

The Effect of Open Learning Environments in Designing and Implementing Successful Distance Learning Programmes During School Closures

Ramona Obermeier¹, Sonja Lenz¹ & Christoph Helm¹

Abstract

Large-scale evaluation studies across the globe indicate that the switch to distance learning as a result of the COVID-19 outbreak in spring 2020 had negative effects on students' study progress. Although the (negative) impact of school closures on students' learning have been intensely researched in recent months, little is known about (pre-COVID-19) instructional designs that are particularly conducive to the implementation of distance learning, i. e., designs that place students' self-regulated learning at the center. Drawing on results from existing studies, we argue that teachers' competencies, instructional quality (including feedback), and conducive features of students' learning (e. g., self-regulation skills, intrinsic motivation) represent central antecedents for students' academic achievement during periods of school closures. Thus, in the present study, we investigate the direct and indirect effects of perceived teacher competencies on students' self-rated academic achievement in distance education. Furthermore, to test the assumption that (pre-COVID-19) open learning environments are conducive to the implementation of distance learning, we analyse the moderating effect of COOL (COoperative Open Learning), an open learning format that is widely used in Austria's upper secondary schools. Results imply that students' self-regulation skills and intrinsic motivation are vital for effective learning during lockdown for all students, irrespective of the learning environment they experienced prior to school closures. Moreover, in both COOL classes and traditional classes, perceived teacher competencies are highly associated with students' self-regulation skills and intrinsic motivation. This highlights the importance of teacher competencies, irrespective of the instructional design used. Regarding the effect of the pre-COVID-19 instructional design, COOL students report significantly higher teacher competencies, feedback, and self-rated achievement. At the same time, our analyses did not reveal any significant differences between COOL students and regular students regarding the relation between our study variables. Hence, our findings broaden existing knowledge on student learning outcomes in distance learning programs and deepen un-

¹ Linz School of Education, Department for Educational Research, Johannes Kepler University of Linz, Altenberger Str. 68, 4040 Linz, Austria; ORCID: 0000-0001-7495-2360 (R.O.); 0000-0002-3089-3685 (S.L.); 0000-0001-5854-4500 (C.H.)

Corresponding author: Ramona Obermeier (ramona.obermeier@jku.at)



derstanding of process indicators of teaching effectiveness that are of major importance in distance learning. Based on these findings, theoretical and practical implications can be derived to support distance learning and deep information processing by students.

Keywords

open learning environments, distance learning, teacher competencies, feedback, self-regulation, intrinsic motivation, learning outcomes

1 Introduction

The COVID-19 outbreak in March 2020 induced manifold changes in educational practice globally. School closures led to an ad-hoc shift to distance education and therefore to severe changes in schooling methods and experiences. Students had to deal with several challenges on their own, e. g., managing digital learning and organizing their learning as well as their daily activities (Eppler, 1990; Huber & Helm, 2020a; Steinmayr et al., 2021). Austria was one of the countries that implemented distance education soon after the first infections appeared, but the new situation found the education system to be completely unprepared. The first lockdown was imposed from March 16, 2020, to May 18, 2020. A second nationwide school closure took place from November 3 to December 4, 2020 (primary schools and lower secondary schools); and from November 14 to December 4, 2020 (upper secondary schools). Immediately after the Christmas vacation (January 7, 2021), the third period of school closures started, which lasted until the semester break (February 1 or 8, 2021, depending on the region) (see Altrichter & Helm, in press, for details). Thus, Austrian students – particularly in upper secondary education – missed significantly more days of schooling than their peers in Switzerland or Germany (OECD, 2021).

From the start of the lockdowns, school stakeholders (students, parents, teachers, school administrators and education policymakers) and society were highly interested in the consequences of the pandemic for the school system and, in particular, for students' learning. To satisfy this need, several surveys (see an overview in Helm et al., 2021a) and large-scale evaluations (see an overview in Helm et al., 2021b) were conducted. As a result, we already know a great deal about how the school situation was experienced by school stakeholders during the pandemic and about learning losses and educational inequities due to COVID-19-related school closures. In contrast, little scientific knowledge is available on the question of how (pre-COVID-19) instructional designs affected students' learning during school closures. In this paper, therefore, we attempt to address this research gap by investigating if open learning formats are conducive to enhanced learning outcomes in distance learning. While there is consensus in the relevant literature that open learning formats are neither significantly superior nor inferior to traditional instruction, it is not yet known whether open instruction can unleash its potential in COVID-19-related

distance learning. “Open teaching” has established itself as a collective term for various teaching-learning arrangements that are geared toward student-centeredness and action orientation (Gruschka, 2008). This includes, for example, daily schedule and weekly schedule lessons, station learning, free work, projects, but also certain forms of group work. However, open instruction should not be misunderstood as a specific method or methodological variation. Rather, it represents a pedagogical attitude that is intended to facilitate self-directed learning in a targeted manner (Helm, 2014; Helm 2016a; Hascher, 2010). Open instruction stands for individualizing, discovering-problem-solving as well as self-directed learning and thus for the total of instructional settings that are based on the self-activity of students (Hascher, 2010; Jürgens, 2018). COOL (COoperative Open Learning; see chapter 3) is an example of open teaching.

This study is significant in several ways. Not only is it the first to investigate the effects of different pre-COVID-19 instructional designs on learning during times of school closures, it also contributes to the limited number of studies examining predictors of students’ learning success in such circumstances (Blume et al., 2020; Champeaux et al., 2020; Dietrich et al., 2020; Grätz & Lipps, 2021; Grewenig et al., 2020; Holzer et al., 2021a; Huber & Helm, 2020a, 2020b; Nusser et al., 2021; Pelikan et al., 2021; Steinmayr et al., 2021; Zaccoletti et al., 2020; Züchner & Jäkel, 2021). This study therefore aims to deepen our understanding of the mechanisms underlying distance learning during COVID-19-related school closures. In pursuing this aim, we analyse individual (i. e., self-regulation, intrinsic motivation) and contextual (i. e., teacher competencies, feedback) predictors of students’ achievement in times of school closures using students’ self-reports. This study also extends the research on school development processes, especially regarding characteristics of crisis-resilient schools. If it turns out that open instruction is conducive to enhanced distance learning, this would be a clear indicator for development towards more crisis-resilient schools. Regarding the practical relevance of the study, we have already indicated that knowledge about teaching formats conducive to distance learning (e. g., possible preventive and/or compensatory effects concerning the negative consequences of school closures) is particularly relevant to the field of educational policy. Educational policymakers would then have a tool in hand to better prepare for future school closures. Finally, the domain specificity of our study should be highlighted. Since most of our sample consists of students from various types of vocational schools, we shed light on a domain that, to our knowledge, has not yet been the subject of large-scale student surveys.

To address the questions of whether different pre-COVID-19 instructional designs affected students’ learning during school closures, we draw on theories that focus on students’ self-regulation skills and motivation (e. g., Deci & Ryan, 1993) and empirical findings that highlight the impact of instructional designs on students’ self-regulation skills and motivation (Praetorius et al., 2018). Against that background, we assume that students who are accustomed to open, self-determined learning are in favor of distance learning.

In other words, we investigate whether students' experiences concerning open learning formats are beneficial in distance learning situations.

