establishing real collaborations across the students. With students being around people in the sessions that

they did not know well, they became increasingly shy to speak in public during the class. This was especially problematic for students, who would have needed more assistance with potential struggles with course content.

Students also mentioned that teachers could have used the chat features more often, as they felt it easier to write a quick note than to open their camera, unmute the mic and talk aloud to everybody. Based on the student interviews, even though the number included in our study is very small, it already seems fair to argue that teachers need to consider how to better organise the live online classroom sessions so that the atmosphere is inviting and engaging, and that it supports building personal relations. Lowering the threshold for allowing students to bring up their need for support must be considered in online sessions.

Confusion. Towards the autumn the course syllabi were not appropriately updated, as courses needed to accommodate a slightly different plan than the previous curriculum. When teachers had left the revision of the syllabus to the last minute, students had to make choices between courses based on insufficient and ambiguous information. For elective courses students often tend to drop out if the course does not meet their expectations, which caused unnecessary turbulence in some courses where student worked in teams.

Students also reported being confused, because they needed to plan and coordinate their studies through multiple digital platforms, such as course registration, personal study plan management, and online learning, which may have some overlaps and parallel functionalities. Moreover, different teachers also have different course-specific practices in how they utilise such platforms, e.g., for providing students with follow-up materials after lectures.

LIVE ONLINE TEACHING EXPERIENCE

We ran a workshop to frame an open-ended design challenge in the field of human-centred research and design in the context of crisis. This was our very first experience in running a workshop completely in an online setting, and it was the very first workshop that we organised together (the first and last author). We are experienced workshop facilitators, both with over 15 years of facilitator experience, and we relied heavily on our experiences when planning the workshop.

Previously, when facilitating a live in-person workshop, the following kinds of concerns usually needed to be taken care of before the session:

- 1) finding and reserving a suitable venue
- 2) ordering refreshments for participants
- 3) organising the tables, seating and working materials in the space

- 4) making sure that technology in the rooms works (projectors, audio, lighting, Wi-Fi)
- 5) planning the seating of participants, ensuring those working together are co-located
- 6) bringing along pens, papers, and other physical materials for design and co-creation
- 7) reserving, preparing, and bringing documentation equipment, such as video cameras, microphones, and stands

An in-person workshop day begins with commuting; some of the participants may need to travel substantial distances, often by train from other cities to attend. On the workshop day the participants may arrive in a staggered manner, often within 15-20 minutes of each other. This enables people to get coffee, look around, and chat before the workshop starts. In an online workshop most of these behaviours are different.

We organised a live online workshop using a Zoom video call and an online brainstorming platform called Miro (<https://miro.com>). Planning the online workshop was similar in many ways to in-person sessions:

- Outlining a preliminary task for the participants so that they come to the workshop with some prepared materials and thoughts
- Defining a schedule with key transition points and objectives (expressing observations, clustering observations, and articulating design directions)

This time setting up of the workshop space happened virtually, by outlining specific digital spaces on Miro for the students to articulate their observations.

The workshop start. We (three facilitators) started with 9 students that were joining in from multiple continents (Europe, Asia and Australia). The students had been given a task to provide their thoughts about the workshop themes on the Miro canvas prior to the workshop. This was expected to help the students to familiarise with the Miro platform as well as prepare their thoughts for the workshop (see Figure 1).

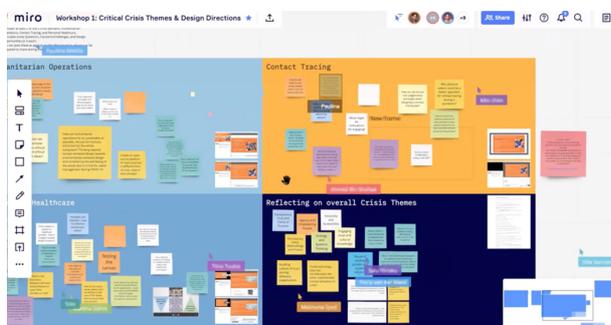


Figure 1. Initial themes on a pre-defined four-field table on a Miro board.

