



# “Every morning I take two steps to my desk...”: students’ perspectives on distance learning during the COVID-19 pandemic

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## Abstract

During the COVID-19 pandemic, distance learning became the predominant teaching method at most universities, exposing students and teachers alike to novel and unexpected challenges and learning opportunities. Our study is situated in the context of higher physics education at a large Swedish university and adopts a mixed-methods approach to explore how students perceive shifts to distance learning. Quantitative student survey responses comparing distance learning during the pandemic with previous in-person learning are analyzed with k-means cluster analysis and with a random-intercept multilevel linear model. Combined analyses produce a consistent picture of students who report having experienced the greatest challenges. They are on average younger, report being less autonomous in their learning, and find it harder than peers to ask questions to the instructor. They are also less likely to have access to a place where they can study without interruptions. Variation across courses is small with students being largely subjected to the same set of challenges. Qualitative data from semi-structured focus group interviews and open-ended questions supports these findings, provides a deeper understanding of the struggles, and reveals possibilities for future interventions. Students report an overall collapse of structure in their learning that takes place along multiple dimensions. Our findings highlight a fundamental role played by informal peer-to-peer and student-instructor interactions, and by the exchange of what we refer to as “structural information.” We discuss implications for teachers and institutions regarding the possibility of providing support structures, such as study spaces, as well as fostering student autonomy.

**Keywords** Higher education · Physics · Distance learning · COVID-19 · Mixed methods · Vulnerability

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## Introduction

*“(…) At night I take two steps back and go to bed.”*

Distance learning (DL)<sup>1</sup> moves learning from the physical classroom to a technology-moderated space of communication and information exchange. During the COVID-19 pandemic, instruction was moved online with very short notice, presenting teachers and students alike with novel challenges. A growing body of literature explores this shift to DL. The lack of face-to-face interaction with teachers and peers is emphasized as a particularly critical factor in multiple national and disciplinary contexts, such as higher education in Pakistan (Adnan & Anwar, 2020), Germany (Hoss et al., 2021), the USA (Serhan, 2020), and Turkey (Yazgan, 2022), as well as chemistry higher education in the USA (Jeffrey & Bauer, 2020) and physics higher education in Italy (Marzoli et al., 2021). A lack of interaction negatively affected engagement, interest, and motivation of students and even changed students' attitudes towards the subject itself (e.g., Marzoli et al., 2021). Meta-studies highlight the importance of supporting students' social needs and guaranteeing the continuity of education (Bozkurt et al., 2022). As the pandemic has accelerated the trend of making DL more mainstream, teachers and institutions are now presented with the question of which of the enacted changes in education delivery should be kept in non-pandemic times (Sharaievska et al., 2022).

Students display mixed reactions to the shift to DL, with negative attitudes, on average, being more prominent than positive attitudes (Hoss et al., 2021; Sharaievska et al., 2022; Yazgan, 2022). Not all students respond to the transition in the same way, prompting the question on why some groups respond more positively than others (Sharaievska et al., 2022). While student attitudes and perceptions in general have been intensely investigated, Bond et al. (2021) highlight a lack of consideration for marginalized and vulnerable populations. Identifying potentially vulnerable students is therefore crucial to ensure that nobody is left behind. Evidence shows that international students (Whatley & Castiello-Gutiérrez, 2022), black students and students from ethnic minorities (Arday & Jones, 2022; Donham et al., 2022; Lederer et al., 2021), and students with disabilities (Bartz, 2020) are particularly vulnerable. At the level of individual students, several factors have been reported to affect responses to DL, such as autonomy and self-regulation (Broadbent & Poon, 2015; Pintrich, 2004; Zimmerman, 2002). Motivation, self-efficacy, and use of technology are linked to better engagement and increased academic performance (Aguilera-Hermida, 2020). Students who have access to, and higher competence using, computers also display more positive attitudes to DL (Terzi et al., 2021). First-year students have been recognized to struggle with self-regulation, self-organization, and communication skills (Klein et al., 2021). Other studies find that education level and seniority correlate with student attitudes (Malkawi et al., 2021).

With DL being an umbrella term encompassing very different implementations, it is important to attend to which structures, practices, and tools lead to better outcomes for different groups of students. Among the studies that investigate this issue in the context of the pandemic, the difference between synchronous and asynchronous online teaching appears

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<sup>1</sup> We use distance learning as a term encompassing implementations ranging from Emergency Remote Teaching in the first months of the pandemic (Bozkurt et al., 2020; Hodges et al., 2020) to instructional designs for which more preparation time has been available.

to be particularly relevant (Guo, 2020). Synchronous collaborative tools have been found to be common in studies conducted during the first year of the pandemic (Bond et al., 2021). Several studies have argued that teaching methods such as flipped classrooms<sup>2</sup> (Lage et al., 2000) alleviated some of the negative aspects of the shift to DL (Divjak et al., 2022). From a constructivist perspective on learning, instructors shape learning environments, yet students are responsible for their learning (Bransford et al., 2000). Tanner (2013) highlights the importance of providing structure that invites all students to participate in learning and to shape an inclusive classroom environment, providing another angle from which different implementations of DL can be assessed.