2 Educational Effectiveness in Distance Learning

Existing models of educational effectiveness such as the context, input, process, and output model (CIPO, e. g., Scheerens, 1990) emphasize various features of teachers, students and the context as being particularly important for students' learning in traditional education. However, these models cannot simply be transferred 'as is' to distance learning situations. Rather, it is necessary to focus on those aspects that are relevant for student learning in the new situation of enforced school closures (Huber & Helm, 2020a; Steinmayr et al., 2021). To guide the investigation of relevant dimensions of distance learning, we apply the logic underlying the CIPO model (Scheerens, 2017). Following the assumption of Scheerens (1990), process indicators (teachers' instructional quality, students' use of learning opportunities) transfer the input (teachers' competencies) to the output (students' academic achievement). This process is embedded in a context that may be conducive or detrimental, for example, students' socio-economic backgrounds. In the following sections, we use the logic of the CIPO model to describe the choice and justification of those aspects that we consider to be particularly relevant for distance learning, and that we subsequently analyse in our empirical study. Note, we do not provide a sub-section on "Output Indicators" in COVID-19-related distance learning as we focus on "self-rated achievement" only here; and as we argue the link between the process's indicators and the output indicators in sub-section 2.4.

2.1 Context Indicators

Social and ethnic disparities in students' academic achievement are often explained against the background of Bourdieu's (1983) concept of capital theory (see also Becker, 2017; Blossfeld, 2019). According to capital theory, parents from higher social classes have more resources at their disposal to create environments that are more conducive to their children's learning. The literature distinguishes between the following types of capital: *economic* capital (e. g., financial resources that allow tutoring, own room, own PC); *cultural* capital (e. g., competencies, cultural goods and practices such as books and reading); and *social* capital (e. g., friends, relatives). A growing number of recent surveys on various aspects of distance learning that may account for a widening achievement gap between students from different family backgrounds confirms the assumption that parents from higher social classes fared better in compensating for the loss of school structures due to school closures (see Helm et al., 2021a). There is ample evidence that the learning environment during school closures was less conducive for socio-economically disadvantaged students than it was for privileged students; and that the former group received less or insufficient parental support (Bonal & González, 2020; Ribeiro et al., 2021; Sari et al.,

2021) – or parental support that was of lower quality (Sander et al., 2021; Weber et al., 2021). Moreover, socio-economically disadvantaged students had limited access to learning resources at home (e. g., own study space, available computer or tablet). Finally, studies have shown that there was a socio-economic-status (SES) gap in learning time (Andrew et al., 2020; Grätz & Lipps, 2021; Grewenig et al., 2020; Pensiero et al., 2020; Reimer et al., 2021). The latest review of evaluation studies on learning losses due to the first lockdown in 2021 (Helm et al., 2021a) identifies 14 studies, mainly in the UK and US, that report increased social disparities due to COVID-19-related school closures in 2020.

Given the outlined theoretical and empirical support for the importance of students' socio-economic backgrounds, we incorporate these context indicators in our empirical model (see Fig. 1).

2.2 *Input Indicators*

In empirical educational research, teacher competencies have emerged as significant prerequisites for conducive learning environments and for high quality instruction (Hattie, 2010). While distance learning during the Covid-pandemic brought the home learning environment to the forefront, it did not diminish the importance of teacher expertise. If anything, it can be argued that teachers now require skills in additional areas, such as the implementation and sensible use of digital tools, while maintaining high quality teaching under adverse conditions (Dreer et al., 2020; Eickelmann & Drossel, 2020; forsa, 2020b, 2020a; Huber et al., 2020; Lorenz et al., 2020; Schwab et al., 2020; Schwerzmann & Frenzel, 2020; Spiel & Holzer, 2020; Tengler et al., 2020). Thus, teachers' motivation and competencies that are especially relevant in distance education include their *skills in using digital tools* and being able to provide a *conducive learning environment* from a distance.

Given the outlined theoretical and empirical support for the importance of teachers' competencies and motivation in distance education, we incorporate these variables in our empirical model as input indicators (see Fig. 1).

2.3 *Process Indicators*

In line with the 'offer and use' logic of Helmke (2009), we divide process indicators into teacher- and student-related ones.

Teachers' instructional quality in distance learning. Klieme (2020) and Voss and Wittwer (2020) made recent attempts to re-think the relevance of traditional dimensions of instructional quality (i. e., classroom management, cognitive activation, individual learning support) (Praetorius et al., 2018) for distance learning. These attempts resulted in a shift away from traditional classroom management toward a greater focus on cognitive activation and individual learning support as key features of instructional quality during distance learning. Cognitive activation is related to measures that support students in

acquiring a deep understanding of new concepts, such as providing helpful feedback on completed learning tasks (e. g., Praetorius et al., 2018). Individual learning support refers to the extent to which teachers accept an emotional and supportive relationship with their students, and provide adaptively and individualized advice and feedback (e. g., Praetorius et al., 2018). Due to the discontinuation of the class structure (towards individual learning at home) and the loss of face-to-face teacher-student contact, classroom management in the narrower sense suddenly became less relevant, or even irrelevant. Instead, cognitive activation and individual learning support came into sharper focus. By adopting measures such as cognitive activation and instructional motivation (i. e., frequent and supportive feedback on student assignments) teachers had to address goals that had previously been pursued through regular classroom management, namely, keeping the students actively learning, and ensuring a high proportion of learning time. From an empirical point of view, some studies confirm that feedback was particularly relevant for students' learning during school lockdowns (Steinmayr et al., 2021; Züchner & Jäkel, 2021). Moreover, further studies (Pelikan et al., 2021; Zaccoletti et al., 2020) argue that student engagement can be significantly enhanced by adequate teacher feedback. Hence, in the present paper, we focus on *teachers' feedback* as a measure of cognitive activation and individual learning support during distance education.

Students' use of learning opportunities in distance education. From the student's point of view, learning during school closures was associated with greater autonomy and increased responsibility. In particular, distance learning increased demands upon students' *self-organisation* and *self-regulation* skills (Blume et al., 2020). In line with this assumption, many studies have confirmed the strong relationship between self-organization/-regulation and desirable student outcomes, such as motivation, engagement, and self-rated achievement in distance learning situations (Blume et al., 2020; Grewenig et al., 2020; Holzer et al., 2021a; Holzer et al., 2021b; Huber & Helm, 2020; Korlat Ikanovic et al., 2021; Pelikan et al., 2021; Steinmayr et al., 2021). From a theoretical point of view, self-regulated learning skills can be defined as a student's ability to plan, monitor and evaluate their individual learning processes, and adjust them if necessary (Dignath & Veenman, 2021). Existing theories propose that learners with high self-regulation skills engage "actively and constructively in a process of meaning generation and that they adapt their thoughts, feelings, and actions as needed to affect their learning and motivation" (Boekaerts & Corno, 2005, p. 201). Empirical findings on the significance of students' self-regulation skills – particularly resource or time management – underpin their central role; especially in forms of digital learning (Broadbent & Poon, 2015). This is also true for distance learning during school closures. Findings by Blume et al. (2021) reveal that students with higher self-regulation skills are more likely to learn independently, and ask less frequently for assistance (from parents, peers, or teachers). Furthermore, they are more likely to communicate their needs precisely and thus to seek help in more effective ways (Blume et al., 2020).

Student motivation is another central aspect of distance learning as it is necessary to begin learning activities and to keep them going, even in demanding situations (Boekaerts & Corno, 2005; Pintrich, 1999). In particular, intrinsic motivation (that can be defined as internal striving for subjective meaningful tasks and goals) seems to be vital for self-regulation and positive affective experiences in learning (Ryan & Deci, 2002). Regarding distance learning during COVID-19-related school closures, various findings confirm the assumptions underlying self-determination theory in the context of distance learning, i. e., satisfying students' psychological needs for autonomy, competence, and social relatedness, which in turn, fosters their intrinsic motivation to learn independently (Holzer et al., 2021a; Korlat Ikanovic et al., 2021; Pelikan et al., 2021). In addition, indicators of student motivation, i. e., engagement and positive emotions, are related to their effort (time spent on learning) and learning progress in distance learning situations (Helm & Huber, 2022; Steinmayr et al., 2021).

