






## Determination of student's perception during biology online learning at COVID-19 crisis

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### Abstract

Due to the COVID-19 pandemic, there has been a significant shift from traditional, in-person teaching to online education, which has become indispensable. Nowadays, online learning is increasingly popular, encompassing educational programs delivered exclusively through digital platforms like video conferences and virtual classrooms. The flexibility of online education allows students to learn at their own pace and according to their schedule, but it also poses potential disadvantages. In this article, we explore the impact of online teaching on the practical subject of biology and students' perceptions of education in primary, secondary, and tertiary schools in Slovakia. Our research focuses on evaluating the progress of online biology teaching, examining methods of knowledge testing, and assessing both the positives and negatives.

**Keywords:** COVID-19, online education, biology, students

## INTRODUCTION

In 2019, the world was struck by the unexpected outbreak of the COVID-19 pandemic, which originated in China and spread worldwide (Bacher-Hicks et al., 2021; Mseleku, 2020). The majority of individuals infected with the virus experience only mild symptoms, but some people become seriously ill and require medical assistance. It is precisely for these reasons that the fight against the COVID-19 pandemic necessitated the implementation of new and strict measures to mitigate the spread of the virus (Adedoyin & Soykan, 2023; Camargo et al., 2020). In order to prevent the rapid spread of this disease, governments issued various regulations related to restrictions on movement and reduced opportunities for large gatherings of people in one place. The control of movement and reduced contact had several impacts on socio-economic systems (Johnson et al., 2021; Maatuk et al., 2022).

Strict regulations led to temporary and selective closures not only of businesses and services but also of

schools (Hoofman & Secord, 2021; Tang, 2023). Many educational institutions were closed in various parts of the world, including Slovakia. The closure of schools and universities resulted in the limitation of virus transmission, disrupting traditional classroom teaching, and leading to a shift towards online education at all levels of schooling. The introduction of online teaching necessitated the modification of curricula, syllabi, and assessment methods to ensure quality education despite the existing limitations (Rolak et al., 2020; Tang, 2023). As a result, each educator had to independently modify traditional methods, considering the available resources as well as the impact these changes might have on students. Educators were subsequently compelled to continue researching innovative teaching approaches for two years, aiming to effectively address the challenges posed by this crisis and simultaneously provide access to quality education for all students (Bakare et al., 2023).

The sudden transition to online education brought significant challenges for families and was not without problems. Multiple households were forced to switch to an online mode of teaching not only in terms of their

### Contribution to the literature

- This study significantly contributes to the existing literature by comprehensively exploring the impact of the COVID-19 pandemic on biology education, particularly in Slovakia, and shedding light on students' perceptions of online teaching across different educational levels. Through a detailed analysis of students' experiences and perspectives, the study offers valuable insights into the challenges and opportunities associated with the transition to online biology education.
- Moreover, the research provides a nuanced understanding of the practical implications of online teaching methods, assessment strategies, and the overall effectiveness of online education in the context of biology instruction.
- By addressing these critical aspects, the study enriches the scholarship on online education during times of crisis and informs future educational practices, emphasizing the importance of adaptable teaching methodologies and student-centered approaches in remote learning environments.

work but also with respect to the education of their children and students. Due to school closures, there was pressure on households to ensure that every child had access to online learning. Furthermore, the lack of personal interactions between teachers and students made it difficult for some individuals to feel motivated and engaged in their studies (Babosová et al., 2022; Zheng et al., 2021).

During the teaching of natural science subjects, multiple complications arose. As practical activities and experimentation play an important role in understanding and exploring the natural world during in-person biology teaching, transitioning to online education required finding creative solutions. Verbal methods alone are insufficient to effectively convey scientific knowledge to students. Therefore, teachers had to search for alternatives to enable students to explore and discover biological phenomena in an online environment. Teaching natural science subjects generally requires constant improvement of pedagogical approaches and the processing of topics that would enable students to grasp the topic more easily. In the teaching of biology, which was the focus of our work, it is important to teach students to make connections between theory and what they see in everyday life. In our study from 2022, we examined how biology teachers at primary, secondary, and tertiary schools perceived the outbreak of COVID-19 during school closures and how they adapted to new teaching routines and activities due to distance learning (Babosová et al., 2022). Online teaching led to the experimental part being particularly limited, due to various aspects such as inadequate feedback, lower levels of discipline, and especially the inability to demonstrate the required practical skills.

