

“EVERY MORNING I TAKE TWO STEPS TO MY DESK...”: STUDENTS’ PERSPECTIVES ON DISTANCE LEARNING DURING THE COVID-19 PANDEMIC

Supplemental material

A ADDITIONAL INFORMATION ON CLUSTER ANALYSIS

A.1 Silhouette scores

The k-means clustering was repeated four times, using two, three, four and five clusters respectively. For each case the average silhouette score was calculated and a maximum score of 0.37 was obtained using two clusters. A cluster score of one indicates a dense, well separated cluster, while a score close to zero represents overlapping clusters with many data points on the boundary. A datapoint with a negative score indicates that that point might have been wrongly assigned. Figure 1 shows the silhouette plots for different numbers of clusters.

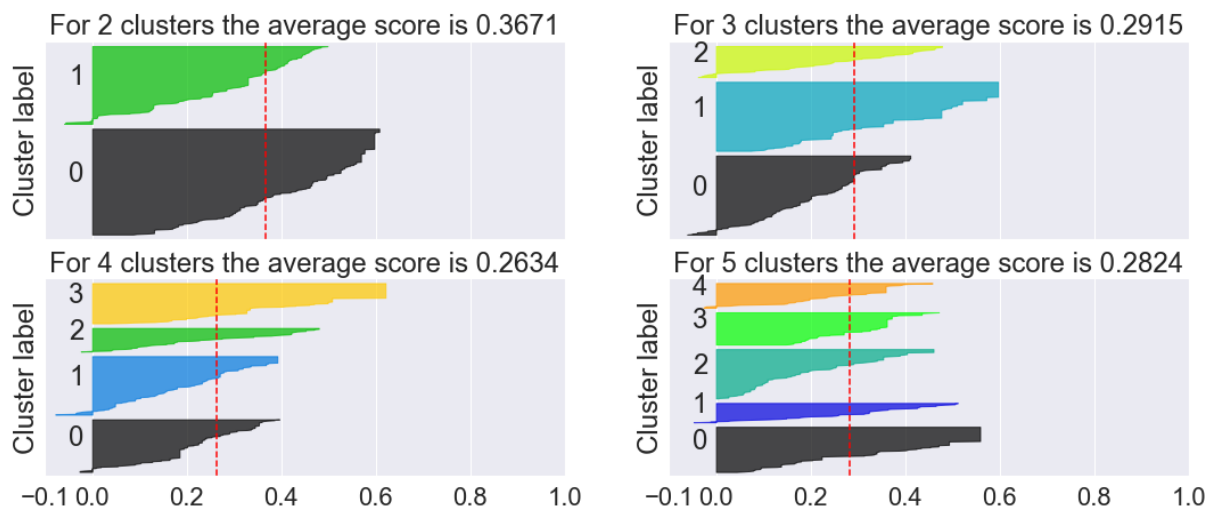


Figure 1: Silhouette plots with scores. The highest score is obtained using two clusters.

A.2 Full cluster analysis results

The result of the cluster analysis for all questions in the survey, as well as the two scales, are presented in Table 1.

	Less affected		More affected		p-value
	mean	std	mean	std	
Age	24.1	4.9	22.3	2.6	2.1E-05 ***
Total number of years studied at a university	3.5	2.8	2.5	1.5	2.47E-05 ***
I started my bachelor education at a Swedish university.	1.17	0.37	1.11	0.31	8.0E-02

Previous experience of DL	2.4	1.1	2.3	1.1	8.0E-01
Gender	1.65	0.48	1.63	0.48	8.1E-01
Semester from beginning of pandemic	3.0	1.5	2.8	1.5	2.2E-01
In general, I find it easy to ask questions to the instructor.	3.3	1.2	3.0	1.1	7.0E-03 **
In the courses I have taken so far at the university level, I mostly get the following grades.	4.01	0.56	4.07	0.58	3.0E-01
I am usually confident that I will do well in my courses.	3.55	0.97	3.57	0.97	8.6E-01
I feel the most comfortable in my courses when I can take part without being noticed.	3.6	1.1	3.2	1.2	5.6E-04 ***
I had access to a place where I could study without being interrupted.	4.36	0.95	3.73	1.25	1.1E-08 ***
I received the support I needed for my learning.	3.79	0.98	2.89	1.09	4.5E-17 ***
Autonomy scale	3.84	0.67	3.42	0.72	2.1E-09 ***
Social-learner scale	3.61	0.84	3.72	0.86	1.9E-01