Learning time. As school closures left students largely to their own devices (especially when parents could not support them), questions quickly arose about how many hours they spent studying at home, or whether they viewed school closures as "new vacations" (Huber et al., 2020). The review by Helm, Huber and Loisinger (2021) shows that the proportion of students who invested less than two hours a day on learning ranged from 25% to almost 60% between the surveys. Studies predicting students' learning time during the lockdown (Dietrich et al., 2020; Grätz & Lipps, 2021; Grewenig et al., 2020; Huber & Helm, 2020a, 2020b; Züchner & Jäkel, 2021), identify the following individual predictors (age, gender, performance, diligence, emotions) as well as contextual predictors (school type, teaching quality, teacher support, home learning resources). Few studies investigate the relationship between students' learning effort and their achievement during distance education. Student engagement (as reported by their parents) (Steinmayr et al., 2021) and their self-reported learning time invested (Huber et al., 2020) positively predicted learning success during COVID-19-related school closures.

Given the outlined theoretical and empirical support for the importance of teachers' feedback and students' self-regulation skills, intrinsic motivation, and learning time, we incorporate these process indicators in our empirical model (see Fig. 1).

2.4 On the Relations between Context, Input, Process and Output Indicators in Distance Learning

The CIPO model (e. g., Scheerens, 1990), as well as related models on instructional processes in regular school settings (e. g., the 'offer-use' model of Helmke, 2009), postulate indirect effects of teacher competencies via instructional quality and learning quality on student achievement. This postulate has been repeatedly confirmed empirically. More concretely, and regarding the present study, teachers' competencies are related to cognitive activation (Baumert et al., 2010; Förtsch et al., 2016) and thus to the quality of teachers'

feedback on student assignments and their promotion of students' self-regulation skills. Moreover, teachers' motivation tends to predict students' motivation (by means of supporting the development of competence and autonomy) (Frenzel et al., 2009; Holzberger et al., 2016; Warwas & Helm, 2017). Finally, there is ample evidence (feedback in this study; Praetorius et al., 2018) that instructional quality and students' motivation (Deci & Ryan, 1993) – as well as students' self-regulation – are related to students' academic achievement (Boekaerts & Corno, 2005; Schoor et al., 2015; Seidel & Shavelson, 2007).

Initial studies on distance learning during the pandemic show that student motivation and their self-regulated learning and self-organisation skills (Holzer, Lüftenegger, et al., 2021a; Huber & Helm, 2020a; Steinmayr et al., 2021; Züchner & Jäkel, 2021) are particularly predictive of self-assessed learning gains in distance learning. Such gains are also affected by the quantity and quality of feedback given by teachers in distance learning situations (Huber & Helm, 2020a; Steinmayr et al., 2021; Züchner & Jäkel, 2021). We are not aware of any empirical studies regarding the effect of teachers' competencies on instructional quality during COVID-19-related distance learning. However, we assume that teachers' digital competencies are a particularly important prerequisite for the quality of distance learning during school closures (Røkenes & Krumsvik, 2014).

In this section, we have detailed our assumptions and findings from empirical studies about how teaching and learning were affected during periods of COVID-19-related school closures. In doing so, we highlighted key predictors of student learning success in distance learning situations. In the following section, we use the COOL (COoperative Open Learning) format as an example to consider the impact of open learning environments on distance learning processes.

3 Open Learning Environments

The COoperative Open Learning (COOL) open learning format was launched in 1996 at an Upper Austrian commercial school by teachers who faced increasing heterogeneity in terms of age, ability, motivation and learning speed that made conventional teacher-centred instruction almost impracticable. The primary goal of COOL is to promote students' soft skills by supporting the development of independence and responsibility. The core elements of COOL are "open instructional time slots", in which students must decide for themselves which work assignment they work on, as well as when, where and how. These phases, in which the teacher takes on a coaching role, may constitute up to one third of the total instructional time. The COOL concept emphasises student-centred teaching and cooperative learning settings (i. e., teamwork), in order to promote students' self-regulated learning skills (e. g., metacognitive skills) and social skills (e. g., cooperative learning skills). Furthermore, teachers are also encouraged to work in teams (Neuhauser & Wittwer, 2002).

Schools that wish to implement the COOL concept must undergo regular certification processes. To date, there are almost 60 COOL-certified upper secondary schools in Austria and about 1600 teachers from 160 schools have obtained the COOL trainer certificate.

As the COOL concept and COVID-19-related distance education share several common features, we hypothesize that teaching and learning during periods of school closures differed between students from COOL schools and those from traditional schools. Specifically, we assume the following differences:

- *Input.* As COOL schools had already implemented digital platforms (e. g., Moodle) prior to the pandemic, and COOL is based on teacher collaboration, the transition from face-to-face to online instruction was less challenging for COOL teachers.
- *Process.* Already before school closures, COOL teachers were accustomed to providing feedback on completed student assignments to steer students' learning.
- *Process.* Because of the "open instructional time slots" that were part of COOL prior to the pandemic, COOL students were accustomed to working and learning through assignments. Moreover, they were also accustomed to working independently in a timely manner.

Based on these considerations, we assume that – not only before the pandemic (see Helm, 2016b) but also in distance learning during COVID-19-related school closures – COOL students rated teacher competencies, feedback, self-regulated learning, and learning motivation higher, compared to traditionally taught students. Regarding "treatment validity", of course, we expect that not all teachers will implement COOL with the same intensity or levels of openness. Conversely, it is also unrealistic to assume that traditional teaching is always implemented in a strictly teacher-centred and guided manner. Rather, we assume some highly guided instruction among COOL students, as well as some highly open instruction among traditionally taught students. However, the study by Helm (2014) shows that the COOL concept is a valid indicator of open learning environments in line with the 'COOL core elements' (where are described above). Although open and traditional instruction are not fully distinct in practice, Helm's (2014) study found – by means of latent class analysis – that 69% of COOL students could be classified as open learning students, while only 27% of students from traditional classes were classified as open learning students. Hence, COOL seems to be a valid indicator of open learning environments in practice.

As to the question whether the relations described in Section 2.4 differ between COOL and traditional learning environments, it is difficult to argue clear differences. On the one hand, it is conceivable that the quality of instruction (here: feedback) and student learning (here: self-regulation, motivation, learning time) depend more strongly on teacher compe-

tencies in COOL classes, since open instruction is considered more presuppositional and challenging (Helm, 2016a). At the same time, it can be argued that in open instruction, students' self-regulation skills (including motivation and learning time) are of higher relevance for learning gains than in traditional instruction where students are more guided by teachers. However, on the contrary, since distance learning requires these skills from both COOL and traditionally taught students, the differences may be less likely.

4 Aims and Hypotheses

To date, studies have been concerned primarily with the consequences of distance learning on student outcomes (see the overview in Helm, Huber & Loisinger, 2021). Due to the recent need to implement distance learning for schools, deeper knowledge about conducive distance learning environments that foster students' self-regulation and intrinsic motivation is required.

Against the abovementioned theoretical background, this study investigates (1) if, and to what extent, various aspects of distance education (feedback received, students' self-regulation skills, students' intrinsic motivation, students' learning time) mediate the relation between perceived teacher competencies and students' self-rated academic achievement during distance learning. Moreover, we test (2) whether pre-COVID-19 instructional designs (COOL vs. traditional instruction) moderate the associations postulated in research question 1. Hence, our hypotheses are as follows:

- H1: Students' self-regulation skills mediate the effect of teacher competencies on learning outcomes during distance learning.
- H2: Students' self-reported intrinsic motivation mediates the effect of teacher competencies on learning outcomes during distance learning.
- H3: Students' perception of feedback mediates the effect of teacher competencies on learning outcomes during distance learning.
- H4: Students' learning time mediates the effect of teacher competencies on learning outcomes during distance learning.
- H5a: Students belonging to COOL classes report significantly higher values in all study variables compared to students belonging to traditional classes.
- H5b: Mediation of the 'teacher competencies–student academic achievement' relationship by all study variables differs significantly between COOL students and traditional students.