This work aims to judge and compare the effects of changing the methods of teaching the natural sciences, concretely biology, from the perspective of Slovakian students of primary, secondary, and tertiary schools during the COVID-19 quarantine. We endeavored to find the answers pertaining to the three most important research questions:

**RQ1** How did online teaching of biology take place at different school levels?

**RQ2** How were students assessed/tested on their knowledge during online biology teaching?

**RQ3** What is the opinion of students on the advantages/disadvantages of online biology education and its use in the future based on the experiences gained during the COVID-19 pandemic?

We expect that our results will help to improve and optimize teaching in Slovakian schools.

## MATERIALS & METHODS

### Research Design

The main objective of this study was to identify the perspectives of students from elementary, middle, and high schools on the impact of online teaching of biology. To collect data, we used an online questionnaire survey prepared in Google Forms. The questionnaire contained 18 questions combining open and closed questions, as presented in **Table 1**. Most of the questions were close ended (with options for single or multiple choices). Respondents also had the option to provide a brief open-ended response to each question. The questionnaire was shared via email by teachers who then made it accessible to their students. In the introductory section, students were informed about the purpose of the study, emphasizing its significance and the processing of data according to the ethical standards of the Constantine the Philosopher University in Nitra.

The first section contained two questions focusing on basic information (school type and duration of biology lessons during online teaching). The second section included research-related questions about the differences between in-person and online forms of education regarding preparation difficulty, resources, practical components of the subject, testing, exam writing, general positives, and negatives. The questionnaire was anonymous, and it took approximately eight minutes to complete.

**Table 1.** List of the questionnaire's open and closed questions

Questions	Characteristic
You study at:	closed-ended question
How many minutes did the online biology lesson last?	closed-ended question
Was online learning more challenging for you than traditional in-person learning?	closed-ended question
Were you able to focus on the lecture during online learning?	closed-ended question
What tools did the biology teacher use during online teaching?	open-ended question
How were practical biology exercises conducted during online teaching?	open-ended question
In what way did the teacher provide you with study materials for biology?	open-ended question
Did the teacher assign homework during online biology teaching?	closed-ended question
During online biology class, did the teacher also conduct assessments?	closed-ended question
Did you have enough time to complete the online tests during the assessments?	closed-ended question
During the online test, did you work:	closed-ended question
Online education was for you:	closed-ended question
What advantages did online learning have for you?	open-ended question
What were the negatives of online teaching for you?	open-ended question
Did online teaching have an impact on your health?	closed-ended question
How did the teacher handle it if you didn't provide prior notification for not attending online teaching?	closed-ended question
How would you describe online teaching for you?	closed-ended question
Could you imagine biology teaching in the future being conducted in a blended format (combining in-person and online methods)?	closed-ended question

**Table 2.** Demographic information

Variable	n	Percentage	SD
Students	Primary	94	15.67
	Secondary	413	68.83
	Tertiary	93	15.50
Lesson duration	20 minutes	25	4.17
	30 minutes	34	5.67
	45 minutes	382	63.67
	60 minutes	40	6.67
	90 minutes	119	19.83

Note. SD: Standard deviation & n: Number of respondents

### Study Group

A total of 600 students from primary, secondary, and tertiary schools in Slovakia voluntarily participated in the research. The majority of participants were students from secondary schools. The most common duration of a biology lesson during online teaching was the same as in the in-person form, which is 45 minutes (Table 2).

### Data Analysis

The collected data were transferred from Google Forms to the analytical program MS Excel after the closure of the questionnaire survey. Subsequently, they were evaluated using inductive statistical methods. For short responses, we utilized open coding and subsequent categorization of answers (Hendl, 2016). Initially, we identified general concepts in the responses and then merged them into categories with similar focus (Švaříček et al., 2014). Two researchers analyzed the answers, and we compared different categories to enhance reliability. We used Pearson's Chi-square test in R Program ver. 3.6.3 (2020) to evaluate respondents' answers.