Table 1: Result of clustered data for all questions and scales using k-means clustering and Welch's t-test. ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

A.3 Non-parametric comparison of clustered data

For ordinal data, like single Likert items, non-parametric tests like the Mann–Whitney U-test is preferred. This test is based on the median, rather than the mean and standard deviation. However, Likert scales, based on several items, are usually assumed to be interval data for which a standard t-test is best used.

If the Welch's t-test is replaced by the non-parametric Mann–Whitney U-test, all observed statistically-significant differences remain. The results are summarized in Table 2.

A.4 Alternative clustering algorithm

K-means clustering is based on the principle of assigning each datapoint to the cluster with the nearest (shortest euclidean distance) cluster center, where the cluster center is determined as the mean for all data points in the respective cluster. It is debated whether single Likert items should be considered to be ordinal or interval data. If an intervalist approach is adopted, K-means clustering can be used. However, if the data is considered only to be ordinal, the cluster mean is not well defined and other approaches might be more applicable.

	Less affected	More affected	p-value
	median	median	
Age	23	22	2.6E-04 ***
Total number of years studied at a university	3	2	7.4E-04 ***

I started my bachelor education at a Swedish university.	1	1	7.1E-02
Previous experience of DL	2	2	8.0E-01
Gender	2	2	8.1E-01
Semester from beginning of pandemic	3	3	2.0E-01
In general, I find it easy to ask questions to the instructor.	3	3	6.4E-03 **
In the courses I have taken so far at the university level, I mostly get the following grades.	4	4	2.8E-01
I am usually confident that I will do well in my courses.	4	4	8.5E-01
I feel the most comfortable in my courses when I can take part without being noticed.	4	3	5.8E-04 ***
I had access to a place where I could study without being interrupted.	5	4	6.5E-08 ***
I received the support I needed for my learning.	4	3	1.7E-15 ***
Autonomy scale	4.0	3.4	1.4E-09 ***
Social-learner scale	3.8	3.8	1.6E-01

Table 2: Result of clustered data for all questions and scales using K-means clustering and the non-parametric Mann–Whitney U-test. ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

A non-parametric alternative to K-means which does not assume interval data is K-modes clustering. In fact, K-modes does not even assume an ordinal structure and is therefore mainly used with categorical data. It defines the cluster center using the mode and calculates the distance between the center and each data point using the Hamming metric. Repeating the analysis using K-modes clustering results in the same items being significantly different as with K-means, with only slightly lower significance. The result using K-modes clustering and the non-parametric Mann–Whitney U-test is presented in Table 3.

	Less affected median	More affected median	p-value
Age	22	22	8.9E-03 **
Total number of years studied at a university	2.5	2	4.8E-03 **
I started my bachelor education at a Swedish university.	1	1	2.0E-01
Previous experience of DL	2	2	4.0E-01
Gender	2	2	8.0E-01
Semester from beginning of pandemic	3	3	7.6E-01
In general, I find it easy to ask questions to the instructor.	3	3	1.2E-02 *
In the courses I have taken so far at the university level, I mostly get	4	4	3.9E-01

the following grades.