5 Method

5.1 Study Design and Sample

The study aimed to investigate students' perceptions of distance learning during school closures, and was conducted from 14th April to 23rd July 2021. Data was collected by means of an online questionnaire distributed via contact lists provided by the COOL Impulse Centre and the Department for Educational Research at the Johannes Kepler University of Linz (JKU). The study was approved by the relevant Education Administration Offices of various Austrian federal states. Participation was voluntary for the students. Data protection guidelines and ethnic research guidelines of the JKU were strictly adhered to (e. g., anonymity of the data).

The data collection has resulted in a total sample of $N = 2,290$ students. A subsample of $N = 1,539$ students who were attending upper secondary schools in all Austrian federal states were analysed in the present study. The students were $M = 16.58$ ($SD = 1.30$) years old and 68.3% of the sample were female. The proportion of students who reported that a language other than German is predominantly spoken at home was 9.9%. After weighting the sample with respect to the proportion of students who do not speak German at home and the proportion of female students in upper secondary schools all over Austria, the sample reflected the frequencies in the population. Thus, 70.6% of the students were female and 21.8% of the students do not speak German at home. Weighting by gender and language spoken at home should not obscure the possibility that the sample may nevertheless be biased with respect to other characteristics relevant to the present research questions. For this reason, more information follows on the socio-economic background of students, as well as socio-economic-related challenges in distance learning.

Regarding the pre-COVID-19 instructional designs, 41.5% ($N = 631$) of the students ($N = 898$, 40.8% in the weighted sample) were taught in COOL classes. The students in both groups did not differ in any of the indicators of the socio-economic status (language spoken at home, technical equipment, educational background of the parents).

Educational background. 13.3% of the students come from families where the mother holds an academic degree, which is a slightly smaller proportion than in the Austrian population (17.2%) according to information by Statistik Austria.

Technical equipment. 78.1% of the students did not agree at all, that they had no technical equipment to study with. Further, 9.3% did not fully agree, while 6.9% partly agreed.

Internet connection. About one third (38.4%) of the students did not agree at all, that they could not attend lessons due to an insufficient internet connection. Nearly one quarter of the students reported that their internet connection was mostly sufficient, whereas 19.6% had to deal with poor internet connections.

Parental support. Slightly more than the half of the students (51.2%) did not agree at all, that it was a big challenge for them if parents could not provide help. Further, 19% mostly did not agree with this statement, while 14.2% found it partly challenging if their parents were not able to help them.

Regarding the last three challenges, findings from a non-representative but large-scale study in Austria (Schober et al., 2020; $N = 8,349$) reveal that 94% of upper secondary students from commercial colleges ($N = 4,724$) reported having their own PC/laptop. In that study, 19% of students stated that learning was particularly difficult because of technical problems (e. g., internet connection), and 35% indicated that they did not get the help they needed at home. Hence, our sample does not appear to be significantly different from larger studies with wider coverage. In addition, the high levels of digital equipment available do not necessarily refer to a selection bias, but may reflect the fact that upper secondary vocational schools in Austria have traditionally always been technically well equipped.

5.2 Instruments

The questionnaire comprised established scale-based constructs (Huber & Helm, 2020a) on several dimensions of distance learning: teacher competencies (4 items, e. g.: ‘My teachers know how to learn digitally with us.’, Cronbach’s $\alpha = .71$); feedback (6 items, e. g.: ‘During the school closure, I could always ask my teachers if I got stuck.’, Cronbach’s $\alpha = .75$); students’ self-regulated learning (4 items, e. g.: ‘While school was closed, I structured my days so that I was able to keep up with the assignments for school.’, Cronbach’s $\alpha = .68$); students’ intrinsic motivation (4 items, e. g.: ‘I liked studying for school at home.’, Cronbach’s $\alpha = .76$); students’ time spent on learning activities (2 items, e. g.: ‘My time for school and learning during school lockdown in hours was ...’); and students’ self-rated academic achievement (2 items, e. g.: ‘School closures have affected my grades.’, Cronbach’s $\alpha = .84$). All variables represent students’ perceptions of self-related and teacher-and-instruction-related aspects.

The mentioned constructs were measured using a 5-point-Likert scale (1 = does not apply at all, to 5 = applies). The self-rated effect of school closures on academic achievement (‘School lockdown affected my test performance.’) and grades (‘School lockdown affected my grades.’) was assessed using response options from 1 = very negative, to 5 = very positive. Learning time was collected in categories ranging from 0 to 40 hours. A mean value was calculated from both items to obtain an index of learning time during school closures.

To control for omitted variables, we included information on students’ background (educational level of the parents, language spoken at home), and home learning resources (technical equipment, parental learning support) during the three periods of school closures in Austria. Home learning resources were captured by asking for aspects that had

been particularly challenging during school lockdown (technical equipment: ‘It was especially challenging for me that I did not have a computer/laptop/tablet to learn with.’; parental support: ‘It was especially challenging for me that my parents could not provide help.’).

5.3 Analyses

Student weights were calculated using SPSS (Version 26). Further analyses were conducted using R (version 4.0.5), the package lavaan (version 0.6.8 – Rosseel, 2012), and the lavaan.survey tool (version 1.1.3.1 – Oberski, 2014).

To test our hypotheses, we made use of mediation and moderated mediation analyses. Prior to these analyses, we report descriptive statistics and bivariate correlations. We conducted a comparison of latent means of students taught in COOL classes and regular classes. The latent means of students in regular classes were fixed to zero so that the latent means of students in COOL classes represent the latent group differences of interest. Cohen’s *d* was calculated in order to estimate the power of the statistical effects. According to Cohen (1988), we used the following rule of thumb to interpret *d*: < 0.5: small effect; 0.5-0.8: moderate effect; > 0.8 strong effect. The fit of the estimated models was evaluated using the cut-off values recommended by Hu and Bentler (1999): CFI \geq .95/.90 and RMSEA \leq .05/.08.

Since the moderated mediation analysis tests a mediation model for two distinct groups of students (students from COOL classes and students from traditional classes), measurement invariance was tested prior to the analyses. Testing measurement invariance (following table 2) provides information as to whether the collected data represents the same construct with the same metric for two or more distinct groups. Configural, metric, and strong measurement invariance – that are commonly distinguished in the literature (Cheung & Rensvold, 2002) – were tested using the MLR estimator which provides robust estimation standardised at mean and variance (Liu et al., 2017). Measurement invariance was calculated for all study variables with more than two indicators: ‘teacher competencies’, ‘feedback’, ‘intrinsic motivation’ and ‘self-regulation skills’. The models were compared using χ^2 -difference tests for nested models. In addition, measurement invariance was assessed using the rule of thumb according to Chen (2007), and Cheung & Rensvold (2002) for unequal sample sizes. Following cut-off criteria are defined according to Chen (2007): If the model fit of the more restricted model (representing higher levels of measurement invariance) does not drop too much (CFI does not decrease by more than .010; and RMSEA does not increase by more than .015), strong measurement invariance can be assumed.