## RESULTS

### RQ1 - How did Online Teaching of Biology Take Place at Different School Levels?

Using the Pearson's Chi-square test, we confirmed a significant difference in the question focusing on the difficulty of online teaching between types of schools ( $p$ -value=0.02752,  $X$ -squared=10.917,  $df$ =4). The majority of students (53.49%) responded that online education was equally challenging as in-person teaching. Since online teaching is not as dynamic as in-person teaching and can become monotonous, we were interested in whether students were able to concentrate sufficiently on the explanations during online teaching. Again, we observed significant differences in students' responses ( $p$ -value=0.001702,  $X$ -squared=21.181,  $df$ =6). Up to 71.18% of respondents stated that they could not concentrate as well as in the classroom, while 40.06% were able to concentrate the same way. Significant differences were also found in the question "What tools did the teachers use in online biology teaching?" among the responses from students at different school levels ( $p$ -value=0.00000022,  $X$ -squared=112.67,  $df$ =12). Students most frequently mentioned presentations (34.21%), videos (21.12%), and textbooks (20.55%) as the main tools used. Practical exercises, which are an essential part of biology education, were challenging to implement during online teaching. Once again, we found significant differences in the responses from students at different school types ( $p$ -value=0.00000022,  $X$ -squared=170.94,  $df$ =8). Students reported that they either worked on practical exercises independently as part of projects or special assignments, worksheets (30.50%), or did not have any practical exercises at all (26.33%). Regarding the question of how teachers provided study materials to students, we observed a significant difference in students' responses using the Pearson's Chi-square test

**Table 3.** Results of the Pearson Chi-square test analysis of respondents' answers on online biology education

Question/answer	Primary		Secondary		Tertiary		p-value
	n	P (%)	n	P (%)	n	P (%)	
<b>Was online learning more challenging for you than traditional in-person learning?</b>	<b>94</b>	<b>15.61</b>	<b>413</b>	<b>68.60</b>	<b>95</b>	<b>15.78</b>	0.02800000000000
Yes, it was more difficult for me.	31	5.15	143	23.75	28	4.65	
As difficult as in-person learning.	48	7.97	211	35.05	63	10.47	
No, online learning was easier (but also less efficient).	15	2.49	59	9.80	4	0.66	
<b>Were you able to focus on the lecture during online learning?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.00200000000000
I partially focus.	28	4.67	81	13.50	12	2.00	
Not as during in-person learning.	29	4.83	186	31.00	32	5.33	
Not at all.	16	2.67	64	10.67	15	2.50	
I focus the same as during in-person learning.	21	3.50	82	13.67	34	5.67	
<b>What tools did the biology teacher use during online teaching?</b>	<b>276</b>	<b>17.61</b>	<b>1,099</b>	<b>70.13</b>	<b>192</b>	<b>12.25</b>	0.0000000220000
Textbook.	78	4.98	231	14.74	13	0.83	
Worksheets.	56	3.57	182	11.61	3	0.19	
Presentation.	89	5.68	356	22.72	91	5.81	
Videos.	45	2.87	214	13.66	72	4.59	
Audio recordings.	6	0.38	102	6.51	12	0.77	
No tools.	1	0.06	10	0.64	0	0.00	
Notes in word.	1	0.06	4	0.26	1	0.06	
<b>How were practical biology exercises conducted during online teaching?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.0000000220000
We did not have any practical exercises.	12	2.00	143	23.83	3	0.50	
Practical exercises were carried out individually as part of projects or special homework assignments, worksheets.	40	6.67	137	22.83	6	1.00	
The teacher prepared the practical exercises in the form of videos, photos, and other materials, which were then provided to us students during the class.	17	2.83	21	3.50	45	7.50	
Teacher compensated for practical part by using various videos from the Internet or other study materials to supplement our learning.	6	1.00	41	6.83	13	2.17	
The teacher conducted the practical exercises only in theory, without any actual hands-on activities.	19	3.17	71	11.83	26	4.33	
<b>In what way did the teacher provide you with study materials for biology?</b>	<b>96</b>	<b>15.84</b>	<b>417</b>	<b>68.81</b>	<b>93</b>	<b>15.35</b>	0.0000000220000
Using our student e-mail addresses.	49	8.09	25	4.13	67	11.06	
Using school web page.	2	0.33	2	0.33	2	0.33	
Using EduPage.	33	5.45	285	47.03	18	2.97	
Using MS Teams.	12	1.98	67	11.06	2	0.33	
Using Discord.	0	0.00	9	1.49	0	0.00	
We were not getting any study materials.	0	0.00	29	4.79	4	0.66	
<b>Did the teacher assign homework during online biology teaching?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.000000006961
Yes, but only simple problem-based questions to enhance understanding of the subject matter.	72	12.00	139	23.17	33	5.50	
Yes, we worked on projects that were graded.	14	2.33	99	16.50	20	3.33	
No.	8	1.33	175	29.17	40	6.67	

Note. n: Number of respondents & P: Percentage

(p-value=0.000000022, X-squared=248.31, df=10). The most common response was through EduPage (55.45%) and student email addresses (23.27%). Significant differences were also found in students' responses to the question of whether teachers assigned homework during online learning (p-value=0.000000006961, X-squared=62.947, df=4), with the most common answer being "yes, but only simple problem-based questions to enhance understanding of the subject" (40.67%) (Table 3).

