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Latent class analysis of distance learning arrangements in secondary mathematics education during COVID-19

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Teaching and learning practices used synchronous and asynchronous methods during distance learning due to COVID-19. In this study, latent class analysis was used to identify different distance learning arrangement classes in Finnish upper secondary schools (n = 18). These arrangements were examined from the students' (n = 552) perspective, taking into account communication, independent work, and technology utilization. The results supported a 3-class model. The two largest classes were characterized by active (class 2) and moderately active (class 3) use of diverse and interactive distance learning arrangements. These classes were followed by a class of mainly independent and passive distance learning (class 1). This study provides exploratory results of distance learning arrangement categories and adds to the understanding of students' perspective in the implementation of distance learning during the pandemic.

Keywords: Distance learning arrangements, latent class analysis, mathematics, upper secondary school.

Introduction

Successful distance learning takes advantage of technological opportunities (Oliver, 1999), has a clear structure (Lauret & Bayram Jacobs, 2021), and is designed for the learner profile (Tay et al., 2021). During COVID-19 synchronous and asynchronous distance teaching and learning methods were utilized (Bergdahl & Nouri, 2021; Drijvers et al., 2021; Kaqinari et al., 2022; Tay et al., 2021). Synchronous methods are used to model a typical class teaching setup with the help of technology (Tay et al., 2021). On the other hand, flexible asynchronous methods enable students to progress at their own pace (Bernard et al., 2004).

As a synchronous teaching method, video conference tools were widely used for distance teaching during COVID-19 (Bergdahl & Nouri, 2021; Drijvers et al., 2021; Kaqinari et al., 2022). In Finland, the majority of upper secondary students had regular real-time video connection with their teacher (Ministry of Education and Culture, 2021). In addition, learning management systems were used frequently (Bergdahl & Nouri, 2021; Francom et al., 2021; Kaqinari et al., 2022). These systems enabled sharing and returning completed assignments as well as tracking students' progress (Bergdahl & Nouri, 2021; Drijvers et al., 2021; Francom et al., 2021; Tay et al., 2021).

Changed learning environment placed new demands on the teacher, as the social interaction of distance learning differed from traditional classroom practice (Bergdahl & Nouri, 2021). The results of previous studies differ in their views on interaction and communication during distance learning (e.g., Wester et al., 2021; Yates et al., 2021). On the one hand, students have been found to prefer online discussions that, when well-organized, enables active student participation (Yates et al., 2021). On the other hand, it has been discovered that distance learning reduced students' interaction (Goman

et al., 2021) and participation in the lesson (Drijvers et al., 2021; Wester et al., 2021). This was observed not only from the students' point of view, but also from teachers who were unable to provide individual guidance or feedback to students (Lauret & Bayram Jacobs, 2021; Mælan et al., 2021). However, some students also preferred a reduced interaction, if they found participating burdensome (Goman et al., 2021).

Technology has made it possible for students to participate in distance learning practices in multiple ways. Teachers have used various chat tools, discussion forums, and polls (Kaqinari et al., 2022). These enable participation by writing or voting on a question. Students also liked the inclusion of gamification elements in distance learning (Yates et al., 2021). For example, learning games offered opportunities for competition between students. All in all, students were found to prefer visual information over textual information in distance learning (Yates et al., 2021).

Latent class analysis (LCA) has been used to form categories of teaching practices (e.g., Campbell et al., 2016; Kaqinari et al., 2022). Kaqinari et al. (2022) studied lecturers' technology utilization at the university level during COVID-19. The four classes they found included communication-based, presentation-oriented, and versatile profiles of technology utilization, as well as a profile that made little use of the opportunities offered by technology (Kaqinari et al., 2022).