In a subsequent step, structural equation models were calculated for both groups of students, based on direct and indirect paths following from teacher competencies via feedback, intrinsic motivation, self-regulations skills, and learning time of the students. So-

cio-economic indicators (educational level of the mother, language spoken at home) and home learning resources (technical equipment, parental learning support) were controlled within the analyses. Firstly, we estimated the direct effect of teacher competencies on student achievement (c-path, see Fig. 1). Secondly, the effects of teacher competencies on the mediating variables perceived feedback, self-regulation skills, intrinsic motivation, and learning time (a-paths) were calculated. Additionally, we specified effects from these mediators to student achievement (b-paths). Finally, paths from perceived feedback, self-regulation skills, and intrinsic motivation to learning time were specified (d-paths). The statistical significance of the indirect effects was tested using bootstrapping techniques (500 draws). Common method bias and discriminant validity were tested prior to the analyses (Tehseen et al., 2017; Zait & Berteza, 2011). Statistical power was analysed and interpreted according to Cohen (1988) with $d \geq 0.4$ indicating a small, $d \geq 0.7$ indicating a moderate and $d \geq 0.8$ indicating a high effect size.

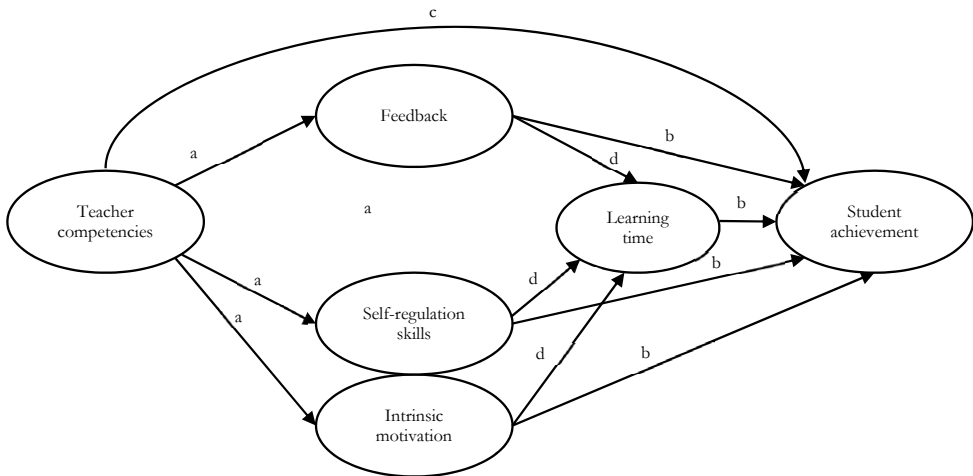


Figure 1: Schematic representation of the tested model

6 Results

6.1 Descriptive Statistics

Students' perceptions of teacher competencies ($M = 3.12$, $SD = 0.80$) and of the feedback provided by teachers was moderate ($M = 3.33$, $SD = 0.75$), as they were in the middle of the scale that ranged between 1 = does not apply, to 5 = applies. The mean values of students' self-regulation skills ($M = 3.24$, $SD = 0.88$) and intrinsic motivation ($M = 2.57$, $SD = 0.99$) in distance learning were also moderate. Time spent on learning activities averaged over all three school lockdowns was $M = 12.75$ ($SD = 5.50$) hours per week. The self-rated effect of distance learning on students' academic achievement (i. e., test results and grades) was rated neither particularly positive nor particularly negative by the students ($M = 2.84$, $SD = 0.99$). Notably, the amount of online lessons reported varied greatly between the students (min = 1 to max = 40 hours a week). Following table 1 provides correlation coefficients calculated for all investigated variables.

Table 1: Means, standard deviations, and correlations according to Pearson and Spearman

Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
1. Sex ^a	-	-	-											
2. Age	16.65	1.33	-0.4**											
3. Language ^a	-	-	-0.1**	-0.14**										
4. Parental support ^b	2.02	1.29	.08**	.00**	-0.18**									
5. Technical equipment ^b	1.42	0.93	.01**	-0.00**	-0.16**	-0.18**								
6. Academic degree mother	-	-	-0.10**	-0.08**	.05**	-0.07**	.03**							
7. COOL class ^a	-	-	-0.03**	-0.09**	.04**	-0.04**	-0.04**	.01						
8. Intrinsic motivation	2.57	0.99	.10**	.04**	.10**	-0.22**	-0.08**	-0.05	.01**					
9. Self-regulation skills	3.24	0.88	.10**	.08**	.16**	-0.23**	-0.09**	-0.03	.01**	.54**				
10. Feedback	3.33	0.75	.13**	-0.11**	.02**	-0.19**	-0.14**	-0.04	.13**	.30**	.24**			
11. Teacher competencies	3.12	0.80	.08**	-0.11**	.02**	-0.13**	-0.10**	-0.01	.13**	.31**	.24**	.63**		
12. Achievement	2.84	0.99	.03**	.01**	.08**	-0.18**	-0.06**	.02	-0.02	.37**	.33**	.16**	.16**	
13. Time (learning)	12.75	5.50	.08**	.01**	.17**	-0.06**	-0.04**	.01	.09**	.07**	.17**	.11**	.11**	.03

Note: *M* and *SD* represent mean and standard deviation, respectively.

* indicates $p < .05$. ** indicates $p < .01$

^a for dichotomous variables, coefficients according to Spearman were calculated

^b High values indicate that it was a big challenge for students if parents could not provide help or technical resources were lacking at home

6.2 Measurement invariance

As the fit of the more restricted model does not drop too much strong measurement invariance can be assumed for all the study variables. For teacher competencies, the CFI dropped only slightly (Δ CFI = .001) from weak to strong measurement variance, while the RMSEA decreased steadily (Δ RMSEA = -.011). For feedback we observed a decrease of CFI (Δ CFI = -.009) and an increase of RMSEA (Δ RMSEA = .012) from weak to strong measurement invariance. The model fit of strong measurement invariance of self-regulation was a bit lower than the fit of the model that tested weak invariance (Δ CFI = -.011, Δ RMSEA = .013) but acceptable according to the cut-off criteria defined by Chen (2007). This also applied for the difference between weak and strong measurement invariance of intrinsic motivation, where CFI dropped with an Δ of -.007 and RMSEA inclined with an Δ of .001 (see Table 2).

Table 2: Measurement invariance test of the study variables for students in COOL classes and traditional classes

Invariance level	Model-Fit							χ^2 -difference test		
	χ^2	df	p	CFI	Δ CFI	RMSEA	Δ RMSEA	$\Delta \chi^2$	Δ df	p
Teacher competencies										
Configural	30.19	4	.001	.976		.093				
Weak	34.79	7	.001	.975	-.001	.072	-.021	4.50	3	.212
Strong	38.58	10	.001	.974	-.001	.061	-.011	3.79	3	.285
Feedback										
	χ^2	df	P	CFI	Δ CFI	RMSEA	Δ RMSEA	$\Delta \chi^2$	Δ df	p
Configural	28.31	12	.005	.992		.042				
Weak	30.29	17	.024	.993	+0.001	.032	-.010	1.98	5	.852
Strong	48.98	20	.001	.984	-.009	.044	+0.012	24.90	5	.001
Self-regulation										
	χ^2	df	p	CFI	Δ CFI	RMSEA	Δ RMSEA	$\Delta \chi^2$	Δ df	p
Configural	11.37	4	.023	.993		.049				
Weak	14.98	7	.038	.993	.000	.038	-.011	3.51	3	.320
Strong	29.95	10	.001	.982	-.011	.051	+0.013	15.08	3	.002
Intrinsic motivation										
	χ^2	df	p	CFI	Δ CFI	RMSEA	Δ RMSEA	$\Delta \chi^2$	Δ df	p
Configural	28.67	4	.001	.985		.090				
Weak	30.90	7	.001	.986	+0.001	.067	-.023	2.23	3	.525
Strong	45.39	22	.001	.979	-.007	.068	+0.001	14.49	3	.002