Guiding attention. One phenomenon of virtual meetings is how orientation towards shared objects (such as post-

it notes, displays, etc) and participants may become ambiguous. We had both the Zoom video call as well as Miro collaboration happening in parallel. While one the facilitators was explaining materials on the Miro board, the other kept switching between the Zoom call screen, which showed the other facilitator's view into the canvas. It was easy to see there, what they were talking about. However, during some of the turns, when a person explaining did not have their screen shared, it was sometimes confusing to find which note they were referring to. This provoked the facilitators to do more dynamic switching between the open windows on the screen and the Miro canvas to look for the notes being mentioned. Miro has a feature to highlight all the participants' mouse cursors on the screen, which helped in finding a coordinated target for shared attention.

Students' reflections. Students commented "it was interesting to see one's own notes being moved by the others". This happened when a student was constructing a cluster of their own, but then another student dragged their notes into a different location. It provoked the student to reflect on why this move was happening, and then to look at what was going on. The students also mentioned that they enjoyed working on the canvas together, and that it was fun to see what everybody was doing at the same time. They stated that it feels more efficient than physical post-its, the pixels are easier to move around, and looks more legible. The success of the Miro platform use, however, depends on the dynamics of the team. For this session we had teams working very collaboratively and creatively.

In addition to enabling the facilitators to propose clearly outlined surfaces, i.e. those 'boards' to express the design directions, the 'surfaces' could be dynamically adjusted in response to what kind of content was shared. Compared to a flip sheet, they too often have overly constrained space for the kinds of creative expression that the workshop participants may desire. The resulting outcome was the most visually diverse affinity diagram that the facilitators have experienced in any 2-hour workshop (see Figure 2).

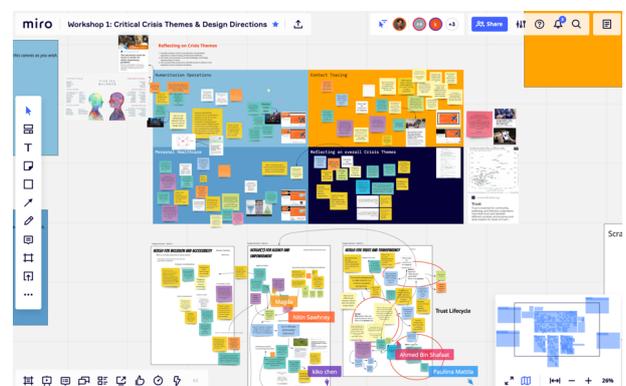


Figure 2. The Miro board at the end of the workshop; new themes emerged beside the earlier shared notes.

The feedback from the students about the workshop experience was very positive, and also we, the facilitators of the workshop, felt it was a very productive and collaborative way to advance the project. Real-time interactions were highly valued as well as observing what other participants were working on.

DISCUSSION

The challenges we identified in the paper related to online disembodiment, interaction, and human relations mostly echo findings from earlier studies in the fields of HCI and CSCW. Our work complements these with experiences of appropriating existing technologies into live interactions in online teaching, learning, and co-design during the COVID-19 pandemic. Below we reflect on our findings with the hope of supporting the design of high-quality online learning experiences.

EMBODIED INTERACTION

Online interactions were considered challenging due to its disembodied character, as people could not use their bodies to orient and gesture (Sellen et al., 1992; Nguyen & Canny, 2007). Based on our experience, the collaborative use of the shared Miro canvas and the parallel use of screen sharing through Zoom, enabled people to signal both their visual orientation (the shared screen) and gestures (visible mouse pointer) to the collaborators. The participants experienced the collaborative editing of a shared canvas to give a sense of spatial setting, where the others are working simultaneously. It enabled participants to observe what others were attending to by rendering each participant's named mouse pointer visible to the others; students liked this experience of virtual co-presence. It seems that this 2D-screen-based solution can achieve, at least to an extent, some of the key goals of the technically way more complicated solutions, such as the one studied by Rhee et al. (2020). Moreover, we have tested the solution with online workshops with up to 160 participants, and the 2D web canvas can support remote learning and design activities at a substantial scale.

Some of the courses involved on-site lab and prototyping exercises. Teachers considered online simulation tools not able to properly address the embodied characteristics of actually working with materials. For example, in electronics, it requires one to take extra care to not damage the components through wrong handling, and in physical prototyping the process typically involves a lot of improvisation with what is available. It seems that digital systems do not yet provide an enough rich context to support a 'thick practice' (Klemmer et al., 2006) in order to replace actual situated learning within physical design and technology settings.