The current study approaches the distance learning arrangements from a broader perspective. In addition to the technology used, this study considered how it was used for distance learning. In particular, we examined different communication and working methods. The research question was: *What categories of mathematics distance learning arrangements can be identified in Finnish upper secondary schools during the COVID-19 pandemic?* The aim of the research was to find out what kind of combinations of pedagogical activities were present in distance learning. Analysis of these combinations assists in comparing different distance learning pedagogies and enables further study of the connection between distance learning arrangements and other variables, such as affect.

Method

Participants

Data were collected from 18 upper secondary schools across Finland during the spring term in 2022 as part of a larger research project. Total of 1,066 students responded to the data collection. For this study, we selected students who participated in distance learning via a video conferencing tool between spring 2020 and spring 2022. Thus, the number of students in this study was 552.

Measures

Distance learning arrangements were identified from the students' responses to 16 questionnaire items (see Appendix). The questionnaire was created for the purposes of this study, and it included question items in three broad topics: communication (8 items), student's individual work (4 items), and technology use or applications (4 items). These topics were selected based on previous research (e.g., technology use: Crompton et al., 2021). Students answered these items on a four-point Likert scale (1 = not at all, 2 = to a small extent, 3 = to a moderate extent, 4 = to a large extent). In the analysis, we recoded the items by combining the options to a moderate and to a large extent, due to the small number of answers in those options.

Data analysis

Analysis was conducted using the R programming language (version 4.1.3; R Core Team, 2022), and the poLCA package (version 1.6.0.1; Lewis & Linzer, 2011). Latent class analysis (LCA) was used to identify different subgroups in terms of distance learning arrangements. LCA is considered as a person-oriented analysis (Collins & Lanza, 2010), where individuals are grouped into different classes based on the probability of belonging to the class (Muthén & Muthén, 2000).

To identify distance learning arrangement classes, we first created a one-class model and then added classes until we identified the best-fitting model (Weller et al., 2020). The following statistical and diagnostic methods were used to identify the best model: 1) Bayesian information criterion (BIC; standard and sample adjusted), 2) Akaike information criterion (AIC), 3) entropy, and 4) the average latent class posterior probabilities (ALCPP). The BIC value is considered the most reliable indicator of model fit, where a lower value indicates a better fit (Nylund et al., 2007). For entropy, recommended cut-off point is above .8 (Celeux & Soromenho, 1996). In terms of ALCPP, higher diagonal values (cut-off .8 for acceptable) and lower off-diagonal values (closer to 0) are desirable (Weller et al., 2020).

In addition to statistical and diagnostic methods, the number of participants in each class should be considered. It has been recommended that each class includes at least 50 (Muthén & Muthén, 2000) or more than 10% of participants in models with three or more classes (Sinha et al., 2020).

Results

The model fit criteria are presented in Table 1. As is typical for LCA analysis, different indices provided different information about the fit of the model (Nylund-Gibson & Choi, 2018). The BIC, SABIC, and entropy values were considered in addition to number of participants in each class when choosing the most suitable model. Based on the reliable BIC value (see Nylund et al., 2007), the 3-class model was found to be the best way to describe distance learning arrangement classes. A 4-class model was also possible, but in this model the difference between the classes was not clear and one class was clearly smaller than the others.

Table 1: Evaluating class solutions

Models	Model fit criteria					
	LL	AIC	BIC	SABIC	Entropy	Smallest <i>n</i> (%)
1 Class	-8122.71	16309.43	16447.46	16345.88	–	552 (100)
2 Class	-7688.35	15506.69	15787.07	15580.73	.79	215 (38.95)
3 Class	-7581.75	15359.49	15782.22	15471.13	.78	134 (24.28)
4 Class	-7514.27	15290.54	15855.61	15439.76	.80	55 (9.96)
5 Class	-7466.98	15261.95	15969.37	15488.76	.69	34 (6.16)

Note: LL = log-likelihood; AIC = Akaike information criterion; BIC = Bayesian information criterion; SABIC = sample adjusted BIC.

