

Distant science practicals–COVID-19 experience from Czech lower secondary schools

Vanda Janštová^{1*} , Helena Zdobinská¹ 

¹ Department of Biology Education, Faculty of Science, Charles University, Prague, CZECH REPUBLIC

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Abstract

This study contributes to description of teaching changes resulting from COVID-19 epidemic. It focuses on online teaching of practical exercises in science subjects from pupils' and teachers' perspectives. Views on the distance learning of practical exercises were obtained from Czech lower-secondary school pupils (n=543) and science teachers (n=24). Most teachers conducted science practicum classes using a combination of synchronous and asynchronous methods and rated support from school management as rather adequate. Teachers assigned fewer hands-on activities, specifically experiments, observations, and activities resulting in a product, in distance teaching than in face-to-face lessons, although they rated them as the most useful. Pupils found experimentation and observation to be the most interesting and useful, followed by activities that result in a product (e.g., herbarium). Pupils generally preferred the present form of practical activities.

Keywords: science teaching, distance learning, science practicals, COVID-19

INTRODUCTION

Voluntary distance education has a tradition of several decades and is comparably effective to traditional face-to-face teaching at all levels of education and brings benefits in saving time and costs (Bernard et al., 2004; Cavanaugh et al., 2004). At the same time, although university students are satisfied with distance education, they still prefer traditional face to face approach (Akyildiz, 2020; Allen et al., 2002; He et al., 2021).

Forced Online Teaching

Due to the COVID-19 pandemic, many schools around the world had to switch to distance teaching. Of course, some aspects of distance education suited some pupils (up to 44%), while others (21%) did not find it suitable at all (Rokos & Vančura, 2020). In online education, communication is generally more of a challenge, even in synchronous education where at least the participants' cameras are on to help. If students do not use the cameras, which was a common situation in Czech schools (Pavlas et al., 2021), the teacher may miss out on immediate feedback and the opportunity to help

guide students to the correct procedure and outcome (Moorhouse, 2020). Unsurprisingly, the use of the learning management system (LMS) increased during lockdown teaching, particularly Microsoft Teams in Slovenia. Other means of digital communication such as email or Moodle were already widely used before the lockdown; therefore, there was only a slight increase in usage during the lockdown (Ploj Vrtič et al., 2021), especially in the first year of distance education (Pavlas et al., 2020). The use of applications such as Kahoot or Padlet changed only minimally, i.e., remained low even during the lockdown, when most teachers probably did not have the capacity to try new applications (Ploj Vrtič et al., 2021). In the second year of distance education, there was typically a consolidation of LMS within the school, and in the Czech environment, teachers most frequently used MS Teams (Pavlas et al., 2021). As shown by Amin and Sundari (2020), different LMSs are rated as similarly suitable, and users do not see major differences between them. Students appreciate writing in chat, which is more convenient for them than writing a formal email or going to the teacher's office for a consultation (Lee et al., 2021). At the same time, individual feedback is essential for them even in distance education (Balderas-Solís et al., 2021).

Contribution to the literature

- Teachers and pupils recognize experiments, observations, and other hands-on science activities as useful and interesting parts of school science, but these methods were not included in distant science teaching during lockdown.
- Although inspiration on distant practicals teaching quickly emerged during lockdown, teachers did not include suggested kitchen experiments, outdoor observations, or computer simulations/virtual reality. This is probably due to the lack of capacity to search for the materials.
- We suggest that these methods should become part of pre-service teacher training.

What students lack in distance education is contact with peers (Parent et al., 2021; Rokos & Vančura, 2020). Another disadvantage of forced distance education is the “opening of educational scissors” between children from socioeconomically weaker and stronger families. This is due to the greater attention and motivation problem for students with lower socioeconomic backgrounds, which is also evident in face-to-face teaching, while for online teaching, the family could not provide the necessary technology for the child due to economic reasons (Pavlas et al., 2021). Some studies concluded that although the social aspect of teaching was unfulfilled, university students managed teaching during lockdown better than often thought, specifically rating that they knew what to do and felt guided and supported by their teachers (Lee et al., 2021).