In this study, we combine perspectives on affordances and challenges of the shift to DL with a focus on which student groups are particularly vulnerable and which methods students understand to positively affect their experiences. Grounded in the framework of Community of Inquiry (CoI), we employ a mixed-methods approach to build on and reach beyond findings of previous studies. In the context of higher education in Physics and Engineering at a large Swedish university which transitioned to DL in the spring of 2020, we center students' experiences and attitudes and ask:

1. Which specific challenges do students report in the shift to DL?
2. Which student groups are particularly affected by these challenges?
3. Which teaching methods and practices are associated with better outcomes?

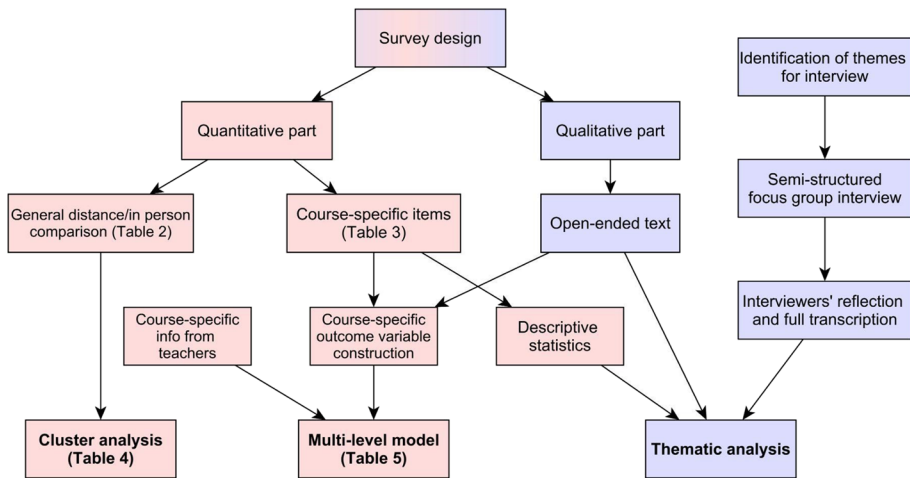
## Theoretical framework

In order to address the complexity of students' DL experiences from multiple perspectives, we draw on the CoI as a robust theoretical foundation (Castellanos-Reyes, 2020; Garrison et al., 2010). The CoI framework recognizes three interconnected elements for higher-order learning: cognitive, teaching, and social presence (Garrison & Arbaugh, 2007; Garrison et al., 2000). Social presence is defined as "the ability of participants in a CoI to project themselves socially and emotionally as real people" (Garrison et al., 2000, 89). It stands in contrast to the potential deficit of social interaction in a DL context and is characterized in terms of "the participants identifying with the community, communicating purposefully in a trusting environment, and developing interpersonal relationships" (Garrison et al., 2010, 7). The positive relationship between CoI presences and self-efficacy, motivation, and student relationships has already been pinpointed in the context of the pandemic (Harrison, 2021; Donham et al., 2022). Scott et al. (2016) also find that students value and engage in online informal learning spaces, showing high levels of social presence, as well as cognitive, learning, and teaching presences. Additionally, Shea & Bidjerano (2010) propose the CoI to be augmented to cover learning presence as an additional pillar, explicitly including and highlighting learners' active role in technology-mediated environments.

While grounded in the CoI framework, we also draw from the broader concept of learning communities, which West & Williams (2017) define along access, relationships, visions, and functions. Feeling part of a community of learners is positively related to engagement, learning, and educational outcomes (Akyol & Garrison, 2011; Arbaugh, 2008). Students' understanding of their learning communities during the pandemic can

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<sup>2</sup> With flipped classrooms, students asynchronously view and prepare material outside of class, while active and collaborative learning is prioritized in synchronous moments.



**Fig. 1** Schematic representation of our research methodology with references to tables in the article

be understood in terms consistent with West and Williams' model, also highlighting the impact of isolation and lack of informal interaction in and beyond the classroom on community creation (Prodggers et al., 2022). Community building has been recognized as a necessary step in addressing vulnerability (Powietrzynska et al., 2021), leading to a call on institutions to play a role in alleviating the social challenges students face (Branchu & Flaureau, 2022).

## Methodology

We adopt a mixed-methods approach (Johnson & Onwuegbuzie, 2016) that combines a quantitative student survey, an open-ended question, a semi-structured focus-group interview, and the collection of course-specific information from instructors (see Fig. 1).

