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Social interaction and agency in self-organizing student teams during their transition from face-to-face to online learning

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ABSTRACT

Online collaboration is becoming increasingly more common in work life and education, a development that is accentuated by the Covid-19 pandemic. It is thus imperative that students learn to work in and as teams in online settings, and that teachers and educational researchers and policymakers understand how online environments enable and constrain student collaboration. However, what has been missing in research on online student collaboration is a focus on students as *agents* rather than passive learners as well as a lack of focus on student teams as *self-organizing* teams. This paper reports on a study that investigated the experiences of 1611 graduate students in 315 teams enrolled in an interdisciplinary project-based course during their (forced) transition from face-to-face to online collaboration due to the COVID-19 pandemic. We explored how the transition to online learning affected social interaction and how teams changed their practices to support and sustain social interaction in the online environment. The findings show that the changed conditions of the learning environment influenced social interaction in negative ways, but also that team reflection seemed to enable the students to reverse some of the adverse effects and develop practices that supported both the cognitive and socio-emotional dimensions of social interaction. Theoretically, this study suggests possible causes for why social interaction was reduced and provides in-depth knowledge about the relationships between social interaction, social presence, and social space. The study also provides support for theories of learning that emphasize the need to consider students as active agents rather than merely users of the affordances of a virtual learning environment or guided by the teacher's interventions. It makes a unique contribution to the scarce empirical literature on virtual self-organizing student teams in higher education and provides practical implications for teachers and educational researchers and policy makers.

CRediT author statement

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1. Introduction

Project-based learning, a form of student-centric, collaborative learning whereby students work on projects with real-world problems (Guo et al., 2020; Krajcik & Blumenfeld, 2006), is increasingly becoming a mandatory part of curricula in higher education (Elken et al., 2020). One of the main expected learning outcomes of project-based learning is that students learn to work in and as a team. The delivery of project-based learning courses through online platforms is a growing trend and can provide opportunities for teamwork experiences that differ from those associated with face-to-face courses (Saghafian & O'Neill, 2018) and enable collaboration between students across institutions and national borders (Usher & Barak, 2020). However, the preferred mode for project-based learning has traditionally been face-to-face, with the main argument being that online environments pose considerable challenges for successful teamwork.

At the beginning of 2020, the COVID-19 pandemic brought an abrupt change in this situation by causing all teaching and learning to move to online platforms. What many people believed to be a short-term state of emergency seems to have led to lasting changes in education and work life, with increased use of online teaching and new hybrid collaboration practices (Sjølie & Moe, 2021; Smite et al., 2021). In light of these changes, it is imperative that students learn to work in and as teams in distributed online settings, and that teachers and educational researchers and policymakers understand how online environments enable and constrain student collaboration.

The problems related to online collaboration have largely been traced back to impeded social interaction between team members (Janssen & Kirschner, 2020; Tseng & Yeh, 2013). Social interaction is an essential condition for collaborative learning (Johnson & Johnson, 2009) and is necessary for team members to learn from each other and for personal wellbeing and team performance. However, research has shown that social interaction is more difficult when communication and collaboration take place digitally (Janssen & Kirschner, 2020; Kreijns et al., 2013). Therefore, scholars have begun to focus on how social interaction can be enabled and stimulated in online environments. One line of research has focused on how technology can influence social interaction, such as through the design of sociable learning environments (Kreijns et al., 2013; Weidlich & Bastiaens, 2019) and on evaluating the effect of specific technologies (e.g. Ma et al., 2020; Popescu & Badea, 2020). Others have explored the teacher's role and specific online pedagogies, such as prescribing sequences of collaborative actions (scripts) to scaffold the collaboration process (e.g. Lin, 2020; Splichal et al., 2018).

However, what has been missing in research on online student collaboration is a focus on students as *agents* rather than passive learners who are molded by teachers or technology. There is also a lack of focus on student teams as *self-organizing* teams. One way of understanding the affordances and hindrances of online project-based learning is to identify how student collaboration plays out when students (primarily) organize and lead themselves in interaction with a *variety* of online platforms and tools. This paper reports on a study that investigated the experiences of 1611 graduate students in 315 teams enrolled in an interdisciplinary project-based course during their (forced) transition from face-to-face to online collaboration during the COVID-19 pandemic. The abrupt change comprised a kind of "natural experiment" that enabled us to study how a transition to online collaboration affected social interaction in student teams in a large interdisciplinary population. Using a combination of open-ended survey questions, individual interviews, and written team exam reports, we explored the following research questions: RQ1) How did the transition to online learning affect social interaction in student teams? RQ2) How did teams change their practices to support and sustain social interaction in the online environment? The study makes a unique contribution to the scarce empirical literature on virtual self-organizing student teams in higher education.

2. Conceptual framework

2.1. Social interaction in virtual learning environments

Social interaction is the process of exchanging messages and communicating within a team. It involves both a cognitive and a socio-emotional dimension (Bales, 2001). The cognitive dimension is primarily task related and refers to the acquisition of knowledge and skills, while the socio-emotional dimension refers to the relationships formed within the group and the personal wellbeing of the members. The socio-emotional dimension of social interaction is typically fostered in non-task contexts and is characterized as more casual than task-related interaction (Kreijns et al., 2013). Some researchers understand the socio-emotional dimension as the interaction that is perceived to go beyond what is strictly necessary to achieve an academic goal (Pérez-Mateo & Guitert, 2012). In reality, however, the cognitive and socio-emotional dimensions of social interaction are intertwined. For example, non-task interaction has been shown to be correlated with increased learning outcomes (Abedin et al., 2012), while personal wellbeing has been associated with team performance (Hackman, 1986). Thus, social interaction is essential for team performance, learning, and general wellbeing.