Distance Teaching of Practical Exercises

The teaching methods of all subjects had to be adapted to the online form, including practical exercises in science subjects, which are traditionally considered as opportunities to link theory with practice (Flores & Marzullo, 2021), for example, by verifying theory, deriving new knowledge by conducting experiments, observing real specimens, creating models, or e.g., herbarium. As shown by Abrahams and Millar (2008), teachers most often choose the development of manual skills, such as working with microscopes and other laboratory tools, as learning objectives for science practicals. Fewer teachers choose objectives such as research and the development of problem-solving competence, although this form of teaching is also suitable for the development of other skills and competences (Kelley, 2021a). During the pandemic and subsequent enforced distance education, students were deprived of some of these opportunities. Because teachers typically improved their use of information technology during pandemics (Pavlas et al., 2021), many sought to adapt hands-on activities to the home environment, devising alternative activities or using existing digital versions of face-to-face activities (Kelley, 2021a; Moorhouse, 2020).

In the case of hands-on activities for which aids are necessary, two options emerged. The first was to use similar home-made aids (Cash, 2021). The disadvantage of these may be that they do not meet the necessary

criteria (e.g., safety criteria such as heat resistance). If they are absent at home, the purchase of aids should not significantly interfere with the student’s budget. The second option was to mail the necessary materials to the student or have them ready for pickup. Students can then work with the lab equipment provided for the experiment, which can have a positive effect on their motivation (Kelley, 2021b). Safety is also a consideration for distance hands-on activities that students do at home with provided equipment; for example, chemistry experiments may require working with fire, or toxic or flammable chemicals, or glass and sharp objects (Flores & Marzullo, 2021; Kelley, 2021b). Replacement of some instruments is problematic, while at the same time, for example, home versions or online applications exist for the microscope (Cybulski et al., 2014); see, e.g., <https://www.ncbionetwork.org/iet/microscope/>). Virtual simulations can also be used in cases such as modeling different processes (<https://phet.colorado.edu/>) or virtual dissections (Digital Frog International Inc., 2016; Lalley et al., 2010). Biology teachers recognize both alternatives of dissections as interesting and even pleasant and fun activities (Havlíčková et al., 2018). Virtual execution of experiments shows usefulness for understanding concepts (Chiu et al., 2015; Jaakkola et al., 2011) and for alleviating the nervousness of laboratory work when virtual activity is used before real laboratory work (Gungor et al., 2022). Therefore, a combination of virtual lab and hands-on laboratory seems to be ideal but could not be done during lockdown teaching.

During the pandemic, teachers had the opportunity to choose from a variety of hands-on activities, such as traditional experiments and observations, with more or less adaptation to the distance version of the lesson (Kelley, 2021a). During the distance activities, there was also a chance to try experiments and observations that required a long time to process (e.g., Cash, 2021) and to divide the work into parts from which it was mandatory to submit part of the work continuously (Marincean & Scribner, 2020). For the asynchronous version of a course, there is an option of sharing text materials and instructions for the student to refer to when needed (Kelley, 2021b).

In distance education in Czechia, hands-on activities were limited, with frontal instruction predominating (Pavlas et al., 2021). When teaching physics, teachers

mostly aimed to meet the lower goals of Bloom’s taxonomy as defined in Krathwohl (2002), with a few cases focused on application, which the authors argue is also typical of teaching the subject in a full-time format. In physics specifically, teachers had difficulty selecting experiments that could be done remotely. Teachers tried to reformulate the assignment so that the task had a practical application and was linked to everyday experience, or to use video as a form of motivation (Duffek et al., 2020).

Most of the papers focused on teaching or learning science subjects in general. We were specifically interested in teaching science practicals, as these are a specific part of teaching science subjects.

Aims

The aim of this paper is to map how distant practical exercises in biology, chemistry, and physics were taught during the COVID-19 pandemic forced lockdown in selected lower secondary schools in Czechia, in particular:

- (1) to describe the technical set-up (synchronicity/ asynchronicity of teaching, means of communication, perceived availability of teacher-student interactions), school support and their possible changes during the lockdown and
- (2) to identify the most used methods and methods, which were subjectively perceived as the most interesting and useful by both pupils and teachers.