Quantitative and qualitative data are triangulated and contribute equally to addressing the first research question. We draw primarily on quantitative data when answering the second and third questions. In addressing the second research question, we employ cluster analysis (Antonenko et al, 2012; Everitt et al., 2011) as an exploratory analytic tool to divide respondents in homogeneous groups according to their response to the shift to DL. Cluster analysis is a commonly used method to identify hidden patterns, structures, and relationships within a data set, by revealing groups of similar data points (see, e.g., McNally et al., 2017). Addressing the last research question necessitates the collection of course-specific information. Given its multilevel structure (by course and individual student), this data was analyzed using a random-intercept multilevel linear model (Snijders & Bosker, 2012).

## Participants and setting

At the Swedish university's Department of Physics and Astronomy, all teaching was moved online in March 2020, while some in-person teaching (e.g., laboratory work) was resumed consecutively. As Sweden never experienced a strict lockdown, students had access to

campus facilities, albeit with restrictions. Students and teachers were, however, encouraged to work remotely.

Students from all courses offered by the department between the onset of the pandemic and the end of spring 2021 were invited to participate in the survey through emails distributed by course coordinators. The majority of students in our study are enrolled in an Engineering or Physics program, ranging from first-year undergraduate to second-year master level. The survey had 571 individual responses (293 male, 172 female, and three gender non-binary students). 396 students started their undergraduate education at a Swedish university, 71 at non-Swedish universities. Ages ranged from 18 to 69 years (mean = 23.4 years). We excluded responses in which no specific DL course was mentioned or when students referred to courses from outside the department, resulting in 540 participants included. 361 answered the open-ended questions. Of the 540 student answers, 413 could be used for cluster analysis, after removing answers from students who already had answered the survey for another course and incomplete answers. 470 responses were complete enough to be used in the multilevel analysis, for a total of 89 different courses. Among these, specific information could be collected from instructors and cross-referenced for 50 courses. 24 courses were mostly synchronous, 10 mostly asynchronous, and 12 had a mixed format. Among the methods employed, 25 courses involved in-class group work, 16 used flipped classrooms, and nine just-in-time teaching. Less common strategies include think-pair-share and scheduling extra time for students to meet without the teacher.

All students who answered the survey were invited to the focus-group interview. Eight students responded to the call, and we invited six students, ensuring to represent different programs, courses, and genders. Four students (three men, one woman) joined the online semi-structured focus group interview (Longhurst, 2003), which was conducted by two of the authors who were not involved in the students' teaching.

Swedish universities do not have formal requirements on ethical approval for research that does not involve physical interventions on people, human tissues, or the collection and processing of sensitive personal data (as classified by the Swedish law 2003:460 and the General Data Protection Regulation of the European Union, gender and age are considered non-sensitive data). Participants were informed about the purpose of the study, voluntariness of their participation, protection of their identities through anonymization, and processing and storage of the data collected, and provided their informed consent. We use pseudonyms to preserve participants' anonymity.

## Quantitative survey

The quantitative portion of the student survey was divided into three parts. Aside from age, gender, and international-student status, the first part included questions designed to identify the extent to which the respondent reports being able to learn autonomously. Drawing from our theoretical framework, we also included questions aimed to probe the extent to which the respondent relies on social interaction with peers for learning and feels a sense of belonging (cf. Akjol & Garrison, 2011; Arbaugh, 2008; Branchu & Flaureau, 2022; Powietrzynska et al., 2021). Furthermore, students were asked several stand-alone questions (see Table 1).

**Table 1** Selected questions in the first part of the survey. Answers are on a 1–5 Likert Scale

Question	
In general, I find it easy to ask questions to the instructor.	
In the courses I have taken so far at the university level, I mostly get the following grade...	
Autonomy scale	It is easy for me to identify where I need help/additional clarifications. It is easy for me to connect and organize different concepts in my courses. I can learn effectively on my own. In general, it is easy for me to stay motivated throughout a course. In general, it is easy for me to keep on track and meet deadlines.
Social-learner scale	I can learn effectively by working with others. I usually find it easy to interact with other students in class. I feel a sense of belonging in my program. When I do not understand something in a course, I usually ask my peers or the instructor.
I feel the most comfortable in my courses when I can take part without being noticed.	
I had access to a place where I could study without being interrupted.	

**Table 2** Questions in the second part of the survey comparing distance and in-person learning. Answers are on a Likert Scale with “5— this semester [taught on distance]” and “1—in previous semesters [taught in person]”<sup>a</sup>

Question
It was easier to stay motivated...
It was easier to reach my goals...
It was easier to interact with other students in my courses...
I have learned more...
It was easier to stay up to date on course information...

