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Untangling the Great Online Transition: A network model of teachers' experiences with online practices

Jo Tondeur^{a,b,*}, Sarah K. Howard^{a,b}, Ronny Scherer^c, Fazilat Siddiq^d

^a University of Wollongong, Australia

^b Vrije Universiteit Brussel, Belgium

^c University of Oslo, Norway

^d University of South-Eastern Norway, Norway

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ABSTRACT

The Covid-19 pandemic provided a critical opportunity to understand how teachers experienced and perceived online practices, as they transitioned to emergency remote teaching. However, how these experiences relate, and how they should be addressed together to support teachers and schools, remains unclear. Therefore, the main aim of the current study is to examine associations among teachers' experiences and perceptions of online teaching and learning. The data were captured at the beginning of the COVID pandemic in 2020 through an online questionnaire, when teachers were transitioning to emergency remote teaching. Data included in the analysis comprises 222 secondary school teachers' responses to open-ended questions, analysed through a combined method of thematic and network analysis. The results indicate that perceptions and experiences must be studied from a system of variables that interact in determining the success or failure of online teaching and learning. Findings can contribute to decision making about how these variables assemble and relate in different ways to design more targeted support for teachers' future online and blended teaching practices.

1. Introduction

The field of education has the momentum to shift from predominantly face-to-face to blended teaching and learning after the Great Online Transition (GOT) of 2020 and emergency remote teaching during the COVID-19 pandemic (Howard et al., 2022). This time was an unprecedented natural experiment in educational change and adoption of online teaching and learning practices, as schools moved to emergency remote teaching (ERT). This event provided an opportunity for teachers in secondary education to explore how online teaching practices may integrate and blend in the face-to-face classroom. A large diversity of experiences and perceptions with online teaching practices and the quality of the transition to ERT has been identified (Howard et al., 2021; Ewing & Cooper, 2021; Khlaif et al., 2021). This has provided an interesting case to examine teachers' experiences with this transition and how it might inform technology-related change in the future (cf. An et al., 2021).

One of the main challenges to understanding teacher change is coming to grips with multiple and mixed associations among perceptions and experiences (see e.g., Philipsen et al., 2019b). This paper specifically addresses non-linear associations among teachers' experiences and perceptions transitioning to online teaching and learning practices, at the beginning of the pandemic. In

* Corresponding author. University of Wollongong, Australia.

E-mail address: jo.tondeur@vub.be (J. Tondeur).

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terms of change and adoption of new teaching practices, teachers' perceptions and unique experiences with digital technologies are key variables (Howard et al., 2021; Redmond & Lock, 2019), which tend to be complex and relate in multiple ways (Caskurlu et al., 2021). The lockdown-driven move to ERT during the pandemic drew heavily on existing online teaching practices. However, while there is extensive research into online learning, the field has primarily focused on students' experiences (cf. Binali et al., 2021; Lemay et al., 2021; Yates et al., 2021). Teachers' experiences have been largely left out of the equation (cf. Bruggeman et al., 2021).

To explore this issue, the current research draws on results from an online teacher questionnaire to explore associations among experiences and perceptions of online teaching and learning. The questionnaire was launched in March 2020. Importantly, the data was captured before the field started using the term 'emergency remote teaching' and questions asked specifically about 'online teaching and learning'. Data from three open-ended questions were analysed through a system thinking lens, using a combined method of thematic content analysis (e.g., Neuendorf, 2018) and network analysis (e.g., Epskamp, 2021; Epskamp & Fried, 2018). This novel mixed method allows for visualisation of multiple and diverse associations among experiences and perceptions, drawn from teachers' open text responses. Using open response questions provides a way to observe associations among what teachers really experienced in the transition rather than looking for specific perception of the experience limited by the questionnaire. By untangling experiences and perceptions, associations can be observed and applied to develop an integrated approach to teacher support and professional learning for future technology-related change.

2. Background

The term online learning is often interchangeably used with other terms such as distance learning, blended learning, e-learning or MOOCs. It is also described in different ways, with a range of meanings attached to it (Scherer et al., 2021; Moore et al., 2011; Singh & Thurman, 2019). Singh and Thurman (2019) conducted a systematic review that identified 46 definitions of online education. From this work, they arrived at a definition we apply in this study: "Online education is defined as education being delivered in an online environment through the use of the internet for teaching and learning. This includes online learning on the part of the students that is not dependent on their physical or virtual co-location. The teaching content is delivered online and the instructors develop teaching modules that enhance learning and interactivity in the synchronous or asynchronous environment" (Singh & Thurman, 2019, p. 302). There are in fact nine dimensions of online learning design, which include: modality, pacing, student-instructor ratio, pedagogy, instructor role online, student role online, online communication synchrony, role of online assessments, and source of feedback (Means et al., 2014). Thus, a design process would typically take 6–9 months, and 2–3 teaching cycles to optimise (Barbour et al., 2020). Effective online learning and teaching needs to include more than learning resources, but also social support, engaging interaction and feedback. These components in particular shape and define quality online learning, regardless of the mode of online learning.

However, much of the teaching and learning during the pandemic was not actually online teaching and learning per se; it was emergency remote teaching using online practices. ERT is defined as "a temporary shift of instructional delivery to an alternative delivery mode due to crisis circumstances" (Hodges et al., 2020). This may include a range of learning models, such as blended learning, radio, paper-based approaches, etc. It also extends beyond the COVID-19 pandemic. In 2011, Davies and Bentrovato (2011), through the Inter-Agency Network for Education in Emergencies, considered four case studies where alternative modes of instruction were needed at times when children could not attend school, such as during conflict and natural disasters. This is termed 'education's role in fragility' and considered how the human right of education can be delivered in fragile social contexts. One approach was the provision of distance (e.g., DVDs) and radio education in Afghanistan, which allowed children in unsafe and insecure areas to participate in learning. They conceded that ERT approaches are not truly comparable with face-to-face learning and teaching, and compromises in quality are made; it does support critical access to learning during times of crisis. Acknowledging that the educational transition to online teaching and learning due to the Covid-19 lock-down was an ERT-situation, we argue that much can be learned from this and is highly relevant for online teaching and learning in general. In particular, we believe knowledge of teachers' perceptions of, experiences with online practices and the associations among them from this transition is valuable for teachers' future professional development in online teaching and learning.