6.3 Mediation Analysis

To test our hypotheses 1 to 4, direct (*c-path*) and indirect effects of perceived teacher competencies on students' self-rated achievement during school closures were tested in the total sample. More precisely, indirect effects of teacher competencies mediated through students' perceived feedback, self-regulation skills, intrinsic motivation, and learning time were calculated (*a-paths*). Furthermore, the direct effects of these mediators on student achievement were estimated (*b-paths*). Additionally, double mediation through feedback, self-regulation skills, and intrinsic motivation via learning time (*d-paths*) was specified. The corresponding mediation model shows an adequate fit ($\chi^2(336) = 6865.38, p < .001$, CFI = .918, TLI = .906, RMSEA = .035, SRMR = .042). Coefficients of the several tested paths are provided within table 3. Common method bias and discriminant validity of the construct were tested by Herman's Single-Factor test (Tehseen et al., 2017) and by comparing the initial mediation model with a model that included a superordinate factor on which all items loaded. Herman's single-factor test did not confirm a single-factor solution. The factor-loadings (in the model with the superordinate factor) were higher on the different scales than the factor-loadings on the additional factor. Furthermore, χ^2 -difference tests for comparison of a model with correlated and a model with non-correlated constructs revealed no significant difference ($\Delta \chi^2 = 1601, \Delta df = 9, p < .001$). Hence, discriminant validity can be assumed (Zait & Berteau, 2011).

Table 3: Path coefficients of the initial mediation model (without moderation of the learning environment)

	<i>b</i>	<i>S.E.</i>	β	<i>p</i>	<i>R</i> ²
<i>Student achievement on ... (c-path)</i>					
Teacher competencies	.11	.14	.08	.42	
<i>Student achievement on ... (b-paths)</i>					
Feedback	-.08	.13	-.06	.53	.23
Motivation	.26	.05	.29	.00	
Self-regulation skills	.21	.05	.22	.00	
Learning time	-.01	.01	-.01	.15	
Sex	-.01	.06	-.00	.91	
Age	.01	.02	.01	.65	
Language	.03	.09	.03	.74	
Parental support	-.06	.03	-.08	.02	
Technical equipment	.01	.03	.01	.85	
Academic degree mother	-.07	.09	.02	.46	

<i>Feedback on ... (a-path)</i>					.69
Teacher competencies	.92	.06	.84	.00	
<i>Intrinsic motivation on ... (a-path)</i>					.12
Teacher competencies	.62	.06	.40	.00	
<i>Self-regulation skills on ... (a-path)</i>					.14
Teacher competencies	.53	.06	.36	.00	
<i>Learning time on ... (d-paths)</i>					.04
Teacher competencies	.31	.74	.04	.67	
Feedback	.59	.71	.08	.43	
Motivation	-.47	.25	-.09	.06	
Self-regulation skills	.98	.28	.18	.00	

Note: Dependent variables are written in *italics*. Significant coefficients are **bold**.

c-path. After controlling for the mediating variables, teacher competencies no longer significantly affect students' achievement in distance learning.

a-paths. Teacher competencies significantly predict feedback ($\beta = .84, p < .001$), students' self-regulation skills ($\beta = .36, r = .41, d = .90, p < .001$), and students' intrinsic motivation ($\beta = .40, r = .45, d = 1.01, p < .001$). There is no significant effect on the mediating variable students' learning time.

b-paths. The mediators have a partial effect on students' academic achievement, which is predicted by self-regulations skills ($\beta = .22, r = .27, d = .56, p < .001$) and intrinsic motivation ($\beta = .29, r = .34, d = .72, p < .001$). Perceived feedback and students' learning time do not predict students' achievement.

d-paths. Learning time as an outcome is predicted by students' self-regulation skills ($\beta = .18, r = .23, d = .47, p < .001$) only.

Indirect effects. The results suggest a mediation of the 'teacher competencies–student academic achievement' relation via students' self-regulation skills ($\beta = .08, r = .13, d = .26, p < .001$) and students' intrinsic motivation ($\beta = .11, r = .16, d = .32, p < .001$), even if the effect size found is rather small. No significant effects were found with respect to the assumed indirect path between teacher competencies and students' achievement via perceived feedback ($\beta = -.05, p = .54$) or students' learning time ($\beta = -.00, p = .69$). The same applies to the indirect effect of teacher competencies mediated through self-regulation

skills and learning time ($\beta = -.03, p = .20$), or mediated through motivation and learning time ($\beta = .00, p = .27$). The indirect effect of teacher competencies mediated by perceived feedback and learning time is also not significant ($\beta = -.00, p = .47$).

Total effect. The total effect as sum of the direct effect of teacher competencies and the indirect effects of teacher competencies mediated by feedback received, self-regulation skills, intrinsic motivation and learning time is statistically significant and shows a moderate statistical power ($\beta = .21, r = .26, d = .54, p < .001$).

Effects of control variables. Parental support is related to students' achievement ($\beta = -.08, r = .13, d = .26, p = .02$). All other contextual variables do not predict student achievement in distance learning.

6.4 Moderated Mediation Analysis

Since we also aimed to investigate the moderation effect of COOL, further models that took into account student membership of COOL classes or regular classes were tested.

6.4.1 Hypothesis 5a – Differences of the Latent Means on Study Variables between COOL and Traditional Students

A comparison between students in COOL classes and in regular classes reveals differences in the manifest and latent mean values of the two groups. Regarding the input variable, students in COOL classes reported higher teacher competencies than students in regular classes (COOL students: $M = 3.24, SD = 0.76$; traditional students: $M = 3.04, SD = 0.82$). Comparison of the latent means of both groups reveals a statistically significant difference (*difference of the latent means* = 0.196, $p < .001$). Cohen's d indicates rather small effect sizes: $d = .25$ to $d = .29$. Regarding the mediating process variables, again, students in COOL classes rated feedback significantly higher than students in regular classes (COOL students: $M = 3.45, SD = 0.71$; traditional students: $M = 3.25, SD = 0.77$) (*difference of the latent means* = 0.201, $p < .001$).

Learning time is not significantly higher in COOL classes (COOL students: $M = 13.36, SD = 5.56$; traditional students: $M = 12.38, SD = 5.39$) (*difference of the latent means* = .080, $p = .17$). Regarding students' self-regulation and intrinsic motivation, no statistically significant differences could be observed (self-regulation skills: *difference of the latent means* = -.017, $p = .78$; intrinsic motivation: *difference of the latent means* = -.028, $p = .66$). Students' outcomes (self-rated academic achievement) during school closures were significantly higher among COOL students than regular students (*difference of the latent means* = -.077, $p = .17$). No significant differences were observed in the context variables. Thus, hypothesis 5a can be confirmed for the majority of the study variables. This is a clear indication that COOL students experienced a significantly more conducive learning environment during distance learning, compared to students in traditional classes.

Relations between input, process, and output variables. Manifest bivariate correlations (see Table 1) show that teacher competencies (as rated by students) are weakly, but highly significantly linked to students' academic achievement during school closures ($r = .16, p < .001$). Regarding the relation between teacher competencies and the mediating study variables, bivariate correlations yield the strongest association with perceived feedback ($r = .63, p < .001$). A lot weaker, but still statistically significant, are the correlations of perceived teacher competencies with self-regulated learning ($r = .24, p < .001$), intrinsic motivation ($r = .31, p < .000$), and learning time ($r = .11, p < .001$). Regarding the correlations between students' outcomes (i. e., academic achievement) and the mediating variables, the bivariate analysis points at moderate relations (feedback: $r = .16, p < .000$; self-regulation skills: $r = .33, p < .001$; intrinsic motivation: $r = .37, p < .001$; learning time: $r = .11, p < .001$).