<sup>a</sup>See McNally et al. (2017) for use of similar Likert Scales

The second part of the survey compares students’ perception of DL to their previous experience with in-person teaching without reference to a specific course (see Table 2). This comparison is similar to the one in McNally et al. (2017), where flipped classrooms were compared to regular teaching. These questions are designed to explore various aspects of learning and are analyzed with k-means cluster analysis,<sup>3</sup> assuming the students could be grouped into two or more clusters based on how they rate their experience with DL, and using the silhouette method to assess the number of clusters that best describes the data. Answers to the first part of the survey are then compared using the Welch’s *t* test to identify differences between clusters.<sup>4</sup> We note that cluster analysis has already been employed to

<sup>3</sup> k-means clustering is a commonly used algorithm in unsupervised machine learning to partition a given data set into *k* groups. Each cluster is represented by its center, determined by the mean of the points assigned to the cluster.

<sup>4</sup> It is debated whether parametric methods like k-means clustering and the Welch’s *t* test could be applied to Likert data, which is generally considered to be ordinal. A common approach is to consider individual Likert items with few points as ordinal and items with many points, or scales consisting of several items, as interval data (Wu & Leung, 2017). To account for this, a non-parametric approach, using K-modes clustering and the Mann-Whitney *U* test, is reported in the supplemental material. These results agree with the parametric analysis.

**Table 3** Selected questions in the third part of the survey. Answers are on a scale with “5 in the DL course” and “1 in previous courses taught in person”

Question	
Outcome scale	<ol style="list-style-type: none"> <li>1. I could better interact with the instructor...</li> <li>2. I felt I had more autonomy and control over my learning...</li> <li>3. I needed more help managing my time ...</li> <li>4. I found it more difficult to stay motivated...</li> <li>5. I felt more comfortable asking questions...</li> <li>6. I could better interact with other students...</li> <li>7. I achieved a better understanding of the course content...</li> </ol>
	8. I spent more time on finding information that I needed for my learning...

divide students in different groups based on their response to the shift to DL (Biber et al., 2021; Toumpalidou & Konstantoulaki, 2023).

In the third part of the survey, students were asked to identify and refer to a specific course taught with DL. They were asked to compare 12 different aspects of their learning experience with previous courses they had taken in person. Based on the open-ended answers, eight of the 12 items were selected as corresponding to major factors affecting the shift to DL (see Table 3). Among these, items 1–7 were grouped to construct a course-specific outcome variable, while item 8 was treated separately, since it correlated weakly with the others. Information about specific courses was cross-referenced with a teacher survey and also complemented with information taken from the courses’ websites regarding enrollment and presence of specific instruction methods. Given its multilevel structure, this data was analyzed using a random-intercept multilevel linear model. The possibility of cross checking level-one variables in the multilevel model with the results of cluster analysis was designed to provide a robustness test on the identification of individual student factors affecting responses to DL.

### Open-ended question and focus group interview

In the survey, students are asked in an open-ended question to name three major factors that affected their learning in comparison with previous semesters and to explain how. Answers were analyzed using thematic analysis (Braun & Clarke, 2006), identifying the most common themes and whether they were referred to positively, negatively, or neutrally. The coding was done by two of the authors independently at first and re-coded after agreeing on a common set of themes.

The semi-structured focus-group interview (Longhurst, 2003) was structured along: learning; students’ autonomy; role of peer interactions; teachers’ role and interactions<sup>5</sup>; and structure and clarity (the interview schedule is in the supplemental material). We, for instance, asked students what kind of teaching they experienced with DL and how it was different from experiences before the pandemic and posed follow-up questions expanding on given answers and to ensure comprehension. Particular attention was paid to equal distribution of speaking time and the opportunity for all participants to contribute. The interview was conducted in English. After closing the interview, the two interviewers reflected

<sup>5</sup> In our study, “teacher” and “instructor” are used to indicate university teachers at all levels, including professors, lecturers, and researchers with instructional responsibilities.

together on what they considered the main themes as inspired by reflexive ethnography (Davies, 2008). Interview recordings were transcribed using AI-based transcription software and revised and anonymized by one of the interviewers. All research-group members conducted a thematic analysis on the interview transcript (Braun & Clarke, 2006), and themes were iteratively discussed in the research group.

Following the iterative process on the focus group data, we jointly analyzed the open-ended question and the focus group transcript applying preliminary themes and refining them into seven final themes. These themes were furthermore triangulated with the quantitative data, identifying Likert questions in the survey that are relevant for each theme and using descriptive statistics (see the supplemental material).

## Results

This section merges responses from the open-ended survey question and the focus group interview and presents results from the quantitative part of the survey. We triangulate the qualitative analysis with quantitative findings, identifying complex relationships between the various themes. More information about the students can be found in the supplemental material.

### The collapse of structure

We describe seven intertwined themes: interaction with other students, interaction with the teacher, environment, autonomy, collecting and sharing information, motivation, and understanding the content. While these themes can stand for themselves, they are all strongly interwoven with one another and, as we will show, tied together by one identifier, a *collapse of structure*. This sentiment becomes visible in Magnus' title quote:

Every morning I take two steps from my bed to my desk, and sit down at my computer. At night, I take two steps back and go to bed. Time no longer has meaning. I have not met anyone my age in forever. Everything is gray. (...) I don't feel like I have study time and I don't feel like I have free time. I only feel like I have time. (Magnus)

In the following, we will map out the different themes, how themes are intertwined with each other, and how they contribute to the collapse of structure.