METHODS

A questionnaire was designed for pupils and their teachers of science subjects, namely biology, chemistry, physics. The questionnaires (Kelley, 2021a; Rupnik, 2021) containing similar questions about the conduct of distance hands-on activities, communication platforms, and students’ opinions about them were used as inspiration. The pupil and teacher questionnaires are complementary, containing the same or similar questions, namely open-ended and closed-ended multiple choice or scale questions. Most of the questions are related to practical activities during distance education and ask for respondents’ subjective evaluation. The student version of the questionnaire contains a total of 21 questions, while the teacher version contains 32 questions,

- (1) with a choice of answers on a five-point scale (completely agree–agree–I cannot judge disagree–completely disagree) and

Table 1. Synchronous & asynchronous teaching by subjects taught

Type of teaching/subject	Biology	Chemistry	Physics
Synchronous	0	1	0
Asynchronous	4	6	0
Combination	7	1	11

Note. Total is higher than number of respondents because teachers could teach two subjects

- (2) open-ended.

The anonymous paper and pencil questionnaire survey was conducted in five available schools in Prague and the Central Bohemia Region. Preference was given to classes that had completed both years of distance education at the same school and the same grade level.

Four respondents who were found to have completed the questionnaires falsely were excluded from analysis. Responses to open-ended questions were classified and evaluated as frequencies. Low-frequency responses from students were categorized as “other”. The independence of responses to selected questions was tested by the Pearson chi-square test of independence. A difference was considered significant if the significance level p was less than 0.05.

Respondents

The questionnaires were administered to 535 pupils and 24 teachers (10 physicist, five biologists, two chemists, seven who taught a combination of science subjects; 16 teachers reported teaching also other subjects such as maths, languages, geography, and IT). The mean duration of experience was 18 years, with a median duration of experience of 20 years. The shortest length of experience was three years, the longest 37 years.

RESULTS

Characteristics of the Technical Set-Up

Most teachers chose a combination of synchronous and asynchronous teaching for the subject, although in case of chemistry, asynchronous teaching predominated. There was also a single case of only synchronous teaching among chemistry teachers (**Table 1**).

Most of the teachers interviewed used a combination of communication media. Only four respondents chose one option (**Table 2**).

The average student rating of the suitability of online platforms for practical distance activities was slightly positive ($\mu=3.67$). Teachers were more likely to rate online platforms as appropriate ($\mu=3.96$). At the same

Table 2. Communication means used in teaching

Mean of communication	MS Teams	E-mail	Google Classroom	Cell phone message	SMS	Pick up at school	Other
Number of teachers	19	15	7	7		5	7

Note. Total is higher than the number of respondents because teachers could indicate more means of communication used

Table 3. Frequencies of response changes between two school years of distance education

	None	Adaptation	Mean of communication	Organization	Loss of motivation	Other
Teachers	9	8	4	6	1	0
Pupils	186	104	116	97	14	26

Table 4. Teaching methods used before COVID-19/during forced distance education

Method/subject	Number of teachers using the method before COVID-19/during force distant teaching		
	Biology (12)	Chemistry (8)	Physics (11)
Pupils' experiment	6/3	6/3	11/9
Demonstration experiment*	8/1	8/0	11/8
Watching videos	12/12	8/7	11/11
Virtual reality	0/0	0/0	0/1
Hands-on making products	8/7	3/2	7/6
Work with literature resources	8/10	6/6	6/6
Other	2/3	0/0	0/0

Note. *Significant decrease

time, neither teachers nor students could assess whether the use of these platforms for practical activities of distance education led to increased student productivity (teachers: $\mu=3.08$, $Me=3$, $min=1$, and $max=5$; students: $\mu=2.64$, $Me=3$, $min=1$, and $max=5$). There was no difference in the perception of MS Teams and Google Classroom from the point of suitability for teaching online science practicals ($\chi^2=14.98$, $df=8$, and $p=0.06$). Changing the communication mean and adaptation were the two most frequently mentioned changes between the first and second lockdown year (Table 3).

Most teachers, in their opinion and in the opinion of their students, did rather better during the second year of distance education (teachers: $\mu=4.42$, $Me=4$, $min=4$, and $max=5$; students: $\mu=3.75$, $Me=4$, $min=1$, and $max=5$). Similarly, and conversely, teachers and pupils consistently rated that pupils "did better" in the second year (teachers: $\mu=3.88$, $Me=4$, $min=3$, and $max=5$; pupils: $\mu=3.63$, $Me=4$, $min=1$, and $max=5$).