2.1. Online education in secondary schools

During the pandemic, online learning and teaching practices were appropriated in schools to support ERT. They were employed with the aim to replicate the face-to-face classroom, rather than to support online learning and teaching. The difference is subtle, but critical in understanding emergency remote teaching during the pandemic and school teachers' experiences (Ewing & Cooper, 2021). In this respect, the COVID-19 pandemic could be seen as one of the largest educational change initiatives in secondary schools, given that en masse school teachers were required to shift to an online delivery mode (Wong et al., 2021). In the transition, the rapid rate of change is one of the key dimensions distinguishing ERT from online learning and teaching. In many cases, teachers were only afforded a few weeks or even a few days to transition their teaching to the online space. Given the lack of experience school teachers had with online teaching, their overall readiness for this shift was quite low (Badiozaman, 2021; Howard et al., 2021).

Such a significant change requires time and effort, and trial and error to build experience and competence. Given this level of readiness, the rate of change and rapid professional learning resulting from the sudden transition to online teaching was challenging and stressful for many teachers - even though most teachers were motivated and valued its importance (see also Wong et al., 2021). This finding suggests that while teachers were not prepared, they did value the shift to teaching online and were motivated. Teachers' experience, competence and perceptions of online teaching are closely related and interdependent (Howard et al., 2021; Redmond & Lock, 2019). Knowledge about these variables and how they relate is increasingly important to understand how to support teachers in

online teaching and learning in general and future (emergency) transitions.

2.2. Teachers' perceptions of and experiences with online teaching and learning

The research community has mainly focused more on students' perspectives of online teaching and learning and relatively less attention was given to teachers' perspectives (Conrad et al., 2022; Yeung & Yau, 2022). Half of the 619 studies reviewed in the systematic literature on online teaching and learning focused on students, such as their motivational or demographic characteristics, while less than 4% reviewed teachers' perceptions (Martin et al., 2020). As an example, one review highlighted that challenges related to students' self-regulation skills are widely addressed but did not find any study about teachers' self-regulation challenges. Even though, teachers' experiences and perceptions are essential to better understand how to support them in the development of future online practices (e.g., Baran et al., 2011; Dhawan, 2020).

Of the studies that have looked at teachers' perceptions and experience, the adoption of online teaching and learning practices (e.g., Dhawan, 2020; Scherer et al., 2021) and challenges related to accessing digital resources and technical support have been highlighted (Howard et al., 2021; Wong et al., 2021). To illustrate, Wong et al. (2021) investigated secondary school teachers' psychological status, self-reported competencies in online teaching and work motivation during the Covid-19 pandemic. Their results showed that teachers' levels of stress, anxiety and depression (psychological status), along with their competencies in online teaching and work motivation were all at moderate levels. However, their results showed negative correlations between the psychological status variables and online teaching competencies, suggesting a positive relationship between the teachers' lower levels of stress, anxiety and depression and online teaching competencies. Also, teachers' personal conditions matter, and their perceptions and experiences are important to avoid burnout (Ismail et al., 2020) and prepare them for favourable working conditions and adequate competencies in online and blended teaching (Apperibai et al., 2020).

Difficulties relating to teacher and student interactions have also been identified. The Selvaraj et al. (2021) study provided a first detailed study on both teacher's and learner's view on online education in India. They reported a lack of direct interaction between students and teachers as one of the biggest challenges of online education. Another important concern addressed in their survey was students' attentiveness. Ang and Wu (2021) identified that middle school teachers in China had difficulty monitoring students' learning situation, experienced technical issues and felt there was a lack of technical and pedagogical competencies to teach online (Ang & Wu, 2021). These two studies represent only a few of the many variables impacting on online education (cf. Howard et al., 2021). From the challenges, it is apparent that the teachers' perceptions and experiences with teaching and design of it can be associated. At the same time, experiences and perceptions are presented as separate components in most of the studies, which fails to address the system and ecology of change.

2.3. Ecologies of online teaching and learning

The wide reaching, common and unique teacher experience during the COVID-19 pandemic, provided a critical opportunity to understand teacher change processes on a grand scale. At the same time, researchers have struggled to understand teachers' change processes (Philipson et al., 2019b). Consequently, this limited understanding restricts how well teachers are supported to engage in change processes (Abel et al., 2022). Clearly, change exponentially increases the complexity of these practices by bringing them into question and introducing new unknown practices (see e.g., Greenhow et al., 2021). It also impacts on teachers' perceptions of their own identity and quality of learning (Niemi & Kousa, 2020). Moreover, change affects individual teachers in a range of ways that may not be predictable or visible. It is therefore necessary to better understand teachers' perceptions of and experiences with change, such as the move to online teaching and ERT, in order to better support schools and teachers.

In the current study, we draw on the concepts of ecologies and complexity to attempt to gain a better understanding of teachers' experiences in and perception of change (cf. Tondeur et al., 2015). Complexity can be understood as: a whole that is made up of a range of interrelated parts. Relationships among these parts may be bi-directional, multi-directional, dynamic and nonlinear (Yurkofsky et al., 2020). In this respect, teaching and learning are already complex and dynamic, social and personal endeavours. Some researchers have tried to understand change and unpack its complexity, using several different approaches. A few examples of this work are an ecological perspective of technology integration in a school (e.g., Zhao & Frank, 2003), rhizomatic mapping to look at online learning (e.g., Grellier, 2013), using data science approach to understand online learning (e.g., Bravo-Agapito et al., 2021), and employing systems thinking to understand teachers' technology adoption (Howard & Thompson, 2016). These approaches reveal and visualise some of the nonlinear and dynamic associations among teachers' perceptions and experiences with technology-related change. To illustrate, Castellanos-Reyes (2021) used a panel network data of 386 MOOC learners to explore the mechanisms that drive learner-learner interaction over time. Specifically, the patterns and evolution of learner-learner interaction in a MOOC were examined through a stochastic-actor-oriented model. Their study explored indicators for real-time measurement of social presence by using available data from the learning management system.

Approaches such as Castellanos-Reyes (2021) and Zhao and Frank's (2003) ecological model, systems thinking (e.g., Authors, 2016) and the rhizomatic approach (e.g., Grellier, 2013) support the conceptualization of a range of key variables in a system. To approach the complexity of change, these studies engaged in a wide range of consultation and consideration to identify experience and components of the change process, and what was enabling and constraining that process. However, they are often deductive and are limited to what is identified by individuals. In the current study, we build towards deeper investigations by using inductive processes, supporting a wide range of variables, including both qualitative and quantitative data and being able to handle multiple and bi-directional associations among variables (cf. Howard et al., 2022). These combined affordances provide a way to access the gestalt of

combined variables, to better anticipate and support change processes. These approaches are at the ‘system’ level and require an understanding of associations and relationships among variables in a system, to be constructed. This brings us to the scope of the current study.