### Interaction with other students

A prominent theme is the social presence of peers. This includes formal and spontaneous conversations and interactions. Students describe that interactions with other students became more difficult, which made it harder to have group discussions and ask for and receive help.

Cecilia misses to “discuss with the others in the same course” and states that everyone is “so, yeah, all over, all over the country”. Johan feels isolated, too. He shares, “It was hard to chat with other students. I got the feeling that I was the only one thinking the material was difficult, and thus I dared not ask questions.” At the same time, other students mentioned positive effects of investing less energy into social interactions. Esben shows the multidimensionality of social presence and describes strategies to compensate for the lack of interactions with other students in DL,



I mean, the social part is really important. And we had a lot of isolation in the beginning, I would say, in my class. So we actively started studying together (...) and just having each other on (...) speaker, not even doing the same assignments, just having someone there. You can hear the person breathing. You know, if there is a question, you just say it out there to the room, basically, but you get the answer at least. (Esben)

## Interaction with teachers

Similarly to interactions with other students, having interactions and conversations with instructors is perceived as more difficult. This includes the formal dimension of, e.g., asking questions during class, but also having informal conversations.

Our findings indicate that students used to rely on diverse structures created through the presence of teachers. Aside from formal discussions of content and guidance from the teacher(s), informal conversations about course material also supported students in their learning. Kajsa states that, in DL, there were no spontaneous interactions with instructors, “It is almost impossible to make small-talk during for example breaks with instructors about the subjects discussed in class, especially when you do not have an explicit question about a certain concept but might need some help organizing your thoughts.”

Tom highlights that he feels disconnected from both peers and the instructors and that interactions in a DL setting might be more important than with in-person teaching. He shares, “I think that’s really important to bear in mind in such a transition that teachers need to be as present, if not even more present.” He connects a lack of presence and interactions to a lack of guidance:

And I mean, I have almost, if not daily, at least weekly contact with my teacher. But I think far from everyone has that. I’ve sort of stopped having any social contact with anyone in that class. And so I think that’s not a very helpful resource from a teacher just giving out notes. Then you could just read a book by yourself. I mean, the point of having a teacher is to be sort of a guidance to guide you as a group through something. (Tom)

Students remark on the lack of informal interactions in which they can ask questions. In the words of one student (Karl): “generally I would like to have a talk with [the] lecturer and clarify some bigger or more fundamental questions after lecture, but with DL, it’s more difficult to do so.”

## Environment

The impact of the environment on the students is twofold. Firstly, a lack of change in the environment made it harder for students to focus, as learning spaces and life merged into one. Secondly, students reported that they did not have access to study spaces that allowed for uninterrupted and focused study time.

Similarly to Magnus, who provided the quote used in our title, Maja describes that, “It is hard to stay focused when you are not in an environment where you are supposed to learn. I study, eat, entertain myself and relax at the same desk in my 19 sqm room.” While that shows the difficulty of separating learning and studying spaces, Gustav shares that it was hard to find spaces in which he “didn’t get interrupted”. Esben not only describes those challenges, but also that they lead to being frustrated “due to a lot of distractions around in your own apartment.”

A significant part (14.9%) of the survey respondents report to not have access to good study spaces, while 15.5% takes a neutral stance. Access to good study spaces is one of the strongest quantitative predictors of the difficulty experienced in the shift to DL. A lack of physical structures, learning spaces, and life spaces merging negatively impacted students' focus, motivation, and perceived learning success.

### Autonomy

Another theme was grappling with autonomy, especially in relation to time management and study structure. While increased autonomy in combination with access to low-distraction study spaces provided *some* students with more time to study, *many* struggled with increased autonomy and a lack of structure when managing their time and information.

While Lovisa, as a 6th year student, has developed skills to work independently, she also highlights the ambiguity of increased autonomy in relation to spaces. She shares,

Not having to leave the house to study and attend classes was both good and bad. The lines between free time and studies were very blurred, which has made it a little difficult to take time to rest, but I somehow also feel a lot less stressed out. Taking exams at home, in a safe and comfortable space also helped with stress. (Lovisa)

Peter describes how perception on time is different because of a lack of structure and time management. He says,

I mean, like I don't feel like I have time, that it's like study time and I don't feel I have free time. I only have, like, *time* and since all the lectures are recorded, if I don't feel like taking a lecture now, I take it later. And that's like, it gets more stressful, you know. To always have that availability to stop it and demand it. (Peter)