I am usually confident that I will do well in my courses.	4	4	6.2E-01
I feel the most comfortable in my courses when I can take part without being noticed.	4	3	6.9E-04 ***
I had access to a place where I could study without being interrupted.	5	4	2.7E-09 ***
I received the support I needed for my learning.	4	3	1.7E-16 ***
Autonomy scale	3.8	3.4	3.4E-08 ***
Social-learner scale	3.8	3.8	2.3E-01

Table 3: Result of clustered data for all questions and scales using K-modes clustering and the non-parametric Mann–Whitney U-test. ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

B. ADDITIONAL INFORMATION ON MULTILEVEL MODELS

In the Results section of the paper, we present two multilevel models, also reported in Table 4 together with a third model that includes all level 2 effects except synchronous/asynchronous teaching, but has more data points than Model 2.

	Model 1 Estimate (std)	Model 2 Estimate (std)	Model 3 Estimate (std)
<u>Fixed effects</u>			
(intercept)	0.79 (0.39) *	0.75 (0.60)	0.50 (0.54)
<i>Level 1 (student)</i>			
age	0.0252 (0.0076) ***	0.0253 (0.0091) **	0.0279 (0.0089) **
gender	-0.021 (0.067)	-0.073 (0.080)	-0.052 (0.076)
international student	0.177 (0.096)	0.15 (0.13)	0.28 (0.12) *
reported average grade	-0.297 (0.065) ***	-0.387 (0.078) ***	-0.389 (0.075) ***
autonomy scale	0.285 (0.058) ***	0.348 (0.070) ***	0.330 (0.066) ***
social-learner scale	-0.122 (0.042) **	-0.158 (0.049) **	-0.141 (0.046) **
place to study	0.164 (0.028) ***	0.157 (0.034) ***	0.170 (0.032) ***
prefers not being seen	0.145 (0.029) ***	0.141 (0.034) ***	0.143 (0.033) ***
easy to ask questions to the instructor	0.133 (0.028) ***	0.153 (0.033) ***	0.132 (0.031) ***
<i>Level 2 (course)</i>			
size of the course (enrollment)		-0.00086 (0.00092)	-0.00061 (0.00086)
semester		-0.033 (0.037)	-0.038 (0.033)

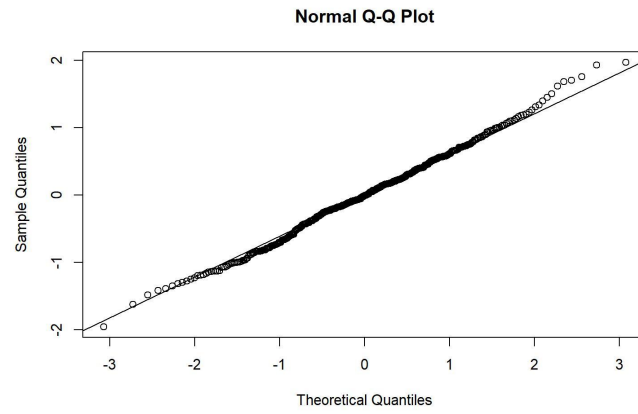
synchronous/asynchronous		-0.020 (0.064)	
DL courses prev. taught by teacher		0.028 (0.036)	0.020 (0.032)
access to equipment needed		0.112 (0.050) *	0.119 (0.045) *
group work		0.10 (0.11)	0.03 (0.10)
flipped classrooms		0.32 (0.13) *	0.27 (0.11) *
just-in-time teaching		-0.07 (0.14)	-0.08 (0.12)
<u>Random effects</u>			
(Intercept)	0.0307	0.0345	0.0251
Residual	0.4390	0.4199	0.4376
N	470	331	375

Table 4: Details on the multilevel random-intercept models employed. ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