2.4. The purpose of the study

The COVID-19 pandemic has provided an opportunity to understand how school teachers experienced and perceived online practices, as they transitioned into ERT. Understanding some of this experience can inform ongoing and future implementation of online and blended learning practices. Based on previous research it can be concluded that there are a variety of experiences and perceptions related to the adoption of online learning in schools. However, as stated above, there is a lack of understanding of the complexity of the multiple associations among their perceptions and experiences (cf. Tondeur et al., 2021). A limitation in existing research is that variables are often studied in isolation or in ways that are not able to account for complex and dynamic relationships. By untangling and integrating these experiences and perceptions, we can develop a more integrated approach towards professional learning and teacher support for online and blended teaching and learning (Bragg et al., 2021). Therefore, the ultimate goal of the current study is to understand the associations within and between perceptions and experiences in online teaching, in order to guide future professional development efforts and school policies. We address the following two research questions in this study:

1. Which teachers’ online perceptions and experiences about online learning can be identified?
2. What are the associations between the teachers’ perceptions and experiences about online learning?

3. Approach and methods

3.1. Research setting

In March 2020, when the COVID-19 pandemic broke out in most parts of the world, an online survey was launched to collect data on teachers’ experiences and perceptions associated with online practices. Importantly, this study addresses the very early moments of the transition of schooling to teaching online, before wide use of the concept ‘emergency remote teaching’. Given this timing, the study does specifically address online teaching and learning, rather than emergency remote teaching. This is a subtle but important distinction in the framing and implications of the results and findings.

The questionnaire included teacher background, technological, pedagogical and content knowledge (TPACK) self-efficacy, perceived online teaching presence, and perceived institutional support items. In the current study only the three open-ended questions were used focusing on perceived benefits, perceived challenges, and general comments about online teaching (i.e., 1. What do you feel are the top three benefits of online learning; 2. What do you feel are the top three challenges of online learning? 3. Anything else you would like to tell us about your online learning and/or transitioning your teaching to online?). For a full description of the questionnaire, please see Scherer et al. (2021). Participation in the survey was voluntary and its purpose was fully disclosed. Participating teachers gave their consent before starting the survey and agreed with the use of their data for research. When the survey was closed, at the end of May 2020, data extracted corresponded to 222 secondary-school teachers (68.8% women). These respondents were from 20 different countries distributed across Africa (3.1%), the Americas (1.8%), Asia (3.2%), Europe (70.7%), and Oceania (21.2%), according to the United Nations Classification of Geographical World Regions (UN, 2023). On average, teachers were 43.5 years old ($SD = 10.7$) and had 15.3 years of teaching experience ($SD = 10.1$). Their online teaching experience averaged 4.4 years ($SD = 2.9$).

3.2. Mixed-method analysis

In the present study, a novel mixed-method approach combining thematic content analysis (Neuendorf, 2018) and network analysis (Epskamp, 2021) was taken. We followed a multi-step research design including three phases: 1. Thematic analysis (open and axial coding) to identify teachers’ perceptions and experiences related to the benefits and challenges of online teaching and learning; 2. Network modelling to identify the associations and interactions between the teachers’ perceived benefits and challenges; and 3. Thematic analysis (selective coding) to validate the network model.

3.2.1. Qualitative thematic analysis phase (phase 1)

The open answers were coded following an inductive thematic approach, grounded on a data-driven analysis of the corpus (Charmaz, 2001, 2006). The objective of coding was to define the primary categories and related sub-categories of the participants’ answers regarding their experiences and perceptions. The corpus was analysed and coded using the NVIVO software package. The analysis included three different steps of inductive coding: open, axial and selective coding. These steps are drawn from a Grounded Theory approach (Charmaz, 2008), where the intention is not to form theory but to gain an initial understanding of this change from the perspective of participants. The first step was open coding, where participants’ open-ended responses were initially analysed. In that our research questions focus on perceptions and experiences related to benefits and challenges in the transition to online/remote teaching, these elements were the focus of open coding. This process included 222 textual comments, from three open-ended questionnaire items. This resulted in 130 initially identified themes. Initial coding was conducted by one researcher and then reviewed by three other experts in the area.

In the second step, axial coding, connections between codes were identified to create a hierarchical coding framework through an iterative process. Codes with similar meanings were combined. This stage resulted in 65 final codes included in the framework. The resulting coding framework was then reviewed again by the three experts and 25% of the open-ended response dataset was re-coded by another researcher. This portion was discussed to refine any coding discrepancies, to 100% agreement. The coding framework was also revised where necessary. The coded open-ended responses with the full set of codes were then exported as a spreadsheet (.csv file) for network analysis - to investigate the relationships/associations among the codes.

3.2.2. Quantitative network modelling (phase 2)

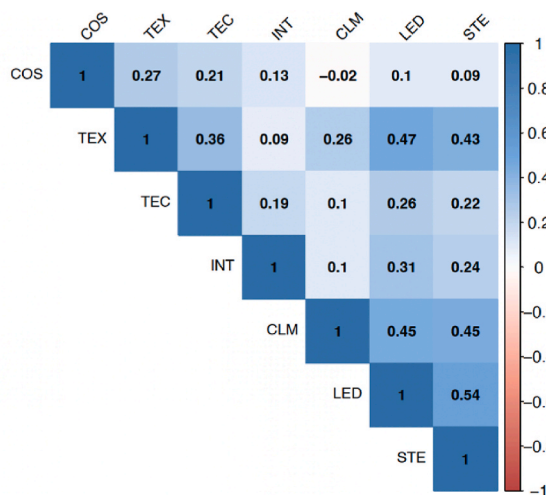
To examine the associations between the categories of perceived benefits and challenges, we utilized psychometric network models. Psychometric network models represent undirected network models that are based on the partial correlations between two variables, controlling for all other relationships (Epskamp & Fried, 2018). These models offer visualizations of the network structure via nodes and edges. Specifically, nodes represent the variables (i.e., binary variables indicating whether or not teachers provided statements within a category), edges represent the partial correlations—which are often referred to as “weights” (ω)—between two variables (i.e., the associations between two binary variables controlling for all other associations), and the width of edges indicates the strength of association (i.e., the size of the partial correlations) (Epskamp et al., 2012). In this way, psychometric network models can indicate unique interactions between variables and identify clusters of variables—these models are primarily concerned with the variance that is *unique* to the variables (van Bork et al., 2019, pp. 1–24).