### Collecting and sharing information

A fifth theme caught our attention. Students reported that more course information and material was available to them, and though helpful, it required structure both from the instructors' and from the students' side to make efficient use of the information. In analyzing student responses, we find it useful to differentiate between course content, and what we call "structural information," namely information about, e.g., deadlines and material, which in a DL setting is less readily available. Erik shares,

While studying on campus, I did not plan very much and simply went with the flow. Most [teachers] reminded us of important hand-ins and when documents have been updated on Studentportalen.<sup>6</sup> When not, there were always some people in class who kept up with work, sometimes me, sometimes others. Together we made sure everyone was on track with what was due. This disappeared entirely while studying [remotely]. (Erik)

It is here this theme strongly intersects with the social aspect of learning and teaching in person. Esben makes this entanglement more explicit and reflects, "you meet people and

<sup>6</sup> The learning management system.

you talk and you plan your work. And if you have missed something, then you'll hear about it (...). So everyone is each other's social net and also like study net." He continues,

But now you have to keep track of everything yourself. So I find that I start my day by going into Studentportalen and see what's new and if something has been updated, there have been cases where a lot of documents have been updated where we haven't done the information about it. You have to check that your documents are up to date. You know, there's so much energy going into planning and (...) how to study. And so less time is actually going into studying. (Esbén)

In the words of Selma, it was

harder to know if you are keeping up okay with the course, since you don't daily interact with other students and talk about the courses. Some parts were barely mentioned but seemed essential on the exams. This was partly due to lack of information and important information embedded in otherwise useless information. (Selma)

The inability to differentiate between important and accessory information can be interpreted as another manifestation of the overarching loss of structure.

## Motivation

While often shared implicitly, struggling with decreased motivation was mentioned explicitly by multiple students. Rebecka feels understimulated and shares that it is hard to keep both one's mood and one's motivation up when not being able to interact with peers in the same room. She continues, "You feel very lonely sometimes and bored because not much happens." Sven mentions, "My motivation was lacking because of all distractions, otherwise pretty much the same." While distractions and loneliness were mentioned as causing a lack of motivation, Anders describes that the lack of motivation is also caused by a general feeling of disconnectedness from learning spaces and practices, "In a rational sense it's obvious that I'm studying, but unconsciously it feels like I am on study leave. Imagine that you go to the Bahamas for a sun bathing trip and then a colleague sends you some emails of things they want you to do."

## Understanding content

In line with the sentiment of a lack of structure, with spaces and practices merging into one, causing disconnectedness and a lack of motivation, students also highlighted how that sentiment leads to difficulties understanding the content. Edvin shares, "Now I frequently forget things even though I studied it a lot; it sort of just becomes part of everything else that is exactly the same as everything else." Similarly, Klas reflects on how disconnectedness and loneliness made it difficult to understand content. He writes, "Also the loneliness from not meeting other students and study with them made it harder to understand everything."

The interconnection between cognitive and social presence is illustrated by Louise, who highlights,

Not having the same opportunity to talk to my classmates about course work or other matters made me think of my work more narrowly. I spent more time memorizing rather than thinking of the coursework more deeply. (Louise)

**Table 4** Analysis of clustered data for selected questions. \*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ 

	Less affected		More affected	
	Mean	STD	Mean	STD
Age***	24.1	4.9	22.3	2.6
In general, I find it easy to ask questions to the instructor.**	3.3	1.2	3.0	1.1
I feel the most comfortable in my courses when I can take part without being noticed.***	3.6	1.1	3.2	1.2
I had access to a place where I could study without being interrupted.***	4.36	0.95	3.7	1.3
I received the support I needed for my learning.***	3.79	0.98	2.9	1.1
Autonomy scale***	3.84	0.67	3.42	0.72
Social-learner scale	3.61	0.84	3.71	0.85

### Cluster analysis and multilevel models

A silhouette analysis suggests that two clusters best represent responses to questions in Table 2 (see the supplemental material). These contain 238 and 175 data points and are dubbed “more affected” and “less affected” students, respectively. Students in the two clusters differ with respect to some of the factors probed in the first part of the survey, as displayed in Table 4. Cronbach’s alphas for the social and autonomy scales were 0.73 and 0.77, respectively.

Random-intercepts models were used to fit an outcome variable<sup>7</sup> constructed from responses to questions in Table 3 using the residual maximum likelihood method. These models are presented in Table 5. Model 1 only includes student-level explanatory variables. Model 2 also includes course-level variables.

**Students experiencing the largest challenges** Students in the more affected cluster, as well as students with a lower value of the outcome variable for the multilevel models, score lower on the autonomy scale, are younger in age, find it generally more difficult to ask questions to the instructor, and are less likely to report that they feel more comfortable taking part in the courses without being seen and that they have access to a place where they can study without interruptions. We do not observe any significant difference regarding previous experience with DL, time from the beginning of the pandemic, gender, or international-student status. Notably, we observe a negative correlation between the outcome variable and both average reported grade and social-learner scale in the multilevel models, but not in the cluster analysis.