The pupils agreed that the teachers were available for consultations ($\mu=3.8$, $Me=4$, $min=1$, and $max=5$) in concordance with teachers claiming they had contact with their students ($\mu=4.13$, $Me=4$, $min=2$, and $max=5$).

Teachers would like to keep the selected features of the online platforms (sharing materials, chat) for future face-to-face teaching; if the students responded, they would also select the advantages of using computers ($n=110$). Furthermore, the pupils appreciated the later start of the class ($n=80$). On the contrary, teachers were most bothered by the lack of contact, which pupils mentioned only in fifth place. The students either did not mind the overload of learning and the increased demands of teaching ($n=166$) or were bothered by the increased workload ($n=115$).

School Support

Most of teachers ($n=14$) confirmed that the school provided students with various equipment, especially of a technical nature—tablets, PCs, laptops, microphones,

and MS Office software. Only one respondent mentioned distilled water for the school Olympiad round as a tool provided. At the same time, according to teachers, schools provided resources and instructions needed to use suitable online platforms ($\mu=3.79$, $Me=4$, $min=1$, and $max=5$), while for resources and instructions to adapt practical activities to the online environment, teachers were unable to assess the school's support ($\mu=3.33$, $Me=3$, $min=1$, and $max=5$).

Most teachers reported having worked with multiple resources during distance activities. Only three managed to do with a single resource—youtube.com. Videos from this source were used in distance education by all but one respondent ($n=23$), and articles or book resources were the second most used source (17) followed by the internet (15). The following groups were mentioned in the "Facebook" responses: Teachers+, Science Teachers, and Teachers Chamber. In the choice of 'other', some attributed the use of apps (Nearpod, Learning apps, Plant-net, Bird-net, and Whatsapp). One teacher used radio programs as a source, audiobook about Czech history. Three teachers relied on their own materials. Half of the teachers ($n=14$) mentioned 'recommended by the school' as a criterion for choosing sources.

Teaching Methods

Online distance education has led to a decline in both student and demonstration experiments, especially in biology and chemistry. The decrease was significant in the case of demonstration experiments ($\chi^2=6.56$, $df=2$, and $p=.04$). There was no significant increase in hands-on activities suitable for distance education, with only one respondent using virtual reality (simulations) to teach physics compared to regular teaching. Another respondent mentioned field observation during distance education as an actual activity, and the application "PlantNET" was mentioned (Table 4).

Although teachers, except physicists, made minimal use of the experiment in distance form, they rated it in agreement with the students as the most interesting and

Table 5. Frequencies of responses to the most interesting activity

	Nothing	Experiment	Hands-on making products	Other
Teachers	0	13	4	5
Pupils	204	156	85 (39 out of these herbarium)	8

Table 6. Frequencies of responses to the most useful activity

	Experiment/observation	Combination	Teacher presenting	None	Hands-on making product	Other
Teachers	5	5	5	3	0	6
Pupils	95	0	0	302	62	84

useful activity in distance science practicals (**Table 5** and **Table 6**). The rationale was that it was an active (teachers) or fun and interesting (pupils) method. The pupils positively rated that they could work with living organisms (n=45), independently (n=38), or that such teaching made them move (n=32). They also appreciated the demonstrations (n=23).

DISCUSSION

As in other schools in the Czech Republic (Pavlas et al., 2020), teachers in our case most often assigned distance education activities using a combination of synchronous and asynchronous instruction. A nationwide survey (Pavlas et al., 2020) showed that in the first year of the lockdown (2020), most teachers used email and phone to communicate with students; if they chose an LMS, it was most likely Google Classroom. In the second year of distance education, teachers were more likely to use Microsoft Teams (Pavlas et al., 2021). The increased use of Microsoft Teams is consistent with our data, and the change in communication mode was also observed by the pupils in our sample. They, in agreement with Amin and Sundari (2020), rated both platforms as comparable. The unification of teaching under one LMS, which took place in most Czech schools (Pavlas et al., 2021), removed one of the disadvantages of distance education repeatedly mentioned by the pupils from our respondents. Schedule changes such as later start times and less synchronous teaching typical of other schools in the Czech Republic were also confirmed in our sample grammar schools (Pavlas et al., 2021).