In the present study, we estimated the Ising model—a network model based on binary variables and originally designed to describe phase transitions in particle fields (Epskamp, Maris, et al., 2018)—for both the main and the dyads of the perceived benefits and challenges in the R package “psychometrics” (Epskamp, 2021), utilizing maximum-likelihood estimation. In this model, the interpretation of the partial correlations is probabilistic, that is, if two variables (categories) are positively associated, the occurrence of the one variable likely results in the occurrence of the other variable, and vice versa (Marsman et al., 2018). The Ising model contains threshold parameters τ_i for each variable X_i and network parameters ω_{ij} between two variables (nodes) X_i and X_j . Epskamp, Borsboom, and Fried (2018) argued that the threshold parameters indicate the preference of a specific state over the other (e.g., 0 vs. 1) and the tendency of a state when all other variables are zero (Haslbeck et al., 2021), with $\tau_i = 0$ suggesting no preference. Network parameters indicate the interaction between variables (nodes) as an alignment of states (e.g., $X_i = 1$ and $X_j = 1$ are likely to occur jointly for $i \neq j$), with $\omega_{ij} = 0$ suggesting no interaction (edge). We evaluated the fit of the Ising models via common model fit indices and their suggested guidelines (for an acceptable fit: insignificant chi-square statistic, Comparative Fit Index CFI ≥ 0.95 , Root Mean Square Error of Approximation RMSEA $\leq .08$; e.g., Marsh et al., 2005).

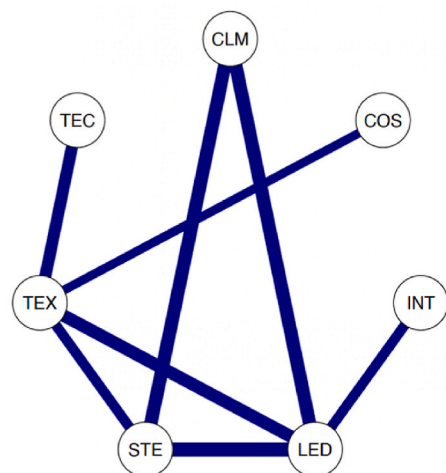
3.2.3. Qualitative validation of the network model (phase 3)

The final phase of this analysis, selective coding, was completed after analysis of the coding network. To do this, the coded open-ended response data was queried to identify where multiple codes occurred in a participant’s response, e.g., they identified ‘self-

(a) Tetrachoric correlation matrix



(b) Ising network model



Note. CLM = Classroom management, COS = Covid-19 specific aspects, INT = Interaction, LED = Learning design, STE = Student experience, TEX = Teacher experience, TEC = Technology. The correlation matrix shows the tetrachoric correlations among the main categories, $N = 222$.

Fig. 1. Correlation Mtrix and Network of the Main Categories.

Note.CLM=Classroom management, COS=Covid-10 specific aspects,INT=Interaction, LED = Learning design, STE=Student experience, TEX = Teacher experience, TEC=Technology. The correlation matrix shows the tetrachoric correlations among the main categories,N= 222.

‘pacing’ and ‘flexibility’ as benefits of online learning. These were captured in a matrix as simple frequency counts within each response. The matrix was then exported as a csv file for another round of network analysis. The process of creating the coding network is in the following section. The result of the network analysis is a model of associations among the codes, which can be interpreted as a system. This provides a way to consider code associations as a whole and the underlying meaning of codes as unit. The network provides a way to see quantitative associations making up the system that are not fully visible through qualitative analysis. To then validate the network model, participants’ open-ended responses were reanalyzed, where codes occurred together. The context and meaning of how and why these codes occurred together was considered to understand the underlying phenomena of the association e. g., the teacher felt they were able to better ‘design’ for both ‘self-paced’ and more ‘flexible’ learning, when online.

4. Results

4.1. Network of main categories

4.1.1. Network model fit

The Ising network model was based on the tetrachoric correlations among the main categories, which ranged between $r = -0.02$ (CLM-COS) and $r = 0.54$ (LED-STE; see Fig. 1a). To find a sparse network model with interpretable edges, we performed pruning (with a correction for false discovery rates at $p = .01$), a step-up search with a 5% significance level to exclude insignificant nodes, added model parameters with the largest modification indices (Epskamp, Borsboom, & Fried, 2018). The resultant, sparse network model showed a very good fit to the data ($[13] = 9.1, p = .76, CFI = 1.00, RMSEA = 0.000, 95\% CI [0.000, 0.054]$). We accepted this network model to describe the connections between the teachers’ perceived benefits and challenges (see Fig. 1b).

4.1.2. Relations within the network

The network of main categories contained eight positive and statistically significant connections between the following dyads, ordered in ascending strength: COS-TEX, LED-INT, STE-TEX, TEC-TEX, LED-TEX, STE-CLM, LED-CLM, and STE-LED. Notice that these dyads represent pairs of variables which themselves represent the categories. These connections suggested that the probability of reporting a benefit or challenge in one category was associated with the reporting of a benefit or challenge in the connected category. None of the categories were completely isolated. The connection between STE (student experience) and LED (learning design) was the strongest ($\omega = 1.18$), and all other connections ranged between $\omega = 0.76$ and $\omega = 1.14$ (see Table 1). Within the network, the node “Learning design” was the most influential category with four connections to other categories (expected influence of 4.3), followed by “Teacher experience” (expected influence of 3.7) with four connections (see Figure A1). Notably, “Covid-19 specific aspects”, “Interaction”, and “Technology” were connected to only one other category.

4.2. Network of the dyad student Experience–Learning design

Next, we estimated the network of the dyad (i.e., the pair of two categories) “Student experience”–“Learning design”, which had the largest partial correlation in the network of main categories.

4.2.1. Network model fit

Fig. 2a shows the tetrachoric correlations among the STE and LED sub-categories, and Supplementary Material S1 details the respective confidence intervals. The correlations were as low as $r = -0.34$ (STEMO-STEHO) and as high as $r = 0.46$ (LEDCD-LEDSS), and did not exhibit large clusters of sub-categories. The resultant Ising network of the STE-LED dyad showed a good fit to the data, $\chi^2(185) = 186.1, p = .46, CFI = 0.97, RMSEA = 0.005, 95\% CI [0.000, 0.030]$.