In virtual environments, all social interaction between team members is mediated by computational artifacts (Ludvigsen et al., 2021). These artifacts have affordances that can either enable or disable certain activities and are often part of a larger digital platform, such as a wiki, a learning management system that contains all courses at a university, or a simulation platform that replicates clinical scenarios for medical students. Computational artifacts can be specifically designed to stimulate social interaction between members of a group (Kreijns et al., 2013).

However, virtual environments tend to be designed for productivity, which means that their functionality with regard to social interaction is generally directed toward cognitive processes, while socio-emotional processes have remained largely neglected (Abedin et al., 2011; Balacheff et al., 2009). Recognizing the importance of developing virtual learning environments that nurture the social dimensions of collaboration and facilitate social interaction in both task *and* non-task contexts, researchers have begun to focus on

so-called sociable learning environments.

2.2. Sociable learning environments

Sociability is an attribute of the learning environment as perceived by students. Kreijns et al. (2007) describe it as the extent to which the environment can facilitate the emergence of a sound social space within a group.¹ A sound social space is characterized by strong interpersonal relationships, trust, respect, and a strong sense of community (Kreijns et al., 2013). These qualities form the conditions for the creation of an optimal social context for collaborative learning and team performance (Rourke & Anderson, 2002; Rovai, 2002). A sociable learning environment contains social affordances that may initiate, encourage, and sustain the socio-emotional dimension of social interaction (Weidlich & Bastiaens, 2019). One concrete example of a social affordance in a physical context is the coffee machine, where people meet for informal and spontaneous conversations.

One of the most researched variables that influences the social aspect of virtual learning environments is social presence. *Social presence* refers to the degree to which people experience each other as “real” in mediated communication (Gunawardena & Zittle, 1997). Virtual environments do not offer the same rich social context and opportunities for non-mediated interactions as face-to-face collaboration, which is one of the reasons why online communication is experienced as more impersonal and formal than face-to-face interaction (e.g. Lin, 2020; Pérez-Mateo & Guitert, 2012). Social presence has been identified as a vital factor in many online learning studies and is positively associated with learning outcomes (Hostetter, 2013; Molinillo et al., 2018), trust (Tseng et al., 2019), satisfaction (Richardson et al., 2017), and the maintenance of positive relational dynamics (Remesal & Colomina, 2013). Fostering social presence in a virtual learning environment can be a way of compensating for the loss of the physical context and reproducing the richness of face-to-face meetings.

Building on Kreijns et al.’s (2013) theoretical framework for computer-supported collaborative learning environments, Weidlich and Bastiaens (2017) present the SIPS model for understanding the relationships between the four core variables associated with sociable learning environments: Sociability, social Interaction, social Presence, and social Space. According to this model, the sociability of a system positively influences social interaction, which fosters the emergence of a sound social space, either directly or via social presence. The SIPS model suggests that the more the team members interact with each other and the more they perceive their peers to be “real,” the more they conceive of the learning environment as a sound social space (Weidlich & Bastiaens, 2019).

2.3. Learners’ agency in virtual environments

In line with the SIPS model, research on online student collaboration has generally focused on the interdependence between computational artifacts and social interaction. It has largely been conducted in the context of specific platforms, often evaluating the effect of specific tools or environments on students’ learning or group performance or investigating how students interact with particular built-in affordances (Ludvigsen et al., 2021). What this research fails to consider is the recent acceleration in the development of digital tools and platforms and thus the *variety* of alternatives that student project teams have at their disposal. In addition to universities’ online learning management systems (e.g., Blackboard or tailored systems), options include the many different video conference systems, tools to support creative processes (e.g., digital whiteboards), and social platforms for synchronous and asynchronous communication (e.g., Slack, Teams, Facebook). These different systems and tools come with different affordances and constraints and can be combined and fitted to the particular task at hand by an individual student team.

Another problem with the existing research is the tendency to focus primarily on the role of the teacher, technology, and methods as ways of shaping students’ behavior and learning. Seeing collaboration as *mediated* by technology acknowledges that the result is dependent on what the participants actually do with the computational artifacts. Nevertheless, researchers have been primarily concerned with changing the features of artifacts with the aim of modifying the ways in which students work together (Ludvigsen et al., 2021). Such perspectives on learning contribute to the construction of learners without agency, a criticism that has been directed toward research on learning in higher education in general (see, e.g. Haggis, 2003; Sjølie, 2014). In the current study, as in many other project-based courses, the students operated and organized their work as a team within an extended and unlimited online learning environment that was not restricted to specific technological systems.