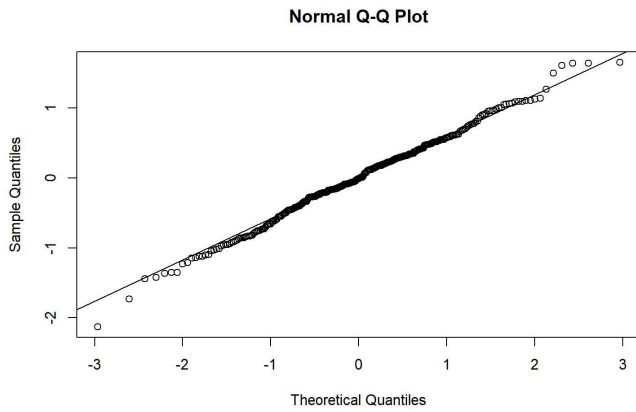
The assumptions entering the three models are normality of the residues and homogeneity of variance (homoscedasticity). The former can be checked by a Jarque-Bera test with gaussianity of the residuals as the null hypothesis. Gaussianity of the residuals can also be assessed by inspecting the normal Q-Q plots (see Figure 2). Homoscedasticity is assessed with Levene's test; we also consider the Fligner-Killeen test as an additional check. Based on the test results, no deviation from gaussianity and homoscedasticity is detected, since all p-values are considerably larger than 0.05.

	Model 1	Model 2	Model 3
Jarque-Bera test (p-val)	0.77	0.64	0.79
Levene test (p-val)	0.67	0.74	0.78
Kurtosis	3.02	3.16	3.01
Skewness	0.08	-0.10	-0.09
Fligner-Killeen test (p-val)	0.52	0.83	0.85

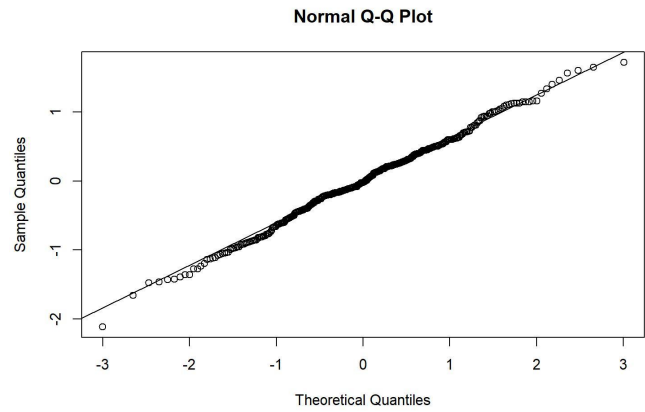
Table 5: tests for the assumptions of the three models presented in the paper



Model 1



Model 2



Model 3

Figure 2: Normal Q-Q Plots for the three models presented in the paper

B.2 Alternative multilevel models

As explained in the paper, our student survey included 12 course-specific items assessing various aspects of learning. An important part of our analysis has been the identification of eight items corresponding to major factors playing a role in the transition to DL, based on students' open-text answers. The course outcome variable was then constructed collecting seven of these items in a scale (since the eight correlated only weakly with the others). The variable constructed in this way is then used in the models as the dependent variable.

As a robustness test, we run the three models also considering an outcome variable constructed combining 11 of the 12 course-specific items in a single scale (i.e. without including/excluding items based on the students' open-text answers). Note that the last item still needs to be excluded because it correlates weakly with the others and would lower the Cronbach alpha of the scale. With the modified dependent variable, we observe the following changes in the three models:

Model 1: the social-learner scale becomes borderline significant with $p=0.05$; international student status becomes significant with $p=0.04$.

Model 2: no change

Model 3: international-student status becomes borderline significant with $p=0.05$.

All other variables are as in the original models.

C COURSE-SPECIFIC ITEMS OF THE SURVEY



Figure 3: Quantitative questions associated with the themes identified with thematic analysis.