Despite a significant number of studies describing the possibility of transferring a hands-on activity to a distance form suitable for the lockdown case (Salta et al., 2022), its frontal form prevailed in Czech schools during distance education (Pavlas et al., 2021). Our data showed that demonstration experiments, in particular, were used significantly less during distance education than for face-to-face instruction, despite the fact that the experiments were generally rated as useful and fun by teachers and students alike, and demonstrations could be made online. The experiments were not replaced by other activities that might be expected, such as virtual simulations (e.g., Wieman et al., 2008) or videos; only one physics teacher used virtual reality to teach practical science exercises. This suggests that teachers did not try

new approaches, likely due to lack of time and capacity as hypothesized by Ploj Vrtič et al. (2021), or due to being unable to use written English resources. Therefore, we believe that it is important to guide pre-service teachers to search for diverse educational resources and make decisions about their quality based on criteria of suitability for teaching (not only) practicals so that they cover the desired areas of science as discussed by (Hodson, 2014). Pre-service teachers should be able to use pedagogical content knowledge related to online education (Rapanta et al., 2020) and be familiar with a broad spectrum of online applications and other approaches suitable for distance education including inquiry, making and using products, simulations, support for outdoor education, in order to prepare them for the possibilities that will arise during their practice.

Distance learners appreciated the opportunity to stay in their home environment and therefore get up later and share digital materials. The next most commonly mentioned positive, at least among students, was personal convenience and the ability to organize their own time. Supporting time management was recommended and its improvement was perceived as one of the possible positive outcomes by Czech authorities (Pavlas et al., 2020).

If teachers mentioned any change during the two years of distance education (the category of none has the highest frequency), it was most often adaptation, and thus better mastery of online resources. As expected, digital competence improved significantly during distance education (Pavlas et al., 2021). However, as shown by Dolenc et al. (2022), the vast majority of university teachers plan to return to the pre-lockdown way of teaching and therefore are unlikely to capitalize on their newly acquired experience, which may be due to the fact that online teaching was not their choice, but they were forced into it. Based on our data, we conclude secondary school teachers will also not enrich their teaching practices based on the experience of COVID-19 except for sharing learning materials online. Maintaining online sharing of materials was also reported from other schools in Czechia (Poluhová, 2020).

One of the disadvantages most frequently mentioned in the literature was the epidemiological reason for lockdowns, that is, limiting contact (Pavlas et al., 2020; Rokos & Vančura, 2020). Consistent with these studies, this was also the most frequently cited disadvantage for

teachers in our sample. However, the students who mentioned the limitation of contact as a disadvantage were less than 5%. This may have been due to the fact that, unlike the aforementioned studies that worked with primary school pupils, we asked respondents from secondary schools. Other predicted disadvantages that emerged in the pupils' responses were problems with technology and difficulty concentrating in the home environment. The most frequent response, in agreement with Rokos and Vančura (2020), was being overwhelmed by schoolwork.

Limitations of the Study

The data for this article were collected after the lockdown, so the respondents may not have remembered everything that would have been interesting to record. This is an accessible sample of respondents from Prague and the Central Bohemian Region who expressed their opinions and self-assessments.

CONCLUSIONS

Practical activities were generally fewer in distance science courses than in face-to-face courses, especially experiments, which were consistently rated by students and teachers as the most interesting and useful activity after self-creation. In general, the pupils appreciated when an activity got them moving. Only one teacher used virtual reality in distance education showing the teachers from our sample did not take full advantage of the opportunities offered for distance practical exercises in science subjects. Possibly knowing how to search for useful teaching resources and knowing some online resources in advance would increase the probability that teachers will use them. Therefore, incorporating the possibilities of distant teaching into the pre-service teachers' curriculum is advisable.

Although pupils generally preferred face-to-face setting, they appreciated the possibility of organizing their own time with distance education, while the disadvantages were overwhelming schoolwork and excessive demands on teachers. Teachers more than pupils lacked physical contact and immediate feedback.

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