2.4. Self-organizing student teams

A self-organizing team is one that is empowered to determine its structure, processes, assessments, and corrections as it performs tasks (Hackman, 1986). These characteristics often apply to student teams in project-based learning, whereby students pursue projects that resemble those pursued by experts in the real world (Krajcik & Blumenfeld, 2006). The teacher’s role is to act as a facilitator rather than an expert, guiding the students and assessing the project outcomes. On the one hand, student project teams are similar to learners in other kinds of collaborative learning activities in that their primary goal is to learn (and be assessed) while working on a problem. On the other hand, student project teams also share characteristics with work life teams. They work with real-life problems, they organize themselves, and their activities are expected to result in some kind of product (Spronken-Smith & Walker, 2010). It may be assumed

¹ In this paper, the terms *group* and *team* are used interchangeably. Although many researchers make a distinction between the two, often building on Katzenbach and Smith’s (1993) definition, the terms are used interchangeably in the literature across disciplines and research contexts. Both terms will therefore be used here, depending on the terminology used in the literature that is referred to.

that they share characteristics with ad hoc project teams in organizations and encounter similar challenges and constraints in developing effective collaboration (Fransen et al., 2013).

One of the main characteristics of a well-functioning (self-organizing) team is that the team members continuously evaluate their work through team reflection (Kneisel, 2020). Team reflection refers to a process of critical discussion and collective examination of team objectives and work processes (Edmondson, 2002; Knipfer et al., 2013). Through regular collective reflections, team members are able to recognize changing environmental conditions, expose the negative consequences of existing practices, and make adjustments aimed at improvement (Edmondson, 1999). In educational contexts, team reflection has a parallel in the concept of *group processing*, which is one of the key principles of collaborative learning. Group processing originates from social interdependence theory and is based on the premise that groups that discuss their interactions and how they might improve them function most effectively (Johnson & Johnson, 2009).

For the student teams in this study, the environmental conditions changed dramatically and suddenly from a physical to a virtual environment. The research questions addressed in this study represent one “passive” and one “active” dimension of social interaction in teams, namely how the new conditions affected social interaction and what measures teams actively took to develop practices that supported and sustained social interaction. The latter question acknowledges the students as learners with agency.

3. Materials and methods

3.1. Context of the study

The study was conducted in conjunction with an interdisciplinary project-based course, Experts in Teams (EiT), at the Norwegian University of Science and Technology (NTNU). The course is mandatory for almost all graduate students at the university. Approximately 3000 students from all faculties are divided into over 100 classes of 30, comprising teams of 5–7 students. The teams work on real-world problems and define their own projects. No specific guidelines are provided on how to distribute team roles and tasks. The teaching staff for each class comprises one faculty member and two learning assistants who have been trained in team facilitation. The students are assessed as a group based on two exam reports, each accounting for 50% of the final grade: one team process report with reflections on situations from their collaboration and one team product report outlining and discussing the project results. One of the main characteristics of the course is its explicit focus on collaboration skills as a learning outcome in its own right. Situations that arise throughout the project life cycle are a key part of the learning process insofar as they are used as a basis for reflection, both orally and in writing. The learning assistants' primary role is to stimulate reflection on situations that occur within the teams throughout the project life cycle by sharing their observations about what happens as it occurs and through structured exercises (e.g., feedback exercises).

In its original form, the course was held each Wednesday throughout the semester, when the student groups met face to face for a full workday, comprising 15 days in total. Attendance was compulsory, and the entire class of 30 sat in the same classroom, with the teaching staff present most of the time. However, in the spring 2020 semester, 1799 students were two-thirds of the way through the course when the university campus was closed due to the COVID-19 pandemic.² Therefore, the final six weeks had to be completed in an online setting. Teaching staff and students had to quickly adapt to a new virtual learning environment with little or no prior training. Apart from a few webinars and crash courses for the teaching staff on how to use Blackboard Collaborate (the university's standard online platform) and how to facilitate teams in a virtual learning environment, students and staff were left to figure out for themselves how to proceed in an online setting. To take advantage of the abrupt change as an opportunity for learning, the teams were encouraged to reflect on how the new situation affected their work and team dynamics and write about this in their process exam report.

3.2. Research design

An explorative multi-methods design was employed, including survey data from 1611 students, 15 individual student interviews, and 21 team process exam reports. In this paper, priority is given to the qualitative data. Fig. 1 presents an overview of the study design. Data collection and analysis were conducted by a research team consisting of the three authors of this paper.

3.2.1. Data collection and preliminary analysis

The survey included questions about the sociability of the virtual learning environment, which digital tools the teams had used, and how they experienced the fully digital version of the course. It was part of a larger course survey that was administered to all students at the end of the semester. The study sample consisted of 1611 students (29.1% women, 63.0% men, 7.9% NA) from eight faculties,³ with a response rate of 89.5%. The question about what tools the team used was posed as a combined multiple-choice/open question, while the inquiry into how the students experienced the fully digital version of the course consisted of two open-ended questions: one about positive experiences and one about negative experiences or challenges. The responses to these questions were short, often comprising only keywords rather than full sentences, but examples were also provided.

The *team sociability scale (TSS)*, developed by Kreijns et al. (2007), was used to measure the perceived sociability of the virtual

² Eight hundred and twenty-six students completed an accelerated version of the course, which they had completed before the pandemic hit.

³ Architecture and Design; Economics and Management; Engineering; Humanities; Information Technology and Electrical Engineering; Medicine and Health Sciences; Natural Sciences; and Social and Educational Sciences.