4.2.2. Relations within the network

The STE-LED network contained five positive connections (see Fig. 2), with weights (i.e., partial correlations) ranging from $\omega = 0.98$ (STEFL-STEEN) to $\omega = 1.84$ (LEDSS-LEDCD). These edges (i.e., associations between variables) suggested that reporting a benefit

Table 1
Network model parameters of the main categories.

Category	Reporting frequency		τ_i (SE)	Network parameters ω_{ij}						
	Code 0 (Not indicated)	Code 1 (indicated)		CLM	COS	INT	LED	STE	TEX	TEC
CLM	74.8%	25.2%	-2.83 (0.51)							
COS	74.3%	25.7%	-1.54 (0.28)							
INT	64.0%	36.0%	-1.17 (0.27)							
LED	34.2%	65.8%	-1.25 (0.32)	1.14**		0.87**				
STE	28.4%	71.6%	-0.44 (0.27)	1.14*			1.18**			
TEX	50.0%	59.1%	-1.40 (0.32)		0.76*		1.08**	0.87**		
TEC	70.7%	29.3%	-1.54 (0.28)							1.03**

Note. CLM = Classroom management, COS = Covid-19 specific aspects, INT = Interaction, LED = Learning design, STE = Student experience, TEX = Teacher experience, TEC = Technology. The estimates were obtained from the Ising network model after the pruning and step-up search. Empty cells in the network parameter matrix indicate the pruned, statistically insignificant parameters. N = 222. * $p < .05$, ** $p < .01$.

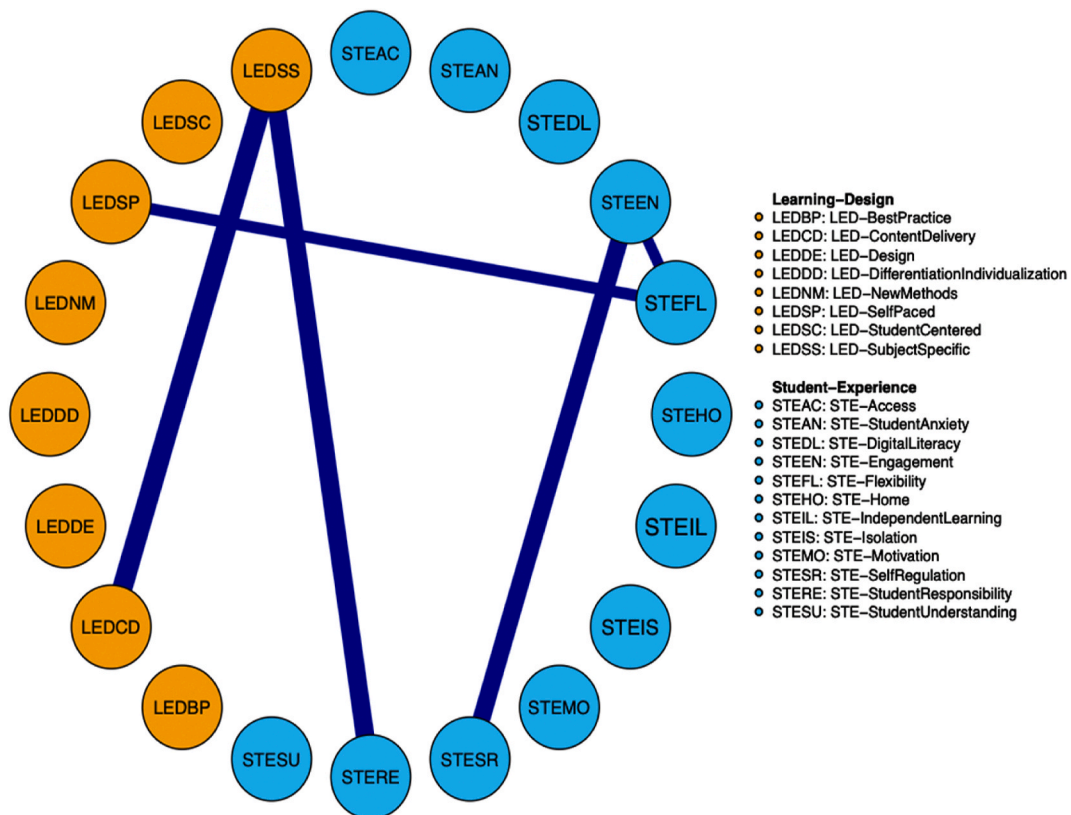


Fig. 2. The STE-LED network.

or challenge in a sub-category was associated with a higher probability of reporting a benefit or challenge in the connected sub-category. The five connections existed both within and between the two categories STE and LED (see Fig. 2b). Specifically, within the category STE, the following sub-categories were connected: STEFL-STEEN ($\omega = 0.98$) and STESR-STEEN ($\omega = 1.60$). Within the category LED, only two sub-categories were connected: LEDSS-LEDSCD ($\omega = 1.84$). The remaining connections existed between the main categories: LEDSP-STEFL ($\omega = 1.00$) and LEDSS-STESR ($\omega = 1.69$). Most sub-categories of learning design (i.e., LEDSC, LEDNM, LEDDD, LEDDE, LEDBP) and student experiences (i.e., STEAC, STEAN, STEDL, STEHO, STEIL, STEIS, STEMO, STESU) were isolated and thus independent of the other nodes. Within the STE-LED network, LEDSS (subject-specific learning design) was the most influential sub-category with an expected influence of 3.5, while LEDSP (self-paced learning) had the lowest, non-zero influence of 1.0 (see Fig. 2). The nodes representing STEEN, STEFL, and LEDSS were the most connected nodes with two connections to other sub-categories.

4.3. Network of the dyad “student Experience”–“Learning design”

The non-linear results presented in Fig. 1 illustrate complexity of all interrelated variables. In a next step, the in-depth investigation begins with teachers’ experiences and perceptions of ‘student experience’ and ‘learning design’ dyad, which provides some insight into associations within and between both variables (see Fig. 2). Noting that teachers’ open-ended responses underlie these associations, here we first unpack associations between ‘Learning Design’ and ‘Student Experience’.

The first of the two visible associations from the analysis, includes three variables related to ‘Student Experience’: ‘Flexibility’ (STEFL), ‘Engagement’ (STEEN) and ‘Self-Regulation’ (STESR). It also includes one variable from ‘Learning Design’, ‘Self-pacing’ (LEDSP). This combined association represents respondents’ growing understanding of students’ experience in the online space, in relation to the increased flexibility and decreased visibility of students and their work. Most teachers did not have experience teaching online before the GOT, which resulted in a lot of questions and new insights into this area.