### RQ2 - How were Students Assessed/Tested on Their Knowledge during Online Biology Teaching?

Assessing and testing students' knowledge during the COVID-19 pandemic presents certain challenges and

requires adaptation to the new circumstances of online education. Given the online environment, it is necessary to consider suitable formats for assessment and testing that are adapted to online learning. This may include online quizzes, electronically submitted written tests, oral examinations via video calls, and similar approaches. We observed significant differences (p-value=0.000000022, X-squared=157.41, df=6) in students' responses to the question "Did the teacher also conduct assessments during online biology teaching?". The most common response from students was that assessments of their knowledge were conducted in a similar manner to face-to-face education (31.17%). Additionally, students mentioned that assessments were conducted

**Table 4.** Results of the Pearson Chi-square test analysis of respondents' answers on assessing/testing students' knowledge during online biology teaching

Question/answer	Primary		Secondary		Tertiary		p-value
	n	P (%)	n	P (%)	n	P (%)	
<b>During online biology class, did the teacher also conduct assessments?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50%</b>	0.0000000220
Yes, but only at the beginning of the lesson, we would answer questions as part of a frontal review.	24	4.00	102	17.00	8	1.33	
Yes, just like in the in-person form.	24	4.00	156	26.00	7	1.17	
No, he just explained a new topic.	20	3.33	42	7.00	63	10.50	
The assessments took place only at the end of each thematic unit in the form of a test.	26	4.33	113	18.83	15	2.50	
<b>Did you have enough time to complete the online tests during the assessments?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.00000001508
Yes, I always had enough time to complete the test and also review my answers.	37	6.17	73	12.17	13	2.17	
The allocated time was sufficient.	25	4.17	191	31.83	27	4.50	
No, the time provided was insufficient, and I always felt stressed about whether I would be able to complete the test in time.	32	5.33	131	21.83	53	8.83	
We did not have online tests.	0	0.00	18	3.00	0	0.00	
<b>During the online test, did you work:</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.00000002200
Collaboratively with classmates to help each other.	19	3.17	141	23.50	5	0.83	
With assistance from parents.	6	1.00	1	0.17	0	0.00	
Independently.	41	6.83	132	22.00	80	13.33	
Independently, but with the help of a workbook/textbook.	28	4.67	139	23.17	8	1.33	

Note. n: Number of respondents & P: Percentage

only at the end of a thematic unit through tests (25.67%). Regarding the tests, we were interested in whether students had enough time to complete them. Once again, we found significant differences in students' responses (p-value=0.00000001508, X-squared=52.458, df=6). According to 40.50% of respondents, online tests provided sufficient time for completion. On the other hand, 36.00% of respondents indicated that the allocated time was insufficient, causing them stress about completing the test on time.

Online education also poses a challenge in terms of maintaining exam integrity. Educators must pay attention to how to ensure that students take exams without cheating and adhere to ethical standards. This may involve monitoring students through webcams, using cheating detection software, and similar measures.

We are pleased that students responded honestly to the question of whether they worked independently during the test. Significant differences were observed in the responses of students from different grade levels (p-value=0.000000022, X-squared=120.04, df=6). As many as 42.17% of students stated that they worked independently during online tests. However, 29.17% of respondents worked independently but used notes in their notebooks and textbooks, while 27.50% of students mentioned that they helped each other with their classmates during online tests (Table 4).

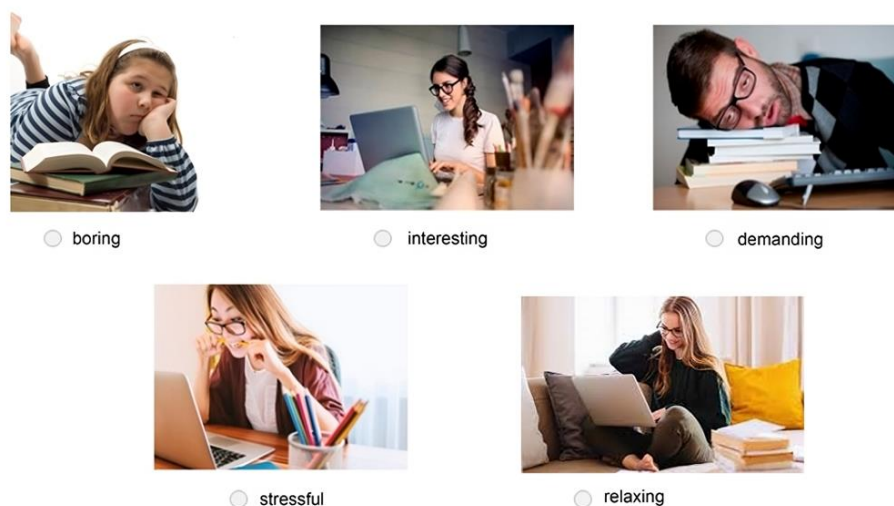
### RQ3 - What is the Opinion of Students on the Advantages/Disadvantages of Online Biology Education and its Use in the Future based on the Experiences Gained during COVID-19 Pandemic?