These observed bivariate correlations suggest not only direct, but also indirect effects of teacher competencies on students' academic achievement during school closures. However, since the mediating variables are substantially related to each other as well (up to $r = .54, p < .001$), it is unclear which of the process variables plays a mediating role. Moreover, there is a negative relation between students' academic achievement and background with regard to parental learning support ($r = -.18, p < .001$), that was not controlled for in the preceding bivariate analyses. Hence, a multivariate analysis as outlined in the next section was required.

6.4.2 Hypothesis 5b – Group Differences in Mediation through Perceived Feedback and Self-regulation Skills

The models ($\chi^2(629) = 1210.47, p < .001, CFI = .912, TLI = .906, RMSEA = .035, SRMR = .062$) reveal similar effects of the included independent and mediator variables on student self-rated academic achievement.

c-path. After controlling for the mediating variables, teacher competencies no longer significantly affect students' achievement in distance learning, neither in COOL classes ($\beta = .09, p = .36$) nor in traditional classes ($\beta = .09, p = .36$).

a-paths. Teacher competencies significantly predict feedback in both classes (COOL: $\beta = .86, p < .001$; traditional: $\beta = .83, p < .001$), students' self-regulation skills (COOL: $\beta = .38, p < .001$; traditional: $\beta = .36, p < .001$), and students' intrinsic motivation (COOL: $\beta = .40, p < .001$; traditional: $\beta = .40, p < .001$). There is no significant effect on the mediator variable students' learning in both groups (COOL: $\beta = .02, p = .85$; traditional: $\beta = .02, p = .85$).

b-paths. The mediators have a partial effect on students' academic achievement, which is predicted by self-regulations skills (COOL: $\beta = .22; r = .27, d = .56, p < .00$; traditional: $\beta = .23, p < .001, r = .28, d = .58$), and intrinsic motivation (COOL: $\beta = .22, r = .27, d = .45, p < .001$; traditional: $\beta = .23, r = .28, d = .58, p < .001$). The effect power can be inter-

preted as moderate (Cohen, 1988). Perceived feedback and students' learning time do not predict students' achievement.

d-paths. Learning time as an outcome is predicted by students' self-regulation skills (COOL: $\beta = .16, r = .21, d = .43, p < .001$; traditional: $\beta = .18, r = .23, d = .37, p < .001$) with a rather low effect size.

Indirect effects. Testing of the indirect effect for both groups suggests the same mediation as in the initial model, without consideration of the moderation of the COOL concept described in section 6.2.

Total effect. The total effect is significant and of medium power for both groups ($\beta = .22, r = .27, d = .56, p < .001$).

Effects of control variables. With respect to control variables, we found significant differences between traditional and COOL students. The lack of parental support is significantly related to students' achievement in COOL classes ($\beta = -.12, r = .17, d = .35, p = .010$), but only with a small effect size. In traditional classes there is no significant relation between both aspects ($\beta = -.05, p = .23$). All other contextual variables do not predict student achievement in distance learning, neither in traditional classes nor in COOL classes.

Figure 2 illustrates the coefficients of the direct paths for the group of students taught in COOL classes, while Figure 3 depicts the coefficients of the students taught in regular classes.

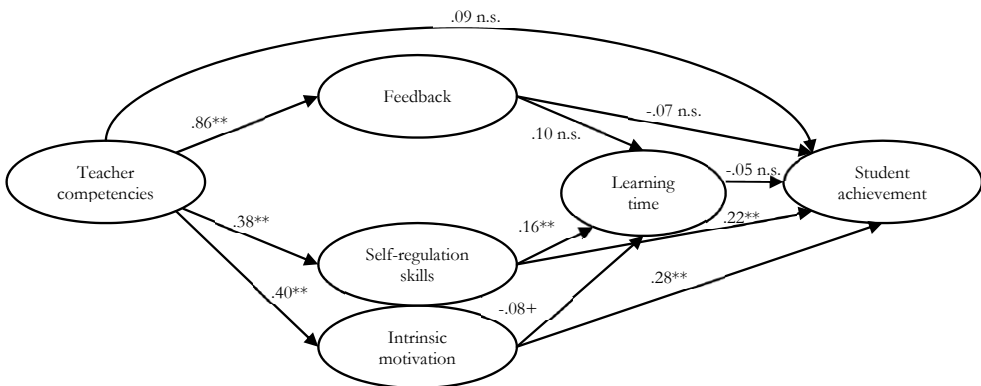


Figure 2: Initial moderated mediation model for students in COOL classes ($N = 631$)
 Notes: + significant tendency ($p \leq .09$), * significant ($p < .05$), ** significant ($p < .01$)

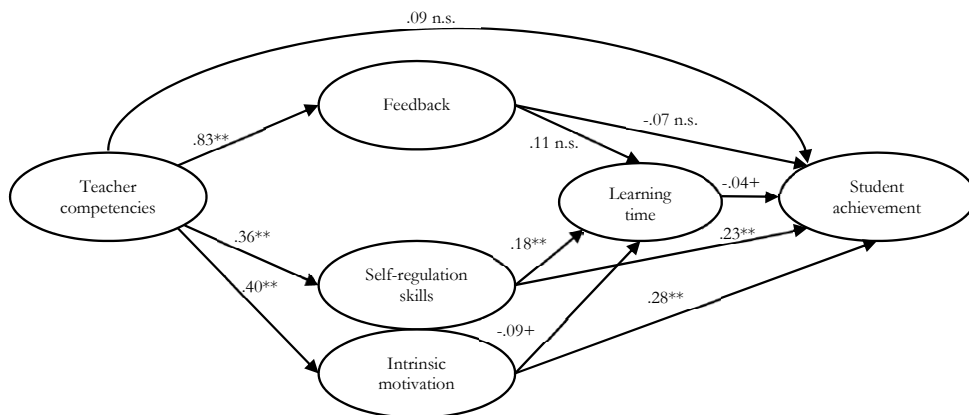


Figure 3: Initial moderated mediation model for students in regular classes ($N = 898$).
Notes: + significant tendency ($p \leq .08$), * significant ($p < .05$), ** significant ($p < .01$).

7 Discussion

Motivated by the question of whether different instructional designs prior to the COVID-19 pandemic had an impact on teaching and learning during COVID-19-related school closures, we collected data from students in both open learning and traditional class situations, and performed moderated mediation analysis to investigate the potential effects of pre-COVID-19 instructional designs.

The findings show that students' self-regulation skills and intrinsic motivation are vital for the maintenance of self-rated academic achievement during school closures. Concerning our first research question, the findings underpin the importance of intrinsic motivation (Deci & Ryan, 1993) and self-regulation skills for learning (Boekaerts & Corno, 2005; Dignath & Veenman, 2021) in distance education. This is in line with previous empirical work on predictors of students' externally or self-rated achievement during school closures in spring 2020 (e. g., Huber & Helm, 2020a; Steinmayr et al., 2021; Züchner & Jäkel, 2021). With respect to theoretical assumptions regarding the major impact of teacher competencies on student motivation and self-regulation skills (e. g., Praetorius et al., 2018), our analyses confirm relations found in regular teaching also apply in distance learning situations, where the effects found are of moderate strength. Thus, hypotheses 1 and 2 can be confirmed. Other predictors of students' academic achievement during distance learning did not prove to be statistically significant. Neither time spent on tasks, nor technical equipment, sex, age, or students' background predicted students' academic outcomes. The only exception was the lack of parental support at home reported by students, which did negatively impact academic achievement.