Participants in each class and ALCAPP values are described in Table 2. In the 3-class model, the participants were almost evenly distributed in each class. The ALCPP met the desired diagonal and off-diagonal values (Weller et al., 2020).

Table 2: Class counts and average latent class posterior probabilities

	<i>n</i> (%)	Average probability		
		Class 1	Class 2	Class 3
Class 1	134 (24.28)	.932	.009	.059
Class 2	207 (37.50)	.004	.901	.095
Class 3	211 (38.22)	.051	.047	.902

The three obtained classes differed in terms of the amount of distance learning methods used and the amount of interaction. In all classes, the students reported that they had received enough help from the teacher in completing assignments, but otherwise receiving personal feedback was minimal. Differences between classes are discussed in more detail below.

Class 1 is characterized by *passive* use of diverse and interactive distance learning arrangements. In terms of communication, students might participate in the lesson by writing in the chat or by using reaction tool (items c5 and c6), but otherwise participation was low. In addition, students regularly returned assignments to teacher (c8) but otherwise work was characterized by doing assignments independently and receiving model solutions (i1 and i4). In this class, the use of technology was also low, but the use of YouTube was at a similar level to the other classes (t2).

Class 2 is characterized by *active* use of diverse and interactive distance learning arrangements in terms of communication and use of technology. Compared to other classes, these students reported doing assignments also together with other students (c3 and c7) in addition to working independently. Communication during the distance learning lesson focused on using chat or raise-your-hand function (c5 and c6). However, students in this class also verbally participated in the lesson (c4). In this class, technology and various applications were used flexibly. This class stood out from the others in the use of social media and educational games in distance learning (t3 and t4). In addition, educational videos made by teacher and YouTube were used more regularly than in other classes (t1 and t2).

Class 3 is characterized by *moderately active* use of diverse and interactive distance learning arrangements. The students of this class are placed between the two categories presented above in terms of communication, independent work, and utilization of technology. Many distance learning methods were used, but to a smaller extent than in class 2. In addition, this class differed from the second in terms of interaction and collaboration between students. Whereas in class 2 students completed assignments together (c7), students in this class focused more on independent work (i1). Although distance learning was characterized by versatile opportunities for communication (c5 and c6 were emphasized), fewer technological opportunities were used in this class. As in the class 1, the use of YouTube during distance learning stood out in this use of technology, but overall, the use of

technology did not stand out. Figure 1 visualizes the differences between the classes according to the measured items.

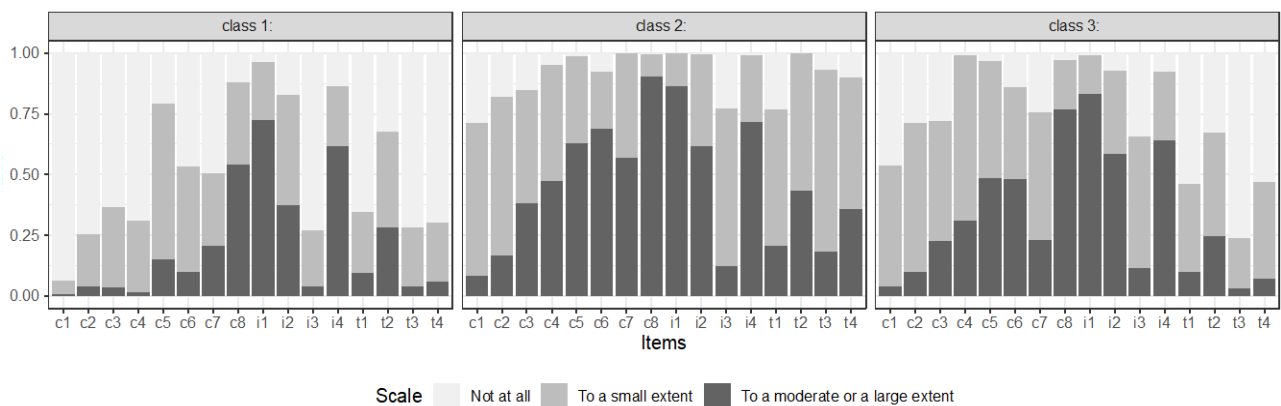


Figure 1: Latent classes based on communication, individual work, and technology use