By using the Pearson's Chi-square test,, we observed a significant difference in the responses of primary school, secondary school, and university students when analyzing the positives (p-value=0.001817, X-squared=34.376, df=14) and negatives (p-value=0.000009134, X-squared=46.179, df=16) of online education.

Most commonly mentioned positive aspect was absence of early wake-ups and travel to school (26.30%), as well as having enough free time for extracurricular activities (16.50%). In terms of negatives, they mentioned spending much time in front of computer (18.31%) and struggling to maintain focus during class (17.86%).

Although online learning was implemented to protect health by eliminating physical contact and reducing the risk of COVID-19 exposure, it can also have a negative impact on health. When asked whether online education had an impact on health, we observed significant differences in the responses of primary, secondary, and tertiary school students (p-value=0.01645, X-squared=24.674, df=12).

Online teaching was for you:



**Figure 1.** Questionnaire pictures for expressing impressions of online education (Source: Authors' own elaboration)

Due to spending a significant amount of time in front of computer, sedentary behavior and physical inactivity caused fatigue and overall exhaustion among students (19.90%), as well as back pain (18.61%). Regarding student health, we were interested in how teachers addressed the situation when a student did not attend a class. From the analysis of responses, we observed significant differences in the students' answers ( $p$ -value=0.04934,  $X$ -squared=15.547,  $df$ =8). The majority of students never skipped a class (45.03%). In response to the question "Online education was for you.", students were asked to depict their experience during pandemic using five pictures representing feelings—stressful, demanding, boring, relaxing, and interesting (Figure 1).

In the analysis of students' opinions, we observed a non-significant difference for this question ( $p$ -value=0.09163;  $X$ -squared=13.64,  $df$ =8). Students from all levels of schooling consider online education to be either relaxed (41.00%) or boring (23.50%). Only 38 students (6.33%) find online education interesting. Finally, we asked students if they could envision a future, where biology education is delivered in a combined form (traditional in-person and online). In this question as well, we observed significant differences among the different levels of schooling ( $p$ -value=0.0002025,  $X$ -squared=21.977,  $df$ =4). The most common response among students was "yes, but practical exercises must be conducted in person" (36.50%) (Table 5).

**Table 5.** Results of the Pearson Chi-square test analysis of respondents' answers on the advantages/disadvantages of online biology education and its use in the future

Question/answer	Primary		Secondary		Tertiary		p-value
	n	P (%)	n	P (%)	n	P (%)	
<b>What advantages did online learning have for you?</b>	<b>296</b>	<b>14.08</b>	<b>1,510</b>	<b>71.80</b>	<b>297</b>	<b>14.12</b>	0.001817000
Not having to wake up early and travel to school.	84	3.99	385	18.31	84	3.99	
Ability to record lessons.	10	0.48	102	4.85	8	0.38	
Greater independence in learning.	23	1.09	139	6.61	22	1.05	
Sufficient free time for extracurricular activities.	55	2.62	250	11.89	42	2.00	
Opportunity to spend more time with family.	37	1.76	181	8.61	56	2.66	
Studying at my own pace.	33	1.57	230	10.94	44	2.09	
Less stress.	53	2.52	222	10.56	39	1.85	
None.	1	0.05	1	0.05	2	0.10	
<b>What were the negatives of online teaching for you?</b>	<b>271</b>	<b>12.13</b>	<b>1,632</b>	<b>73.05</b>	<b>331</b>	<b>14.82</b>	
Connectivity issues, technical problems (malfunctioning microphone, camera, etc.).	47	2.10	233	10.43	67	3.00	
Lack of motivation and self-discipline for studying.	40	1.79	259	11.59	32	1.43	
Missing contact with classmates.	53	2.37	230	10.30	59	2.64	
Difficulty in maintaining attention during the lessons.	55	2.46	297	13.29	47	2.10	
Disturbances or interruptions during the lessons.	12	0.54	77	3.45	12	0.54	
Unsuitable learning environment.	8	0.36	72	3.22	12	0.54	
Monotony of the lessons.	5	0.22	165	7.39	38	1.70	
Spending a lot of time in front of the computer.	50	2.24	295	13.21	64	2.86	
None.	1	0.04	4	0.18	0	0.00	