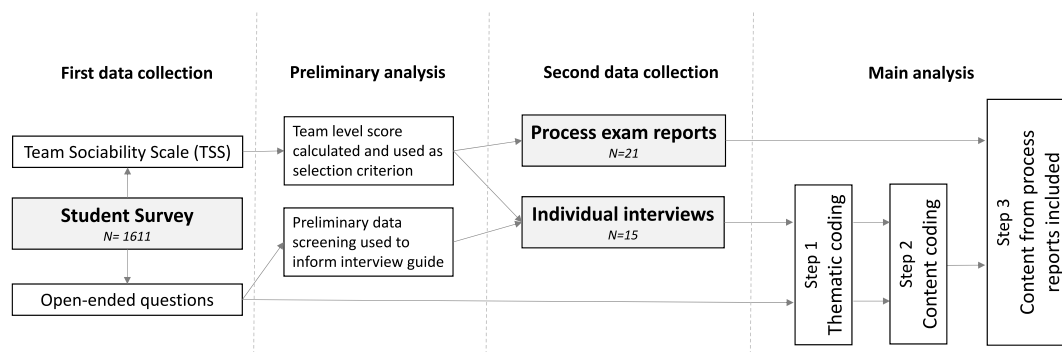


Fig. 1. Overview of data collection and analysis.

learning environment. This is a 10-item instrument with statements about how the learning environment enables the socio-emotional aspects of collaboration (e.g., “This virtual environment allows spontaneous informal conversations”). The validation and more detailed analysis of the instrument are published elsewhere (Sjølie and van Petegem, in press). For the research questions explored in this paper, the scale was used as a selection criterion for subsequent qualitative data collection to secure participants from teams with different scores. First, the team-level score was computed for each of the 315 student teams. The teams were then divided into three groups based on their TSS scores (high, medium, and low). Eight teams from each group were selected, and all students from the selected teams were invited to participate in individual interviews and asked for their consent to use the team’s process report. Preliminary findings from the open-ended survey questions were used to inform the interview guide. Eight weeks after the completion of the course, we conducted 15 semi-structured individual interviews (including students from teams with high, medium, and low TSS scores) and collected process exam reports from 21 teams. The process exam reports were between 20–25 pages long and contained a description of the team and its development throughout the project, reflections on at least three particular situations that occurred during the project (also using team theory), and individual “learning points” for each team member. All interviews were conducted via Zoom and lasted for about 1 h. Interviews were transcribed verbatim and imported into NVivo 20.

3.2.2. Main analysis

The analysis was conducted in three steps, as illustrated in Fig. 1. *In the first step*, the open-ended survey questions and two interviews were coded separately using thematic coding (Saldaña, 2009). For the survey, codes were initially generated using word-counting functions in NVivo, and codes with 10 references or more were used for further screening. All three authors independently analyzed two of the interviews before comparing their results and creating the resulting coding structure. *In the second step*, the thematic coding structure from the survey and the two interviews were merged, and then all interviews were analyzed using conventional qualitative content analysis (Hsieh & Shannon, 2005). The coding structure from the first step was iteratively modified throughout the analysis. *In the third step*, the team process exam reports were analyzed by identifying the parts of the reports concerning the topics that had emerged from the second step. In these excerpts, the teams described how they had worked to support and sustain social interaction in the online environment, largely based on their regular team reflections.

3.3. Ethical considerations

The study follows the ethical guidelines required by the Norwegian National Research Ethics Committees (NESH 2014), and ethical approval was given by the Norwegian Centre for Research Data (NSD). Participants were informed about the study in writing. Consent was collected from all participants via digital surveys. They were informed that they were free to withdraw their consent at any time or for any reason.

4. Findings

4.1. RQ1: how social interaction was affected by the transition to online learning

Table 1 shows the result of the analysis related to RQ1, concerning how the transition to online learning affected social interaction within the teams. The first three columns in the table provide representative examples from the three data sources. The fourth column shows the first-order categories that emerged from the qualitative content analysis. Column five shows the second-order categories, one for each dimension of social interaction. Regarding the presentation of the results, we have chosen not to present the findings using numbers (i.e., comparing the frequencies of the different categories). Although numbers are important and, as some researchers argue, underused in qualitative research (Sandelowski, 2001), presenting numbers in this study, rather than enhancing the descriptions, could be potentially misleading. The responses to the open-ended questions in the survey provided us with an overview of 1611 students’ experiences of the transition to online learning, expressed in relatively few words. The interviews provided us with students’ individual and detailed accounts of *their* understanding of the team’s process. The process reports provided further details on 21 teams’

Table 1
Analysis of RQ1 with resulting categories and extracts from the different data sources.