‘Student engagement’ was at the core of their observations. This was the key to students being able to learn in and benefit from the flexibility of online spaces. Respondents felt that flexibility promoted student independence in learning (4287, 4295). “It helps learners plan their time flexibly. We are free to choose what we need to learn” (4486). Respondents also appreciated that teachers and students could work in their own time and ‘in their pyjamas’ (4032). However, it was strongly noted by respondents that student engagement levels varied widely.

'I feel it has been reasonably smooth so far, but I am lucky in the sense that the students that I work with are from a super selective grammar school. They are keen to learn, reasonably independent already and have incredibly supportive parents. I can see it being a struggle to keep on top of the students that 'fall through the cracks' as I cannot force them to respond to emails and we do have some parents who effectively ignore us'. (4287)

The overall impact of parental and community engagement in school on students' engagement and online participation was quite significant in schools (4287, 4318). The lack of support in some cases also affected students' self-regulation in flexible learning. Respondents felt parent and community support was needed to encourage students to engage in online work (4294), while they were away from school. Teachers were not able to be there to directly interact and engage with these students who may have lacked the self-regulation to work independently and online, while at home. To work well online respondents felt students needed to have self-direction, to be able to manage their own time and be independent. These skills were highly variable, as reported by respondents.

Specifically, self-paced learning was identified as an important design consideration for teachers developing flexibility in their learning. *'Each student can determine its own the schedule, curriculum topics can be reviewed as many times as necessary, questions can be asked any time (on the spot or later)'* (4048). Self-paced learning is a dimension of flexible learning. Respondents spoke about self-paced learning as students being able to reread and review online materials, work at their own pace and style, and when they want. However, respondents also identified that teachers *'must give more ownership to the students'* (4374) in self-paced flexible learning, which many found difficult. Issues identified by respondents were inability to track student progress and understanding, and students' ability to manage their own time.

Ultimately, the associations between 'Student engagement', 'Flexibility', 'Self-regulation' and 'Self-pacing', point to a key issue that was critical for many teachers. Several confounding variables such as student and teacher digital literacy and skills, along with appropriate internet access, also were thought to have strong effects on students' engagement and capacity to engage in online learning. Importantly, moving to an online format provided an opportunity for teachers to experiment (albeit at a rapid rate) with online learning components and see how students were able to engage and some self-pacing design elements. Strengths were fostering independent learning and opportunities for students to have increased ownership of their learning, but this experience was not universal for all students.

The association between 'Subject specific' (LEDSS), which was a dimension of teachers' 'Learning Design', and 'Student responsibility' (STERE) which was discussed in relation to 'Student Experience', represents school teachers who mentioned both variables as a benefit or challenge of online teaching. Based on the findings of the qualitative analysis, it seems that a strong focus on students' responsibility can be challenging for specific subjects and content areas (e.g., practical components). To illustrate, an industrial arts teacher mentioned: *"Most students do have the resources to complete projects/products at home. Depending on the duration of online teaching there should be a modification to outcomes so that student achievement will not be penalised"* (4328). Although the respondents point to the many skills that can get lost by learning online, they also address that new *"life skills for unpredictable situations"* (4249) became more important. At the same time, the qualitative findings show some challenges to assess such skills. The respondents stated for instance that for practical based subjects *"it is a lot more difficult to test online without cheating"* (4177). They also point to students' responsibilities in this respect, such as a *"lack of students' self-discipline"* (4249).

As depicted in Fig. 4, the 'Subject specific' dimension can also be associated with 'Content delivery'. An emerging theme in the qualitative analysis is the strong focus on content: *"I think more about the content when developing online materials"* (2029). According to the respondents, this also leads to more time to teach theory in more depth. Interestingly, the respondents point to the advantage that in online teaching some content *"can be delivered without interruptions from student behavioural issues"* (4026). At the same time, it is clear from the qualitative evidence that online delivery of content is dependent on the subject or even a specific content area. As stated above, some more practical components have had to cease during the GOT (e.g., interaction in language).

In sum, the associations between 'Subject specific' and both 'Content delivery' and 'Student responsibility' point to subject-specific nature of online learning. This can be clearly illustrated by one of the teachers: *"I would like to continue online for some subjects after the crisis is over"* (2029). Clearly, online experiences lead to an emphasis on more (in-depth) theory together with a strong focus on students' responsibility for learning the content. Several challenges have been identified both at the 'students' experience' dimension, such as lack of self-discipline or lower participation) as at the 'learning design' dimension, such as lack of clear routines among staff. These findings will be discussed in the following section.

5. Discussion and conclusion

The event of the COVID-19 pandemic and the respective implementation of a lockdown resulted in a rapid switch to online teaching, and ultimate transition to ERT, for schools around the world. In the current study, we began to untangle the complexity of secondary education teachers' experiences about their online practices. The study explored associations within and between their perceptions and experiences by combining thematic analysis and quantitative network modelling. To illustrate this novel method, we focused on the strongest connections "Learning design" and "Student learning". Below we discuss the key findings and link them to the new mixed-method approach.

5.1. Associations between online learning design and student experiences

Researchers are now beginning to address critical teacher characteristics associated with online ERT in schools (e.g., Howard et al., 2021; Ewing & Cooper, 2021) but have only partly succeeded. Effective implementation of online learning continues to be complex,

contextual, and multi-faceted (Baran et al., 2014; Scherer et al., 2021). To progress research and support change, it is necessary to better understand the complexity of these practices. One of the reasons for this limitation in current research is that many researchers have only investigated the role of a few teacher characteristics, which is often done in isolation and ignoring multiple and complex associations among variables (cf. Song & Kim, 2021). For instance, Song and Kim (2021) studied the relations between self-regulated learning, course participation, and learning performance. In the current study, we explored a range of associations among variables to obtain a more complete empirical understanding of online teaching in secondary schools, as they transitioned to ERT.

The results presented above clearly illustrate that a better understanding is needed of interrelated variables, by untangling the associations between the design of online teaching that potentially influences student experiences. To illustrate, the association between ‘Student engagement’ and ‘Self-regulation’ (see Fig. 3) points to critical issues for many secondary school teachers. They stressed the opportunities for students to have increased ownership of their learning (cf. Shearer et al., 2020), but at the same time they reported that many of their students struggled to engage to learn online (cf. Salas-Pilco et al., 2022). Also, the Bruggeman et al. (2021) study found that educators, in the context of higher education, positively evaluated the flexibility of online learning but saw pitfalls for students to manage their own learning process. Therefore, they pointed to the importance of students’ self-regulating skills, another crucial variable associated with ‘student engagement’ in the network model presented in Fig. 2. Here, in the context of secondary education, the participating teachers felt parent and community support was needed to encourage students who may have lacked the self-regulation to work online at home (cf. McNaughton et al., 2022).