New platforms are emerging to provide promising opportunities for more embodied virtual interaction in live online meetings. For example, a company called Spatial (<https://spatial.io>) offers attractive possibilities for hybrid online meetings, where the participants' upper body is rendered with people's hand gestures and overall bodily orientation. It remains to be seen how well platforms like this will support improved collaborative learning, design, and cooperative work.

LIVE ONLINE PEDAGOGY

Currently, the remote teaching condition has endured for over a year, and as basically all courses have been run online at least once, some several times, whereby, there exists a new, significant, and growing resource of relevant experiences within the organisations. Teachers already know quite well what works and what does not with their students in the context of their own course in the online setting. Moreover, after our interviews, teachers have already been able to adjust their courses to better work online, see e.g. (Chen et al., 2021). Thus, the situation has changed dramatically after the collection of our data, and we would recommend organisations to conduct internal reviews of and dialogue about the emergent best practices that teachers have developed. These experienced may be utilised also for the generation of organisation-wide templates for setting up new courses in the local LMS.

It is now apparent that different topics have different kinds of challenges when taught online. Some, for example, the teaching of programming is quite easy to move online, as screen sharing combined with a live video call works excellently as a teaching tool. This does not work so well with physics and mathematics, where hand-writing is an essential part of the practice, and where collaborative calculation training sessions have proven to be tricky to be organised online.

Teachers have also developed new ways to activate students while they are studying remotely. For example, at the studied university, teachers have after our study radically increased their use of various kinds of quizzes as part of their course material. Moreover, many of them have also adopted the chunking of lectures into 20-25 minute episodes, as suggested by Bao (2020).

Currently teachers are already seeing the prospect of being able to offer more flexible study options for students. It seems likely that teachers will utilise their experiences from the remote teaching in order to reduce their own lecturing burden related to repetitive topics, as well as to offer self-driven students more flexible options for completing certain types of courses, possibly supported by enhanced self- and peer-evaluation processes.

FACILITATING HUMAN ENCOUNTERS

Based on our experiences in facilitating project-based courses, it seems that valuable human encounters are more likely to happen in smaller groups. Thus, it is even more essential in the online context to have students actively engaging with their peers in smaller teams. In such teams they are also much more likely to speak up and also switch on their video cameras. Students also use chat/text-based applications, such as Telegram, to coordinate their team discussions. In a large online course at MIT (<https://computationalthinking.mit.edu/Fall20/>), instructors facilitated students to interact with their peers through a discussion forum application called Discord. We have used Slack workspaces for such forms of synchronous and asynchronous interaction among students and instructors in our courses. This promotes both informal, open format, and rapid interaction between the students, and it does not require conducting all learning, co-design and course coordination over live video-based sessions, which can often be more time-consuming and overwhelming.

Educational institutions should also foster more meaningful pedagogical exchange among instructors of online courses. Through semi-formal or informal discussions instructors could share experiences experimenting with different kinds of live online learning platforms as well as practical tips in overcoming the emerging challenges in recalibrating pedagogical practices in online learning contexts.

CONCLUSIONS

Distributed online learning is a key strategy for higher educational institutions to scale up their offerings to make them accessible to wider audiences. This paper explored the experiences of faculty and students of a Nordic university during the first nine months of the global COVID-19 pandemic. It identified three key challenges that educators need to address in order to design their live online learning sessions to better serve their pedagogical purpose. First, the *disembodied character* of today's live online communication and learning platforms significantly reduces the cognitive resources that people usually have during in-person situations, making it more challenging to interact and communicate, while often excluding training and practices of physical skills, which are essential in many areas of design and engineering. Second, *live online pedagogy* has several characteristics that make it different from in-person pedagogy: bandwidth limitations, digital tools, and multi-channel communication all must be addressed by adapting the pedagogy. And third, live online learning sets up novel *barriers to forming human relations*. Strategic choices that enable students to better connect with their peers while working on their coursework may lower these.

Because the digital context is fundamentally different setting for supporting learning and co-creation, teachers need to improve their understanding of what is possible pedagogically, while learning new tools and platforms that allow enhanced learning experiences in live online settings. Based on the disembodied and multi-channel character of online contexts, both teachers and students can embrace new forms of dynamic interaction, peer-based learning, co-creation, and informal exchange that amplify the potential of distributed online learning.

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