Representative data survey (individual)	Representative data interviews (individual)	Representative data exam reports (team)	First-order categories	Second-order categories
<p>Positive experiences:</p> <ul style="list-style-type: none"> - More structured discussions - Less irrelevant talk <p>Negative experiences:</p> <ul style="list-style-type: none"> - More difficult - Technical issues - Missing face-to-face body language 	<p>It's that distance It probably has a lot to do with body language and appearance ... If I sit and twiddle my thumbs because I think what you say is unpleasant, you don't see it. But if we had seen each other, we could have adapted our language according to the other's reaction. That emotional register is much easier to read when you sit together. (I17)</p>	<p>Although the group focused on keeping the threshold for contact low, there was still less communication in the group. Another significant change was that communication was exclusively professional, and all group members felt that they lacked human contact in the forms of both eye contact and small talk. The technical limitations were perceived as a major source of frustration for everyone in the group. (P15)</p>	Communication	Socio-emotional dimension "It became less social."
<p>Positive experiences:</p> <ul style="list-style-type: none"> - Easier to take part in the discussion <p>Negative experiences:</p> <ul style="list-style-type: none"> - Less personal - Less social 	<p>[Before online learning], we took turns to bring something for lunch, cake, fruit, or something else. There were also some breaks when we played table tennis or just sat around and talked. All that went up in smoke when we switched to digital. The breaks weren't the same anymore, the low-key social settings. We really just ended up talking about work and the project. (I15)</p>	<p>The biggest change for the whole group, however, was at the interpersonal level, as the atmosphere among us changed completely ... [] ... Gunnar in particular noticed that the humor between us, which we had valued so highly and which had been important for the good flow and atmosphere, disappeared somewhat. We found that it became more difficult to joke and keep the mood up, since we sat in front of our screens in different places. (P5)</p>	Relations	
<p>Positive experiences:</p> <ul style="list-style-type: none"> - Better time management - More focus on the project, fewer discussions that lead nowhere <p>Negative experiences:</p> <ul style="list-style-type: none"> - Reduced productivity - Internet problems and lack of feedback made things difficult 	<p>We just distributed the tasks, and then we each wrote our own part. And eventually, we found that almost the opposite happened, that we became less efficient because we didn't know what the others were doing. You lose focus when you're at home and not at school. (I16)</p>	<p>Another consequence of the digital transition was that we structured the days and the tasks even more than before, and worked mostly with our own tasks ... [] ... We agreed on the tasks in the morning after check-in and summarized what we had done with a brief status update at lunchtime before we worked on to check out around 15.30. Mikkel found this way of working very efficient. At the same time, he, and the group in general found the work along the way to be very lonely for group work. (P15)</p>	Efficiency (increased, decreased)	Cognitive dimension "Splitting the work into individual tasks is more efficient."
<p>Negative experiences:</p> <ul style="list-style-type: none"> - Splitting up work meant less interaction; and less direct collaboration 	<p>It became more difficult to help each other, and as a result, I guess we ended up trying to give each other separated tasks ... We had tasks that could quite easily be solved on our own. (I10)</p>	<p>The major change that happened was first and foremost that we did more individual work. This had a large impact on our work dynamics. We went from primarily working together as a group on tasks to primarily working on individual tasks that we were assigned. (P4)</p>	Collaboration	

collective reflections recorded in a written exam report. Consequently, the data sources are neither amenable to counting nor directly comparable, so we focus instead on presenting the content and the nuances within each category.

4.1.1. The socio-emotional dimension: "it became less social"

Findings related to the socio-emotional dimension of social interaction were primarily within the two categories *Communication* and *Relations*. Communication was the most prevalent topic in the survey and was primarily brought up as a response to the question on negative experiences. The tendency that emerged from all three data sources was that students described the time after the transition to online learning as "less social." The participants used different words to describe what "less social" meant for them and their team. In the survey, the most commonly used expression to describe collaboration online was *less personal*. Participants also reported that the *fun disappeared*. In the interviews and process reports, the students referred to reduced social interaction and ascribed this to the loss of opportunities for small talk, such as eating lunch together, walking or taking the bus home from campus, or interacting in in-between-work spaces. As a result, their conversations became almost exclusively task related. Some talked about this in terms of a sense of belonging or social connectedness, which they reported noticeably worsened after the first few weeks. Others described it as weakened personal relations in the group as a result of talking less about how they were doing. Several of the students in the interviews explained that they were glad they had gotten to know each other and established a solid group structure and trust before they went online. One team described it as follows in the process report:

Working virtually led to a predominance of task-related conversations, and it was simply not the same when we sat alone with a microphone instead of around a table where we could read social signs, keep eye contact, and generally have a much better flow in discussions and conversations. Thomas pointed out that the most fun thing about EiT disappeared, namely the bullshit talk and coffee drinking. Halvard asked for more social sidetracks and joint breaks. (P6)

In addition to the loss of small talk opportunities, the students attributed their collaboration becoming less social largely to the nature of video meetings. The students explained that it was more difficult to achieve the same degree of flow in video conversations as in face-to-face conversations. Lags and connection issues caused more interruptions, which many found to be socially uncomfortable. To compensate for this, the students described how they took measures to structure their interaction by implementing discussion moderators and using raise-hand functions. This made the conversations less dynamic and more formal and thus less social. Some reported that the digital medium acted as a filter in the communication, reducing their ability to see other team members' body language and non-verbal social cues. Consequently, it was more difficult to interpret verbal messages and to read the *entire emotional register*. Some also felt more uncertain about how their messages were received by other team members, as they received less non-verbal feedback. Others reported that the team members seemed *more distant*, and that this reduced the sense of being together as a group.

In addition to the lack of body language and the increased distance, the change in the socio-emotional dimension was also attributed to a higher threshold for spontaneous interaction and talk about non-task topics. This is explained in more detail in this excerpt from one of the process reports:

With the digital transition, we also lost some of the good social dynamics that had been established in the group. As we got to know each other better, we were more open and could make a joke when we were together as a group, but after the transition to online collaboration, the focus was almost exclusively on the project. This worked well for the progress, but it was still a pity to lose the opportunity to get to know each other even better. (P14)

However, the effects of more structured and formalized on-task conversations on team dynamics were not all negative. There were also reports of positive changes regarding group participation. Some students seemed to feel safer with the screen as a filter and therefore participated more in the discussions. In some cases, the structuring of the discussion also led to more democratic conversations, as it allowed for different (and more) voices to be heard. One survey respondent reported feeling that "switching to digital made more people in the group more involved during discussions and collaboration." Another wrote, "It became easier for me to share my own thoughts and views," while a third stated, "Everyone started talking more as it became more natural to take their turn." Furthermore, the reduced time spent on social talk had positive effects on the teams' perceived effectiveness, as evidenced in the above excerpt from the process report. This brings us to the second main finding, which concerned how the transition affected how the teams organized their work.