Another interesting finding is the association between learning design and the subject specific nature of online learning (Fig. 4). It seems that online learning can lead to learning theoretical subjects in more depth, but can be a serious challenge for more practical subjects or components at the same time. Therefore, Starkey et al. (2023) suggest that discipline-specific digital competencies should be developed to teach online. Specifically, they stress the need to develop teachers’ competencies in appropriate pedagogical practices that align with disciplinary culture and the technologies available (see also Buchholz et al., 2019; Lim & Richardson, 2022). These findings are particularly important when considering how to develop and support future integration of online and blended learning in education. An effective professional development strategy addressing online learning and teaching needs to address this broad

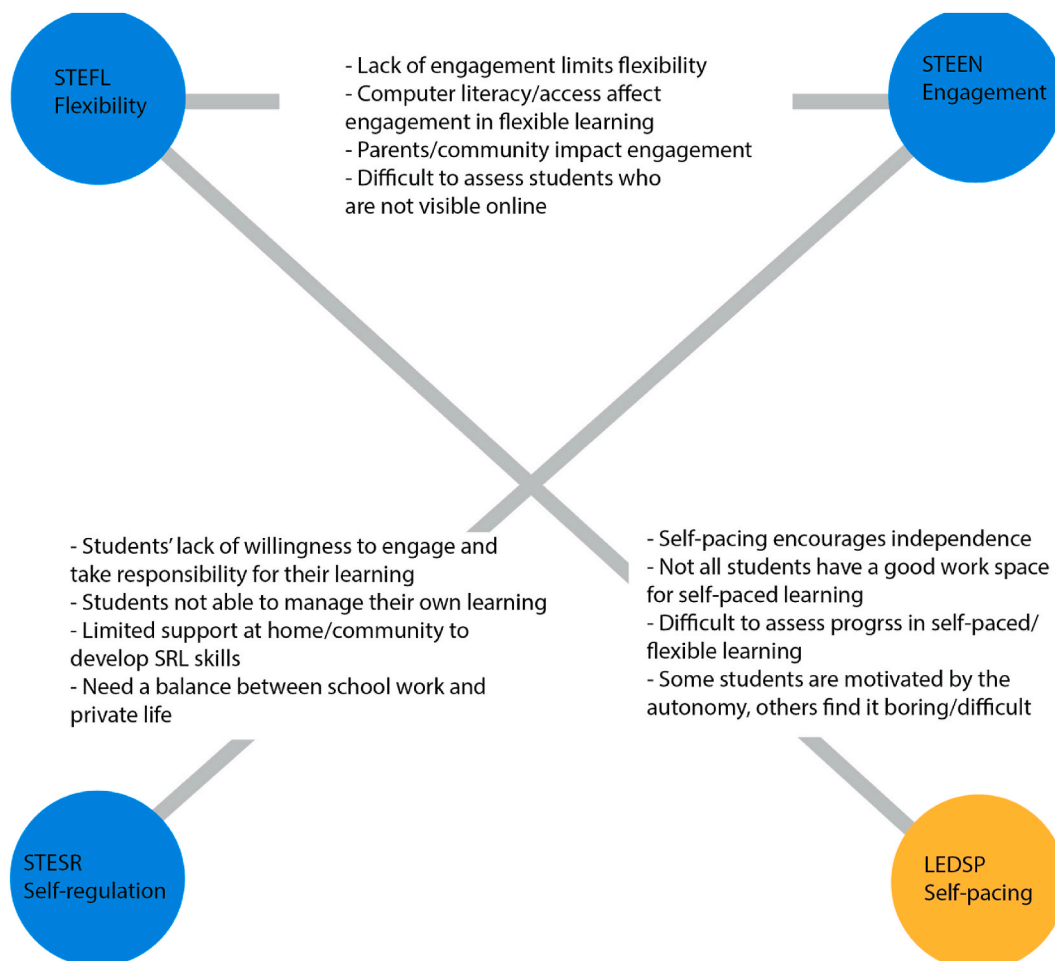


Fig. 3. Flexibility, Engagement, self-regulation and self-pacing network.

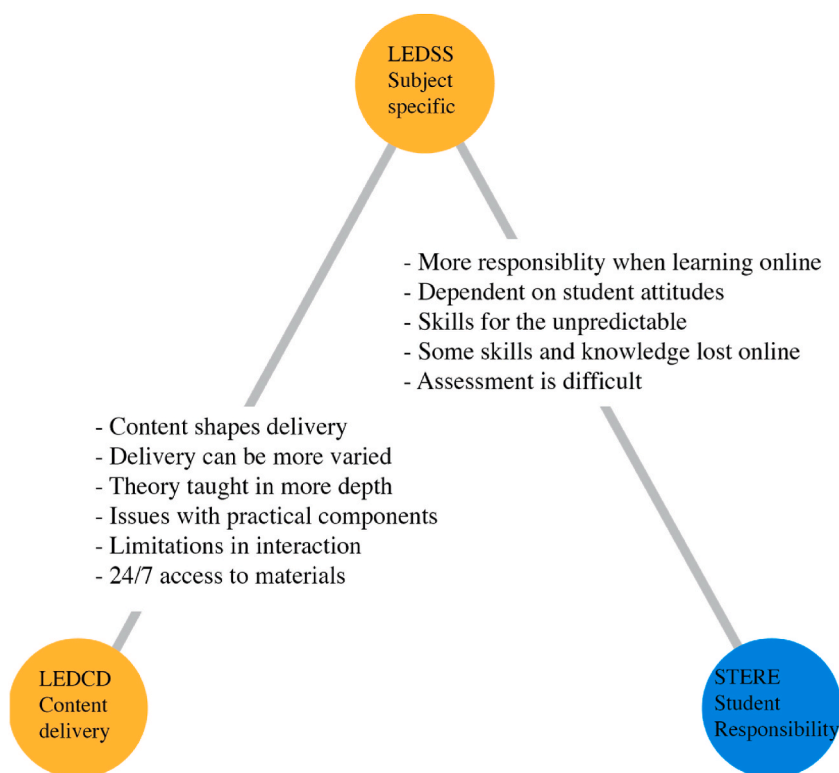


Fig. 4. Subject-specific, content delivery and student responsibility network.

spectrum of teachers' perceptions and experience along with the inherent complexities (cf. [Philipsen et al., 2019a](#)).