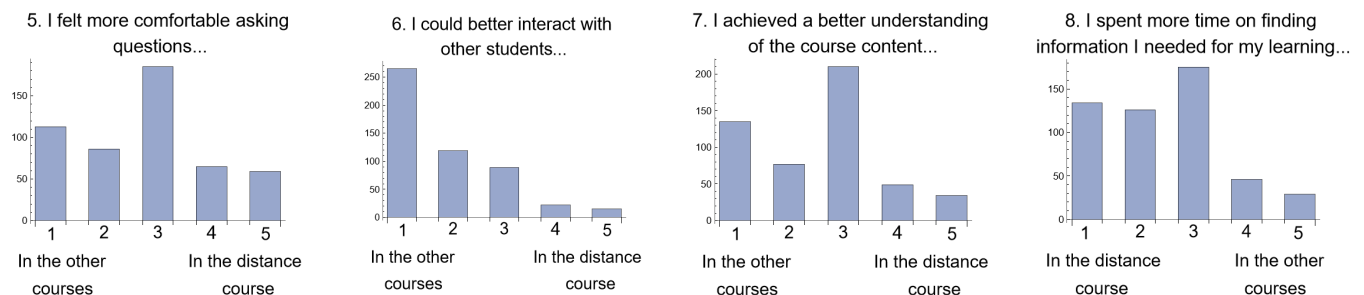


Figure 4: Quantitative questions associated with identified themes.

Histograms for the eight course-specific items are in Figures 3 and 4.

The correlation matrix between the eight course-specific items can be found in Table 7. Note that question 8 (time spent on collecting information) correlates weakly with only some of the others questions. Only statistically significant correlation coefficients are reported in the table, with significance codes as in the rest of the paper.

Note that items 3,4 are reversed when combined in the outcome scale.

	2	3	4	5	6	7	8
1. I could better interact with the instructor	0.422 ***	-0.291 ***	-0.416 ***	0.661 ***	0.432 ***	0.549 ***	
2. I felt I had more autonomy and control		-0.351 ***	-0.404 ***	0.392 ***	0.301 ***	0.547 ***	0.118 *
3. I needed more help managing my time			0.524 ***	-0.236 ***	-0.274 ***	-0.467 ***	0.048 *
4. I found it more difficult to stay motivated				-0.369 ***	-0.422 ***	-0.617 ***	0.095 **
5. I felt more comfortable asking questions					0.415 ***	0.507 ***	
6. I could better interact with other students						0.412 ***	-0.077 **
7. I achieved a better understanding of the content							
8. I spent more time on finding information							

Table 7: correlation matrix between course-specific items in the student survey. ***: $p < 0.001$, **: $p < 0.01$, * $p < 0.05$.

Themes identified in the thematic analysis are also triangulated with Likert questions as outlined in Table 8 below.

Theme	Likert question
Interacting with other students	6. I could better interact with other students...
Interacting with the teacher	1. I could better interact with the instructor... 5. I felt more comfortable asking questions...
Environment	
Autonomy	2. I felt I had more autonomy and control ... 3. I needed more help managing my time ...
Collecting and sharing information	8. I spent more time on finding information...
Motivation	4. I found it more difficult to stay motivated ...
Understanding content	7. I achieved a better understanding of the content...

Table 8: correspondence between themes from the thematic analysis and course specific Likert questions. The latter have answers on a scale with “5 in the DL course” and “1 in previous courses taught in person”.

D INTERVIEW SCHEDULE FOR THE STUDENTS' FOCUS GROUP

The focus group interview was conducted by two members of the research group. Interviewer one, a science education researcher, guided the interview, while interviewer two, a researcher and teacher in physics and astronomy, acted as an assistant. Information about the four participating students is in Table 8.

	Cecilia	Peter	Tom	Esben
gender	woman	man	man	man
programme	physics	engineering physics	physics	electrical engineering
year	2nd year	2nd year	3rd year	1st year
additional information	second career, took up her studies again as they were offered online			has a Bachelor degree in a humanities discipline

Table 8: Background of students participating in the focus group interview.

The interview commenced with an introduction to the project and participants' informed consent was obtained. This was followed by the semi-structured interview in which various themes were explored. The interviewers put particular care in ensuring that speaking time was divided evenly among participants and that they could all contribute to the discussion. The interview schedule is as follows.

Learning

What did your distance education look like in the last couple of months?

- 1) What kind of distance learning have you experienced?
- 2) Is it different from how it was before and how?
- 3) Has the switch to distance learning changed how you study "out-of-class"/ "on-your-own". If yes, in what way?