4.1.2. Cognitive dimension: "splitting the work into individual tasks is more efficient"

Findings concerning the cognitive dimension of social interaction were primarily related to the two categories *Efficiency* and *Collaboration* and to a lesser extent *Communication*. The majority of survey respondents who wrote about efficiency reported that their team became *more efficient* in the online environment (459 respondents versus 68 respondents who claimed to have become less efficient). Efficiency seemed to be used in the meaning that the team was able to reach their common goal (to produce two deliveries for their exam) with the least waste of time and effort. In all three data sources, this increased efficiency was attributed to the fact that the collaboration became much more task oriented. As a result of the obstacles to achieving dynamic conversations in video meetings, the meetings became shorter and more focused on the project, as they used less time on non-task related talk. While this had a negative effect on the socio-emotional dimension, it was perceived to be beneficial for the teams' progress. Being forced to stay on task helped the group move on and work faster. Group discussions and decisions had taken a long time in the face-to-face meetings, and many students reported that they were happy not to have to endure such long discussions. The essence of the findings related to efficiency is captured in the following survey response: "The work became more efficient as people began to work more individually. There was also less talk about irrelevant things." This quotation also relates to the other finding concerning the cognitive dimension of social interaction, namely, reduced collaboration.

To adapt to the new situation, the students reported splitting up into subgroups or working individually rather than together. One of the survey respondents reported, "The group talks less together now. We don't collaborate in the same way but divide the tasks." Many students reported that it was difficult to maintain the same level of collaboration and that it was easier and more efficient to separate tasks. The difficulties regarding collaboration were partly ascribed to communication issues during video meetings but also to a higher threshold for requesting help and talking to other team members between meetings. This is illustrated in the following excerpt from a process report:

For our group, we feel that it [the Covid situation] affected our work and was a hindrance. An immediate experience was that being separated reinforced the problems we had already worked our way through in the past [before lockdown]. Now that all communication took place in a common digital room, it became more difficult to bring up minor issues or ask individuals for help. There was therefore an increasing tendency to dig into one's own work and not to collaborate with each other. (P10)

The analysis revealed that splitting the teamwork into individual work had some adverse effects. One student described how she lost an overall view of the project, as she struggled to keep updated on the others' work. Some students reported that it was more difficult to obtain help and that they were often left alone for too long because it took time to get feedback, which affected the quality of

the project. In the survey, many respondents wrote that it was difficult to know what the others were doing and that it was easier for team members to withdraw or even vanish completely.

4.2. RQ2: changed practices to support and sustain social interaction

The findings related to RQ1 include some examples of how the student teams changed their practices to adapt to the new online situation, such as introducing more structure to the (video) meetings, splitting up into subgroups, and allocating individual tasks. The findings regarding RQ2 yield deeper insights into the active choices the students made to adjust and improve their collaboration from the time of the online transition to the time they submitted their final product for assessment. The findings also include explanations of *why* the changes were made, as the data include content from the team reflections that preceded the changes. Information about these changed practices was obtained from the interviews, the process reports, and the survey question on which digital tools the students had used. All interviews and process reports contained examples of changed practices related to both the cognitive and socio-emotional dimensions of social interaction. A summary of the findings for RQ2 is presented in Table 2.

All the teams considered in our data used a variety of digital tools. However, the particular tools they used varied greatly. Many teams experienced constraints when using the standard system, Blackboard Collaborate. For example, the fact that only five people could be visible on the screen at a time was a considerable constraint on social interaction in teams of six or more. Other reasons for experimenting with different tools were that they served different purposes and needs and that specialized tools served specific needs better than a single general platform (such as Blackboard Collaborate). One of the students interviewed reported using five different

Table 2

A summary of the examples the students provided of how they changed practices to support and sustain social interaction in both the socio-emotional and the cognitive dimension.