**Variation across courses and choice of methods** Intraclass correlation coefficients give an estimate of the ratio between inter- and intracourse variance of the outcome variable and take remarkably small values (0.035 and 0.047 for the two models). Model 2 allows

<sup>7</sup> The outcome variable is constructed combining questions 1–7 in Table 3. While answers to these questions correlate strongly, with correlation coefficients ranging between 0.29 and 0.63 and Cronbach’s alpha=0.84, time spent looking for information correlates weakly only with some of the other questions, indicating that all students have on average spent more time regardless of other factors. For this reason, question 8 is not included in the outcome variable.

**Table 5** Details on the multilevel random-intercept models employed. The models explain respectively 29% and 33% of the total variance. \*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ 

	Model 1 Estimate (STD)	Model 2 Estimate (STD)
Fixed effects		
(Intercept)	0.79 (0.39)*	0.75 (0.60)
<i>Level 1 (student)</i>		
Age	0.0252 (0.0076)***	0.0253 (0.0091)**
Gender	−0.021 (0.067)	−0.073 (0.080)
International student	0.177 (0.096)	0.15 (0.13)
Reported average grade	−0.297 (0.065)***	−0.387 (0.078)***
Autonomy scale	0.285 (0.058)***	0.348 (0.070)***
Social-learner scale	−0.122 (0.042)**	−0.158 (0.049)**
Place to study	0.164 (0.028)***	0.157 (0.034)***
Prefers not being seen	0.145 (0.029)***	0.141 (0.034)***
Easy to ask questions to the instructor	0.133 (0.028)***	0.153 (0.033)***
<i>Level 2 (course)</i>		
Size of the course (enrollment)		−0.00086 (0.00092)
Semester		−0.033 (0.037)
Synchronous/asynchronous		−0.020 (0.064)
DL courses previously taught by teacher		0.028 (0.036)
Access to equipment needed		0.112 (0.050)*
Group work		0.10 (0.11)
Flipped classrooms		0.32 (0.13)*
Just-in-time teaching		−0.07 (0.14)
Random effects		
(Intercept)	0.0307	0.0345
Residual	0.4390	0.4199
<i>N</i>	470	331

us to probe course-specific factors and methods and address our research question 3. Aside from the aforementioned factors at level one, we observe positive effects from reported use of the flipped-classrooms method and from the instructors reporting having access to the equipment needed. Conversely, size of the course, asynchronous or synchronous lecturing, time elapsed since the beginning of the pandemic, and pedagogical methods used (with the exception of flipped classrooms) do not bear any statistically significant effect on the outcome variable.<sup>8</sup>

<sup>8</sup> A Jarque Bera test was conducted to confirm that the residuals are normally distributed. Homogeneity of variance was also confirmed with Levene's test. See the supplemental material for additional checks.

## Discussion and implications

This study explores students' reactions to the shift to DL in courses offered by the Physics and Astronomy department at a major Swedish university in the first year of the COVID-19 pandemic. While individual courses presented a significant variation regarding, e.g., number of students, level, synchronous and asynchronous moments, and pedagogical methods employed, students report a consistent and common set of challenges, and we find that what instructors did at the level of individual courses had a comparatively small impact. The themes we identified in the thematic analysis are all connected by the common thread of the *collapse of structure*, especially of structure that we propose to have been taken for granted in pre-pandemic times. This collapse has multiple dimensions. The sudden reduction of peer and instructor interactions can be seen as an erosion of the social-presence pillar in a CoI (Garrison et al., 2010), affecting students emotionally and intellectually, leading to feeling disconnected. Students are no longer able to use their interactions with peers to shape their learning, contributing to the collapse of the other CoI pillars. The physical environment, with a blurred separation between study and private spaces, as well as study and leisure times, provides another dimension. A third dimension is related to the loss of ability to differentiate between important and non-essential course material and information.

Given these results, we should ask: How is structure created? A first answer could focus on externally provided structure from the instructor, traditionally associated with the teaching-presence CoI pillar. In the focus group, students argued that more structure, and even more mandatory hand-in exercises, would help them. They also asked for more informal teaching moments in which they can meet the teacher and ask questions. In the quantitative data, we see that a reported use of flipped classrooms is correlated with better outcomes, which can be explained by the attempt of regulating and providing structured activities outside the classroom. Simultaneously, students themselves contribute to shaping and structuring their learning, in ways that appear to have been taken for granted before the shift to distance learning. To disentangle these mechanisms of structure creation, we differentiate between course content and meta-level information dubbed “structural information”. While this is seen through the lenses of the CoI framework as a manifestation of the social presence pillar, the role of information exchanges here assumes a dimension that was not previously recognized: students draw an explicit connection between lack of informal face-to-face interaction and increased difficulties accessing structural information. This is also in line with observations in the literature that students found it harder to understand expectations and standards of work due to lack of a social network during the period of DL (e.g., Elmer et al., 2020; Neuwirth et al., 2020; Warfvinge et al., 2022). Non-content language used by instructors in classrooms has recently been recognized as a key for better understanding classroom dynamics (e.g., Harrison et al., 2019; Seidel et al., 2015). Here, we argue that such language plays an equally important role in student–student interaction. Structural information also plays a role in functional cohesion of a learning community as defined by West & Williams (2017).