Students' Autonomy

- 1) How do you study these days?
- 2) Do you experience more or less autonomy/control over your learning in a distance learning course? What are the advantages/disadvantages with that?
- 3) Connection between motivation/autonomy and appreciation for distance learning
- 4) What makes the students stay focused in the online situation: motivation, synchronous vs asynchronous teaching, what helps for motivation vs what helps for learning?

Role of Peer Interactions

- 1) How social is learning compared to before? More or less or the same?
- 2) How does distance learning modify how students interact with each other and the instructor (social component).
- 3) Socialization aspects/interaction with other students - have students become more or less social? What can be done to improve socialization; ice-breaker events etc.

- 4) How are you and how are your friends?

Teachers' Roles and Interactions

- 1) Interaction with teachers - how has the teacher's role changed? What should the teacher focus on if priorities must be made?
- 2) The social aspect of feeling seen by the teacher: did the students feel the teacher had an understanding of their experience with the online teaching? did the students feel that the teacher cared?
- 3) What makes the students comfortable in the online environment? - teachers tend to feel more comfortable when they can see the students, talk to them etc while at the same time these things seem to make students uncomfortable.

Structure and Clarity

- 1) Would you like to have more support in creating structure in your distance learning courses? How can the university/teachers support you with that?
- 2) Structure and clarity (e.g. learning activities and outcomes) - connects to control over one's learning; have teachers provided good and timely information about the course?
- 3) Do you use the learning goals as information for you to understand what you need to get done? How do you use the learning goals?

E STUDENTS' BACKGROUNDS

Information about students participating in the focus group interview or answering the open-ended question is in Table 9. Note that pseudonyms are used to protect students' anonymity.

name	student #	program	age	year	gender	data set
Anders	276	master in chemical engineering	25	6	man	survey
Anna	122	bachelor physics	21	2	woman	survey
Daniel	235	master of engineering energy systems	25	4	man	survey
Edvin	464	bachelor physics	28	2	man	survey
Erik	155	bachelor electrical engineering	30	5	man	survey
Gustav	98	bachelor physics	26	5	man	survey
Johan	70	master engineering physics	23	4	man	survey
Kajsa	195	master physics	24	4	woman	survey
Karl	161	master physics	23	5	man	survey
Klas	450	bachelor physics	19	1	man	survey
Louise	23	master in engineering physics	20	1	woman	survey
Lovisa	394	bachelor physics	28	6	woman	survey
Maja	332	bachelor physics	19	1	woman	survey
Rebecka	418	master in engineering physics	22	3	woman	survey
Selma	359	master in water engineering	25	3	woman	survey

Sven	85	master in engineering physics	20	1	man	survey
Esben	speaker 4	bachelor in electrical engineering		1	man	focus group
Tom	speaker 5	bachelor in physics		3	man	focus group
Peter	speaker 6	bachelor in engineering physics		2	man	focus group
Cecilia	speaker 7	bachelor in physics		2	woman	focus group

Table 9: Further information on participants providing quotes reported in the thematic analysis. Student # gives the response number in the order in which the response was submitted. A lower number is closer to the beginning of the pandemic.

F LIST OF FULL QUOTES USED IN TEXT

In Table 10, we give selected quotes for each theme, including some not given in the main article.

Theme	Description	Quotes from open-text answer	Quotes from the focus group
Interacting with other students	Interactions with other students became more difficult which made it harder to discuss and receive help. Less energy goes into social interactions.	”Isolation, 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.” [Johan] “I get very tired from social interactions, so I had more energy to study when I could do it from home.” [Anna]	“but of course, 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 in Zoom or Discord and just having each other on speak, er 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] “I miss the things you can discuss with the others in the same course. That that I have right now, I would like to have someone to discuss some things with, but everyone is so, yeah, all over, all over the country.” [Cecilia]
Interacting with the teacher	More difficult to talk to the instructor Informal contact during breaks is missing. Use of chat function during lectures described as helpful.	“No spontaneous interactions with instructors: it is almost impossible to make small-talk during e.g. 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.” [Kajsa] “Being able to ask question via chat in zoom [the video conferencing software used] was a lot more	“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 with anyone in that class. And so I think that's that's 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]