Changed practices	What/How	Why
Related to both social-emotional and cognitive dimensions		
Using and experimenting with appropriate digital tools (question in survey)	Experimented with additional digital tools: Messenger, Discord, Facebook, Skype, WhatsApp, Hangout, Zoom, Slack, Facetime, Teams, Whereby, GoToMeeting, Mozilla Hubs, Snapchat, Google apps, Latex, Trello, GitHub, Dropbox Paper.	<ul style="list-style-type: none"> - Overcome challenges with Blackboard Collaborate - Need for different tools for different purposes (e.g., task vs. non-task contexts)
Related to the socio-emotional dimension		
Introducing informal spaces	<ul style="list-style-type: none"> - Quiz, gaming, fun activities - Lunch breaks together 	<ul style="list-style-type: none"> - Compensate for the loss of the many informal small talk opportunities in the physical context - Keep up team cohesion, spirit, fun, and motivation
Negotiating/constructing new explicit group norms	<ul style="list-style-type: none"> - Explicit focus on being positive and showing care for each other - Encouraged informal conversations and verbalizing thoughts and feelings in meetings (e.g., during check-in) - . 	<ul style="list-style-type: none"> - Keep up team cohesion, spirit, fun, and motivation
Related to the cognitive dimension		
Increased use of status updates	<ul style="list-style-type: none"> - Status updates were put on the daily schedule 	<ul style="list-style-type: none"> - Compensate for the loss of in-between and around-the-table talk - Stay updated on each other's work - Increase the level of collaboration and feeling of working as a team
Shift toward more asynchronous collaboration	<ul style="list-style-type: none"> - Detailed plan of when to work together - Changing from synchronous to asynchronous work with deadlines rather than fixed work times 	<ul style="list-style-type: none"> - Higher threshold for contacting others required a more structured plan for communicating and collaborating - Reduced motivation revealed the need for a different strategy
Reverse the splitting up of tasks	<ul style="list-style-type: none"> - Worked in pairs - Swapped tasks 	<ul style="list-style-type: none"> - To increase the level of collaboration and facilitate helping each other - Increase motivation
Communication and video meetings		
More written communication	<ul style="list-style-type: none"> - Wrote decisions and important messages in chat, requiring confirmation of reading from all team members 	<ul style="list-style-type: none"> - To avoid misunderstandings - Compensate for technical problems of some team members
Utilize communication tools and functions	<ul style="list-style-type: none"> - Created multiple communication channels designated to different subtasks - Breakout rooms for subgroups - Raise-hand functions and reaction emoticons - Had an open line for verbal communication while working individually on subtasks 	<ul style="list-style-type: none"> - To promote better team communication - Improve flow and participation in video meetings - Lower threshold for group members to contact each other

platforms for different purposes: project management (Trello), collaborative writing (Google Docs), information sharing (Slack), meetings and work sessions (Discord), and informal meetings and fun activities (MozillaHubs).

Rather than showing similarities between teams, Table 2 illustrates the *different* measures that student teams adopted to support and sustain social interaction in the online environment. Some of the examples show how the teams attempted to reverse the adverse effects of the immediate changes caused by the transition online. In the socio-emotional dimension, these changes were largely aimed at making space for (lost) informal conversations and reinforcing team cohesion and motivation. In the cognitive dimension, changes were mainly aimed at increasing the level of collaboration (which had been reduced after the transition) and included swapping tasks and working in pairs. Other examples of changed practices concerned changing to more appropriate work processes, such as utilizing the affordances of online tools, shifting toward more written communication, and changing from primarily synchronous work with an agreed working time to more asynchronous work with defined deadlines. While it was possible to derive common labels for the measures adopted by the teams (first column in Table 2), what the teams did and why they did it varied greatly (columns two and three).

5. Discussion

This study aimed to explore how the sudden transition from the face-to-face mode to the online mode affected social interaction in self-organizing student project teams and how the teams developed practices to adapt to the new conditions. The study supports research that shows that social interaction, particularly interaction that nurtures the social dimension of teamwork, is more challenging when collaboration takes place online (e.g. Boling et al., 2012; Janssen & Kirschner, 2020). It also shows that the transition had different effects on different teams. Although the study was not set up to measure causal relationships, the findings reveal some possible explanations for the changes that took place in the teams' collaboration after the transition to the online environment.

5.1. Causes of reduced social interaction

The students reported on two main conditions that changed after the transition and that subsequently affected their collaboration: 1) the threshold for contacting (or interrupting) other team members was raised, and 2) communication in video meetings was more challenging than around a table. The general trend was that these two factors influenced social interaction in negative ways, leading to less social interaction, particularly with respect to the socio-emotional dimension of social interaction but also the cognitive dimension.

Regarding the socio-emotional dimension of social interaction, the loss of small talk opportunities and non-task conversations led many teams to experience reduced social connectedness, which might be understood as a weakening of the social space that existed before the transition. The social space also seemed to be weakened by the fact that team members felt more distant and "unreal" in the virtual environment. These results provide supporting evidence for the SIPS model (Weidlich & Bastiaens, 2019), according to which the more team members interact with each other and the more they perceive others to be "real," the stronger their perception of a sound social space. For the students in this study, the spiral went the other way. Less interaction and a reduced sense of social presence led to a weakened social space, which in turn led to even less social interaction. The findings also add explanatory value to the SIPS model by not only describing the *relationships* between social interaction, social presence, and social space but also explaining *why* social interaction was impeded.

The participants reported a reduction in the cognitive dimension of social interaction, namely in relation to task content, with many noting that they collaborated less. Considering that they split up the tasks and worked more independently, individually or in pairs, it can be assumed that this led to reduced interdependence within the teams. While we cannot provide a conclusive account of the consequences this might have had for the student teams or products, it is well established that interdependence is important for learning and team performance (e.g. Alavi & McCormick, 2008; Lazaro et al., 2020). The participants described the need to split up the tasks due to the raised threshold for contacting each other and the communication challenges during video meetings. For the majority of the teams, the immediate effect of less collaboration was *increased* productivity or efficiency. One explanation for this could be that the transaction costs, that is, the effort of communicating as a group and coordinating activities online (Kirschner et al., 2009), were perceived to be greater than the advantages of collaborating as a team. Research on work teams has shown that although it might seem more effective, at least in the short term, to split up tasks, reducing interdependence has negative consequences. Over time, the individual loses track of the larger picture, and there is less discussion and feedback, which makes it more difficult to help each other and weakens the team's understanding of common goals (Moe et al., 2010). However, the effects of reduced interdependence on student teams that work together for a short period of time and with the primary goal of learning or finishing a course cannot be derived from this study.