We can see that some students coped better with the DL conditions. In fact, the comparatively small variation in outcome observed across courses has its counterpart in a large variation at the level of individuals. Tanner (2013) highlights the diversity of students' needs and the importance for structuring the classroom in a way that fosters engagement and inclusivity. This observation can be used to draw a direct line between the observed collapse of structure and the vulnerability of some groups of students. We find that the

students who are most vulnerable in the transition to DL are the ones who are most dependent on the externally provided structure. They, on average, are younger, score lower on our measure of student autonomy, report finding it more difficult to ask questions to the instructor, and are less likely to have access to a suitable place to study. Age may correlate with increased experience studying in a higher education setting, while our measure of student autonomy, as well as ease interacting with the instructor, may also have a mitigating effect on the collapse of structure we have observed.

**Limitations** There are factors that may affect response to DL we did not investigate in our study. Most prominently, the students' ethnic background, as well as (dis)ability, and socioeconomic status were not included in the questionnaire. The literature has already identified students from underrepresented groups (Arday & Jones, 2022; Donham et al., 2022; Lederer et al., 2021) and students with disabilities (Bartz, 2020) as particularly vulnerable groups. Our finding that availability of appropriate study spaces strongly correlates with better outcomes indirectly highlights how students with lower socioeconomic status might have experienced particular challenges. We regard not including a more detailed and intersectional perspective as one of the main limitations of our study. In addition, recruitment of study participants might implicitly overrepresent the perspectives of students more adapted to a DL setting since the survey and focus group were both conducted online. Several questions were based on students' self-reporting and recollection, for example concerning their understanding of the material. The identification of courses using flipped classrooms was based on teachers' self-reporting.

**Implications for teachers and institutions** Our results suggest that teachers developing DL implementations should address the increased need for structure, as well as facilitate information exchanges among students. While flipped classrooms appear to be correlated with better outcomes, we interpret this as a result of a method aiming to regulate and structure students' activities outside of the classroom. Some students also report favorably on a course offering spaces in which students can interact informally. However, the small value of the intraclass correlation highlights that what happened outside of the virtual classrooms has been as important as what happened inside, if not more. Aside from factors linked to individual students, we need to recognize the fundamental role played by institutions in responding to the shift to DL. The identification of vulnerable students can play a role in informing and directing the action of universities faced with similar challenges in the future, as well as more conventional implementations of DL. For example, universities may wish to prioritize options for in-person learning, if these are available, for academically younger students. Student autonomy emerges as one of the fundamental factors that determine the adjustment to DL. Universities should take measures to support students in developing robust study techniques, for example by offering courses on learning methods. The study has emphasized that the lack of a proper physical study environment affects many students, in agreement with similar results (Neuwirth et al., 2020). It is therefore essential that support structures such as study spaces are offered. We suggest that institutions invest resources in, and pay particular attention to, providing students with sufficient virtual and physical spaces for informal interaction to further enhance their sense of community (Branchu & Flaureau, 2022). This is in line with the reconceptualization of the notion of vulnerability proposed by work that argues to adopt a relational view of vulnerability rather than insisting on individual features and dispositions (e.g., Jackson, 2018). Instead of advocating for giving more resources to individuals, Jackson (2018) proposes to address

the problem on a structural level, e.g., by building trust and communication with students. It is also essential to promote acceptance of vulnerabilities and cultivation of resilience (Powietrzynska et al., 2021).

**Implications for theory** Our study can be understood as a setting in which the CoI social-presence pillar is drastically reduced. The fact that our measure of student autonomy is associated with better outcomes favors variations of the CoI that incorporate a fourth pillar for learning presence, such as the one suggested by Shea & Bidjerano (2010). Our findings can be understood in the context of the CoI framework, where the overarching collapse of structure has its counterpart in a deterioration of all three pillars. Mechanisms for structure creation and, in particular, the pivotal role played by structural-information exchanges among students did not receive adequate attention in the past and have the potential to add further nuance both to the social presence and teaching presence categories. Some authors have already observed that student–student communication is characterized by a high level of teaching presence (Scott et al., 2016), while our results indicate a deterioration of the teacher’s own *social* presence. Interestingly, this blurs the lines between CoI pillars, enlarging the importance of the *learning presence*. Ultimately, further investigation is warranted on the mechanisms underlying structural information exchanges.

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## Declarations

**Competing interests** The authors declare no competing interests.

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