		comfortable than speaking up in class.” [Lovisa] “After lecture talking: generally I would like to have a talk with lecturer and clarify some bigger or more fundamental questions after lecture, but in distance learning, it's more difficult to do so.” [Karl]	“And 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.” [Tom]
Environment	Lack of change in the environment made it harder to focus. Difficult separating study and free time A place to study without interruptions was lacking.	“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 [m^2] room.” [Maja] “Environment - Very difficult to find a space where I didn't get interrupted.” [Gustav]	“But also, when you're having my lectures, you get frustrated as well due to a lot of distractions around in your own apartment and such.” [Esben]
Autonomy	Increased autonomy and fewer distractions give more time to study. Lack of externally imposed structure leads to blurred days.	“Having a lot more material accessible on the study platform was nice, as it help with getting into 'study mode'. Studying from home also forced me to structure up my days, which I will have use of also in the future.” [Lovisa] “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]	“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 seen since all the lectures are recorded, if I don't feel like taking a lecture now later. And that's like it gets more stressful, know. To always have that availability to stop it and demand it.” [Peter] “And I think that has kept up sort of the social part of that course. So, yeah, I really think that it's important to have these sort of like beacons to help you structure your own life. I guess I try to set up a goal. OK, I guess I need to copy these notes today. I need to do these two exercises. I need to do this handed today and then I can go running or that I can do something else.” [Tom] “I tried to set up personal objectives, but I think what the university could really do [...] [is]for that is to to give these small slots, to just discuss with the teachers and to to give a lot of active assignments to work with by yourself in addition to the rest of the course” [Tom]
Collecting and sharing information	More available information is helpful but requires structure. More time is spent searching for information.	“Recorded lectures are extremely helpful. I have rewatched the same lectures many times and I learn better this way than just reading lecture notes.” [Daniel] “While studying on campus, I did not plan very much and simply went with the flow. Most [teachers] reminded us of important hand-ins	“you meet people and you talk and you plan your work. And if you have missed something, then you'll hear about it and so forth and so such. So everyone is each other's social net and also like study net.” [Esben] “But now you have to keep track of everything yourself. So I find that I start my day by going into Studenportalen and see what's new and if something has been

		and when documents have been updated on [the learning-management system]. When not there was 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 on distance.” [Erik] “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]	updated, there has 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 you study and how to study. And so less time is actually going into the studying.” [Esben]
Motivation	Difficulties with DL lead to decreased motivation.	“[it is] hard to keep your mood and motivation up when you're not able to interact with fellow students in the same way as when you're in the same room. You feel very lonely sometimes and bored because not much happens.” [Rebecka] “The fact that we never meet people face-to-face makes it very hard for me [...] to feel like I am actually studying. 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.” [Anders] “My motivation was lacking because of all distractions, otherwise pretty much the same” [Sven]	“I get very affected by people's energy. And I study now with a group that's a lot of fun. So we have a lot of fun while we're studying, which makes studying a lot of fun. But, you know, losing that, studying by myself, there's no one I can throw my thoughts at and there's no one to get you back into the study mode when you lose focus. And so it takes a lot more time and a lot more energy to learn stuff now.” [Esben]
Understanding content	Difficulties with DL lead to decreased understanding.	“Now I frequently forget things even though I studied it alot; it sort of just becomes part of everything else that is exactly the same as everything else.” [Edvin] “Also the loneliness from not meeting other students and study with them made it harder to understand everything.” [Klas] “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]	
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Table 10: Thematic analysis of the open ended question: “Name three major factors that affected your learning in comparison with previous periods [before the pandemic]. Explain how.” and of the focus group interview.