5.2. Changed practices and student agency

The findings of this study contrast with previous research that supports the equivalency theory of online learning (e.g. Goñi et al., 2020; Ruth et al., 2008). The equivalency theory posits that the more similar the learning experiences of online learners are to those of face-to-face learners, the more similar the educational outcomes will be (Simonson et al., 1999). When the students' collaboration changed to online only, the teams tried to continue working in the way they had when they had worked face to face. However, due to the changed conditions of the learning environment, many teams soon realized that they had to change their practices (see Table 2). Our findings show that online collaborative practices are different from face-to-face practices and that even if many of the same principles apply for teams whether they meet face to face or online, the nature of their experiences and collaborative practices can be

vitaly different (Saghafian & O'Neill, 2018). In other words, when the conditions change, practices need to change (Sjølie, Francisco, Mahon, Kaukko, & Kemmis, 2020).

First and foremost, the findings related to RQ2 highlight the *agency* of the students and the possibilities for an extended and unlimited virtual learning environment. As previously mentioned, the standard platform for the course in this study was Blackboard Collaborate. However, the student teams did not restrict themselves to this platform. The examples in Table 2 show that the teams were able to support social interaction “in spite of” the built-in affordances (cf. Weidlich & Bastiaens, 2019) of the system rather than because of it (e.g., by using Zoom when Blackboard Collaborate showed only five videos on the screen at any time or by creating their own quiz or moving to gaming platforms to make space for informal interaction). Rather than being limited by particular systems or platforms, the students used affordances in an extended online environment and exercised flexibility in finding tools that matched their particular needs.

Finally, we argue that these examples of changed practices provide support for research that emphasizes the need for team reflection or group processing to be an explicit part of course design in collaborative learning (e.g. Johnson & Johnson, 2009; Veine et al., 2020; Sjølie et al., 2021). The students in this study were, as part of the course design, expected (and “forced”) to continuously reflect on situations that arose in the team and on how they worked together. This explicit focus on reflection seems to have enabled many of the teams to become active agents rather than depending on teachers’ interventions and the affordances of the online learning environment. Although the teams experienced similar conditions and challenges, the transition had different effects on different teams (positive in some cases and negative in others), and different solutions suited different teams.

5.3. Limitations and further research

The main limitation of this study is that it was conducted during a global crisis. The sudden involuntary shift from face-to-face to online collaboration in this particular course was just one aspect of the students’ lives that changed. Teaching staff and students had to adapt to new online learning environments almost overnight, with little or no prior training. Whether the findings that emerged from such an extreme situation can be generalized to virtual student teams and project-based learning in a non-pandemic future is open to question. However, the disruption caused by the pandemic provided the opportunity to conduct a kind of natural experiment and study how a transition to online collaboration affected student teams in a large interdisciplinary population. The study thus provides important knowledge about self-organizing student teams.

Another limitation is that we do not have observational data from the teams but instead rely on individual accounts of what happened (interviews) and on exam reports that were part of the course assessment. Nor did we analyze the link between social interaction in the teams and the pedagogical strategies adopted by the teachers. Although the formal structures and tasks were the same across the many classes in the course, it is reasonable to assume that the pedagogical strategies varied between individual teachers, which might have affected social interaction. However, the examples of how the teams took action to change provide insights into what happened, and the qualitative data indicate that collaborating online worked well for some teams but not for others. Further research should include quantitative and qualitative (observational) data under more controlled conditions, such as different variations of online, face-to-face, and hybrid collaboration, as well as different pedagogical strategies.

6. Conclusion and implications

Reporting on the experiences of 315 student project teams, this paper contributes with knowledge on affordances and hindrances of online project-based learning when students (primarily) organize and lead themselves in interaction with a variety of online platforms and tools. As such, it makes a unique contribution to the scarce empirical literature on virtual self-organizing student teams in higher education. The findings support previous research that shows that social interaction that nurtures the social dimension of teamwork is more challenging when collaboration takes place online (e.g. Boling et al., 2012; Janssen & Kirschner, 2020). The study *extends* existing literature by suggesting possible causes for *why* social interaction was reduced after the transition and provides in-depth knowledge about the relationships between the concepts of social interaction, social presence, and social space. Within the context of online student collaboration, these concepts have primarily been studied using quantitative methods. Finally, the findings make a contribution to theories of learning by emphasizing the need to consider students as active agents rather than merely users of the affordances of a virtual learning environment or guided by the teacher’s interventions.

Practical implications of the study include the importance of integrating regular team reflection as an explicit part of course design in project-based courses. Team reflection seemed to enable the students to reverse some of the adverse effects of the transition and develop practices that supported both the cognitive and socio-emotional dimensions of social interaction. The study also points to the advantages of allowing for flexibility in online project-based courses rather than limiting course participants to one particular learning management system or specific tools. The findings show that the teams had very different needs and consequently chose different solutions to fit the challenges and tasks at hand.

There is reason to believe that the current changes in education and work life will accelerate the trend toward delivering project-based courses through online platforms. Although the larger part of this paper addresses the challenges related to virtual collaboration, the findings also highlight the differences between face-to-face and online environments with respect to the challenges and opportunities they present. These differences indicate the need for future research on hybrid versions of project-based learning and course development.

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