Discussion

The purpose of this study was to examine different distance learning arrangement classes during COVID-19 in the context of studying mathematics. This study was focused on upper secondary students who had participated in distance learning via a video conference tool. LCA supported formation of 3-class model based on communication, independent work, and use of technology. In all classes students reported receiving enough help from teacher in completing assignments but amount of personal feedback was low. This was discovered also in a study by Lauret and Bayram Jacobs (2021). In addition, doing assignments and returning them to the teacher occurred in all classes. This has also been seen in previous studies, where returning assignments to the teacher served as one method of assessment (Drijvers et al., 2021).

Classes mainly differed from each other in terms of distance learning interactions and cooperation between students. Students belonging to class 2 participated most actively in the teaching and worked together with other students. Students have been found to prefer participating in online discussions, especially when the platform was well managed (Yates et al., 2021). Instead, in classes 1 and 3, students worked more independently. A decrease in interaction has been observed in distance learning and it has also been preferred by students who do not like interacting in lessons (Goman et al., 2021; Wester et al., 2021). However, these students could take advantage of the participation opportunities offered by distance learning, such as writing in the chat (Kaqinari et al., 2022).

In addition, differences were observed in the classes regarding the use of various distance learning opportunities and the utilization of technology. It has been observed that in distance learning, students preferred visually transmitted information instead of textual information (Yates et al., 2021). Class 2 stood out from the others with a more active use of technology. In particular, the use of social media and learning games stood out alongside YouTube. Previous research has identified educational games as a form of teaching that students like, as it makes it possible to include a competitive level in teaching (Yates et al., 2021). In addition, teachers have been found to make use of ready-made teaching videos or re-recorded lessons for example, on YouTube (Bergdahl & Nouri, 2021; Kaqinari et al., 2022). The use of YouTube also stood out in distance learning classes that emphasized

independent work (1 and 3). A platform like YouTube can also support the study of a passive and independent worker, as asynchronous methods enable progress at one's own pace (Bernard et al., 2004).

Overall, this study found three profiles of implementing distance learning from the students' responses. The formed classes partly corresponded to the results obtained by Kaqinari et al. (2022). In both studies, both interactive ways of implementing distance learning as well as passive ones that make little use of the possibilities of technology were observed. This study provides a model to categorize distance learning types in upper secondary school and allows further research on how these different types of distance learning are related to student affective and cognitive learning outcomes.

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Appendix: Items measuring distance learning arrangements

Communication	<p>c1. You had to keep the camera on during distance learning.</p> <p>c2. You had to keep the microphone on during distance learning.</p> <p>c3. During distance learning, students were divided into smaller groups (such as a breakout room).</p> <p>c4. I participated in distance learning verbally.</p> <p>c5. I participated in distance learning by typing in the chat.</p> <p>c6. I have reacted during distance learning, for example, by raising my hand.</p> <p>c7. During distance learning, I did mathematics assignments together with other students.</p> <p>c8. Completed mathematics assignments had to be returned to the teacher.</p>
Independent work	<p>i1. During distance learning, I did mathematics assignments independently.</p> <p>i2. I got enough help from the teacher to do the mathematics assignments during distance learning.</p> <p>i3. The teacher gave personal feedback during the distance learning lesson.</p> <p>i4. The teacher gave model solutions to the mathematics assignments.</p>
Technology use / applications	<p>t1. The teaching videos made by own teacher were used during distance learning.</p> <p>t2. YouTube was used in distance learning.</p> <p>t3. Distance learning utilized social media.</p> <p>t4. Educational games such as Kahoot! were used in distance learning.</p>