5.2. Towards an iterative mixed-method approach

Apart from the associations, the current study also highlights the potential of a new methodological approach to dealing with open-ended questions in large datasets. In our study, we aggregated the available qualitative data from the open-ended questions of such a dataset to explore secondary school teachers' experiences with online practices. Data from open-ended questions were analysed through a system thinking lens, using a combined method of thematic content analysis (e.g., [Neuendorf, 2018](#)) and network analysis (e.g., [Epskamp, 2021](#); [Epskamp & Fried, 2018](#)). Specifically, the open answers were first coded following an inductive thematic approach, grounded on a data-driven analysis (cf. [Charmaz, 2006](#)) to define the primary categories and related sub-categories of the participants' answers. To examine the associations between these categories, we then utilized psychometric network models ([Epskamp & Fried, 2018](#)). These models offer visualisations of the network structure via nodes and edges, with the width of edges indicating the strength of association between two variables ([Epskamp et al., 2012](#)). The resulting network provided a way to explore associations that were not fully visible through the qualitative analysis. To then validate the network model, participants' open-ended responses were reanalyzed, where codes between associations occurred together. The context and meaning of how and why these codes occurred together was considered to understand the underlying phenomena of the association.

This novel mixed method allows for visualisation of multiple associations, in this case, among teachers' experiences with online practices as they transitioned to ERT. Using their open response questions provides a way to observe associations among what they experienced during the online transition in a more holistic way, rather than looking for specific perceptions or experiences. The findings clearly demonstrate that online teaching is a complex and dynamic, social and personal endeavour that impacts teachers' identity ([Niemi & Kousa, 2020](#)). By untangling the associations between and within teachers' experiences and perceptions, an integrated approach to teacher support and professional learning for future technology-related change can be developed. The findings demonstrate that several variables such as student and teacher digital literacy and skills, along with appropriate access to technology and the Internet, also were thought to have strong effects on students' engagement and capacity to engage in online learning. In this way, our findings also provide a basis for the statement that the perceptions and experiences must be studied from a system of variables that interact in determining the success or failure of online teaching and learning. The status of one variable is continuously affected by the status of many others (cf. [Yurkofsky et al., 2020](#)). To illustrate, the [Norz et al. \(2022\)](#) used a combination of social network data and log data to identify measures of social presence. This new approach brings us to the suggestions for future research.

5.3. Implications, limitations and future research

The novel mixed-method approach used in this study clearly provided meaningful insights about the associations among teachers' experiences and perceptions of online teaching, but at the same time there are some areas for consideration. First, the associations of the network may evolve over time as teachers gain more experience with online learning. Therefore, longitudinal extensions of the current study, based on day-to-day designs for online learning, together with teachers' and students' experiences could make visible developmental patterns (cf. [Castellanos-Reyes, 2021](#)). Such longitudinal studies could shed light on how the associations may vary or remain stable over time, for instance, in the course of teachers' professional development (cf. [Valtonen et al., 2019](#)). By doing so, future research could investigate how resistant, or risk-taking ([Howard, 2013](#)) secondary school teachers are in the transition from emergency online education to blended learning, and how their perceptions and experiences relate to the results in this study.

Next, future research should also focus on the practical implications of these findings and how they relate to the implementation of online and blended learning. Therefore, the associations found in this study need to be further explored and tested across different teacher samples, background characteristics, and contexts outside the COVID-19 pandemic in which teachers were forced to adopt online teaching practices, as they transitioned to ERT. Moreover, the sample used in the current study was a convenience sample rather than a representative sample of secondary school teachers. In this respect, future research needs to purposely select teachers within a sample of secondary schools in a specific context. Online learning does not exist in isolation (see for instance [Dube, 2020](#)). Researchers need to shift their attention to the complex configuration of practices, contents, and interpersonal processes in a specific context (cf. [Norz et al., 2022](#)).

Clearly, while this was beyond the scope of the current study, future research is also needed to analyse the combined impact of individual and school-level variables (cf. [Chang et al., 2021](#); [Howard et al., 2021](#)). There is still much to learn about the differential impact of school related variables on teachers' perceptions, behaviour and experiences with online learning. Future research should therefore explore the key variables emerging from this study in association to school variables such the institutional vision about online and blended learning and the technical or pedagogical support ([Caskurlu et al., 2021](#); [Garone et al., 2019](#)). Our mixed-method approach can be used to provide a snapshot for the current status of a school or an educational institution and provide a basis for guidance towards achieving the full potential of online and blended learning.

6. Conclusion

The COVID-19 pandemic provided an opportunity for teachers all over the world to experiment with online teaching and learning practices, as they transitioned to ERT. They needed to try new tools, ways of interacting, and explore how their students were able to engage in the online space. In order to capture their unique experiences and perception we used a new mixed-method approach to reveal this innovation as a system. This inductive method, using thematic coding and network analysis, also allows for graphs. These visualisations of multiple associations can be used as a roadmap towards a more integrated approach to 1) understand teachers' practice, their perceptions and experiences and 2) determine how to better support them in online teaching and learning and future transitions to blended learning. To illustrate, our findings show that while school teachers were often not prepared because of the sudden transition, they did value some components of online learning, such as the development of students' self-regulation skills. At the same time, the insights of the network model are increasingly important to untangle the associations between in this case self-regulation and students' engagement. The association between 'Student engagement' and 'Self-regulation' points to critical issues in the context of secondary education: the opportunities for students to have increased ownership of their learning, but at the same time many of the students struggle to learn online and to regulate their online learning. Clearly, the added value of the current study lies in the richer account of how a set of important variables determining online learning can be associated. A better insight into these associations can contribute to decision making about how these variables assemble to design more targeted support for teachers' future online and blended teaching practices.

Credit author statement

Jo Tondeur: Conceptualization, writing-original draft, methodology, investigation, resources, data curation, writing-review & editing, project administration. Sarah K. Howard: Conceptualization, methodology, software, investigation, resources, data curation, writing-review & editing, project administration; Ronny Scherer: Conceptualization, methodology, software, formal analysis, investigation, data curation, writing-review & editing, visualisation; Fazilat Siddiq: Conceptualization, investigation, resources, writing-review & editing.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.compedu.2023.104866>.

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