However, in our study, the effect of feedback – which is of high importance for learning in regular schooling (e. g., Hattie & Timperley, 2007) – did not show any statistical significance. Thus hypothesis 3 cannot be confirmed. This unexpected finding could be due to difficulties for teachers in providing sufficient feedback during distance learning (e. g., Kirsch et al., 2021), or that distance learning leads to less interaction with peers and teachers, thus holding parents more accountable. As previous studies show (Helm & Huber, 2022; Holtgrewe et al., 2020), parents' abilities to cope with the situation influenced students' positive emotions during school closures in spring 2020. Hence, one reason for the missing effect of teachers' feedback on students' perceived achievement during school closures could be that in distance learning, students are more strongly affected by their direct social context (i. e., parents and siblings) rather than by teachers.

Hypothesis 5a regarding perceptions of relevant aspects of distance learning by students from different pre-COVID-19 instructional designs (i. e., COOL classes and regular classes) was (partially) confirmed, as students in COOL classes rated teacher competencies and perceived feedback significantly higher than students in traditional learning environments. This is in line with the findings of Helm (2016b), who showed that prior to the pandemic, COOL students perceived instruction differently (i. e., higher teacher competencies, feedback, motivation, self-regulation, ...) to their peers in regular classes.

Our hypothesis 5b regarding different structural relations of the CIPO model between students in regular classes and students in COOL classes was not confirmed. Again, this is in line with the study by Helm (2016b) who did not observe any differences in the relationships between dimensions relevant for students' self-regulated learning (i. e., teachers' support of basic psychological needs, students' intrinsic and extrinsic types of motivational regulation). In addition, this finding supports the research on open learning that concludes that open learning environments are neither significantly superior, nor inferior (with regard to students learning) compared to regular learning environments (Giaconia & Hedges, 1981; Hattie, 2010).

To sum up, the overall moderated mediation model revealed differences between students in COOL and traditional learning environments only in terms of their perception of various dimensions of distance learning (higher teacher competencies, higher feedback, higher learning time, higher academic achievement, parental support). However, no differences regarding the relations between these dimensions were observed across the two groups. Hence, while COOL students reported a more conducive learning environment during distance learning, these environmental and individual aspects were not of any higher or lower relevance (regarding students' achievement during school closures) for COOL students than for regular students.

7.1 Scientific Significance of the Study

The study extends existing knowledge on relevant predictors of students' learning success during times of school closures. In line with existing studies (e. g., Huber & Helm, 2020a; Steinmayr et al., 2021; Züchner & Jäkel, 2021), we identified contextual (teachers' feedback, parental learning support) as well as individual dimensions (students' self-regulation skills, students' intrinsic motivation) relevant for students' academic achievement during distance learning. Not only does our study confirm the importance of these predictors, but also showed that these predictors are central in another, yet not investigated domain (i. e., vocational schools). Moreover, by analysing indirect effects, we contribute to the sparse number of existing studies on mediating variables of context/input-output relationships in distance education (e. g., Weber et al., 2021). However, the analysis of the indirect effects of teacher competencies on student learning in distance education, represents only the first key novelty value of our study. What is really new, is the issue of differential effects of pre-COVID-19 instructional designs on various aspects of distance learning.

To the best of our knowledge, this is the first study to investigate the effects of different pre-COVID-19 instructional designs on students' learning during times of school closures. Until now, it was unclear whether open learning formats could unleash their potential in distance learning environments. We did assume that distance learning – just like open education – requires a high degree of students' self-regulation skills. In line with our assumption, we made new scientific knowledge available, showing that open education provides an environment that – from the students' perspective – is more conducive to distance learning. By providing insights into the positive effects of COOL on students' learning during distance education, we also extend the scientific knowledge on characteristics to support crisis-resilient schools. Hence, we have added significantly to the literature on school development, as we argue that although open education may not be a panacea for the many challenges associated with school closures, it may be a key piece of the puzzle in combating the negative effects of pandemic-related school closures. Thus, open learning formats should be given special attention in preparing for future school closures. In this regard, our study is particularly interesting and relevant for educational policymakers.

7.2 Strengths and Limitations

The following limitations should be considered when interpreting the findings of this study.

Firstly, the cross-sectional data collected from the sample limits the significance of the findings. The lack of longitudinal data does not allow to control for students' prior knowledge (i. e., students' academic achievement prior to school closures), or their self-concept and learning preferences prior to the pandemic. Thus, in addition to prior knowledge,

students' preference for or against self-directed learning and digital learning could play an important role in the success of distance learning. This should be addressed in further studies.

Secondly, the sample is a convenience one. Although we did adjust our sample to be more representative by means of post-stratification with respect to student gender and their home language – and by including a range of control variables into our models – we are aware that the sample might still not be representative regarding other central aspects (e. g., students' levels of conscientiousness). Moreover, to avoid extremely high weights that would ascribe too much importance to individuals for the analyses conducted, additional aspects (e. g., parents' educational background) were not included within the stratification procedure. Hence, despite the large sample, it is not possible to generalise the findings to the entire population of vocational students in Austria.

Thirdly, student achievement was assessed by means of self-rating, since using objective test instruments would have been almost impossible due to contact restrictions during lockdown. The use of self-ratings is especially critical, since a meta-analysis by Hansford and Hattie (1982) concluded that self-ratings and performance measures are hardly associated with each other or overlap only 4 to 7%. It is therefore unclear to what extent the predictors identified here are also predictive of objectively assessed student performance measures. In addition, students' achievement was measured in the light of their perceived impact of school closures on test performance and grades. Therefore, the variable does not clearly represent any actual changes in performance, but only student assumptions in this respect. However, this is also an important piece of information. We also relied on self-reported questionnaires to assess students' self-regulation skills. To some degree, this type of acquisition is susceptible to misconceptions and participants' lack of awareness of their own learning process (Boekaerts & Corno, 2005).

Fourthly, the hierarchical structure of the data (students nested in classes, nested in schools) was considered only regarding the school level. For reasons of anonymity, it was not possible to collect information on students' class membership. However, we argue that, to a certain extent, distance learning dissolved the classroom structure and put more focus on individual learning at home. In addition, the study does not focus on any particular subject, so students did not necessarily evaluate the same teachers. Hence, student judgments should be rather independent of their class, and thus the class level may be less relevant.

Finally, learning is always embedded in a subject domain (e. g., Mathematics). The interdisciplinary study presented here lacks domain-specific considerations and is therefore subject to limitations in terms of generalisability regarding specific subjects.

We call on researchers to perceive these limitations as an impetus for future studies.

7.3 Conclusion

Did different instructional designs prior to the COVID-19 pandemic have differential effects on teaching and learning during COVID-19-related school closures? Our study shows that in COVID-19-related school closures perceived teacher competencies were significantly associated with students' self-rated academic achievement. However, this association was fully mediated by students' self-regulation skills and intrinsic motivation. This finding brightens the interplay of teacher and student characteristics in distance education. Moreover, we found that students in COOL classes rated various dimensions of distance learning that are considered conducive to students' learning (i. e., teacher competencies, feedback received, learning time) higher than their peers in traditional classes. However, no differences regarding the relations between these dimensions and student achievement were observed across the two groups. Hence, we conclude that while COOL offers a learning environment that seems to be more conducive to distance learning, the mechanisms that underly teaching and learning (i. e., various mediating effects) do not differ between COOL students and regular students. However, as self-regulation skills and intrinsic motivation are vital for effective learning of all students in distance education, those aspects should be facilitated in the context of teaching i. e. by providing cognitive activating tasks and direct feedback (e. g., Blume et al., 2020; Hosler & Arend, 2012; Räisänen et al., 2020).

Disclosure of potential conflicts of interest

We have no conflicting interests to declare.

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