Note. n: Number of respondents & P: Percentage

**Table 5 (continued).** Results of the Pearson Chi-square test analysis of respondents' answers on the advantages/disadvantages of online biology education and its use in the future

Question/answer	Primary		Secondary		Tertiary		p-value
	n	P (%)	n	P (%)	n	P (%)	
<b>Did online teaching have an impact on your health?</b>	<b>210</b>	<b>12.90</b>	<b>1,174</b>	<b>72.11</b>	<b>244</b>	<b>14.99</b>	0.016450000
Eye strain.	29	1.78	179	11.00	45	2.76	
Headaches, migraines.	35	2.15	177	10.87	43	2.64	
Back pain.	33	2.03	220	13.51	50	3.07	
Fatigue and overall exhaustion.	44	2.70	242	14.86	38	2.33	
Stress.	28	1.72	160	9.83	32	1.97	
Anxiety, depression.	14	0.86	129	7.92	22	1.35	
No, I did not notice any impact on my health.	27	1.66	67	4.12	14	0.86	
<b>How did the teacher handle it if you did not provide prior notification for not attending online teaching?</b>	<b>94</b>	<b>15.56</b>	<b>417</b>	<b>69.04</b>	<b>93</b>	<b>15.40</b>	0.049340000
The teacher contacted me by phone/email.	8	1.32	16	2.65	3	0.50	
The teacher contacted my parents by phone/email.	3	0.50	15	2.48	0	0.00	
The teacher did not take any immediate action and waited for me to contact them later with an explanation for my absence.	37	6.13	156	25.83	34	5.63	
Teacher did not take any immediate action but requested a written excuse from me for missed class during following session.	12	1.99	44	7.28	4	0.66	
I never missed an online teaching session.	34	5.63	186	30.79	52	8.61	
<b>How would you describe online teaching for you?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.091630000
Difficult.	8	1.33	61	10.17	16	2.67	
Boring.	25	4.17	99	16.50	17	2.83	
Relaxing.	43	7.17	167	27.83	36	6.00	
Stressful.	12	2.00	66	11.00	12	2.00	
Interesting.	6	1.00	20	3.33	12	2.00	
<b>Could you imagine biology teaching in future being conducted in a blended format (combining in-person &amp; online methods)?</b>	<b>94</b>	<b>15.67</b>	<b>413</b>	<b>68.83</b>	<b>93</b>	<b>15.50</b>	0.000202500
Yes.	45	7.50	127	21.17	27	4.50	
Yes, but practical exercises should be conducted in a face-to-face format.	24	4.00	147	24.50	48	8.00	
No, I prefer to have everything in-person.	25	4.17	139	23.17	18	3.00	

Note. n: Number of respondents & P: Percentage

## DISCUSSION

### RQ1 - How did Online Teaching of Biology Take Place at Different School Levels?

In the first round, we asked questions related to students' opinions on the process of online biology education. The COVID-19 pandemic has brought a significant shift in the method of education. As schools and universities were closed, educators had to adapt to online teaching methods to ensure that students continued their studies without interruption. Students stated that online learning is equally demanding as face-to-face learning, which may indicate the good adaptation of students to online education, as well as the appropriate implementation of online teaching by educators who made efforts to make online education as close as possible to the traditional classroom format. In general, effective online teaching is facilitated by positive perceptions of easy access and the use of flexible learning materials, as well as an autonomous and innovative learning style (Drennan et al., 2005).

One of the most significant challenges of online teaching during COVID-19 was to ensure that students understand the presented material. In face-to-face teaching, teachers can gauge students' understanding

and attentiveness through observing their body language and asking questions. In the online environment, however, it can be more challenging to interpret whether students comprehend the taught concepts or not. According to a study by (Heriyanto et al., 2023), teachers' experiences primarily focused on student interactions and familiarity with various online educational platforms. This highlights the importance of finding ways to engage students and ensure their focus during the instruction. To address this issue, some teachers turned to interactive tools such as quizzes and surveys to engage students and encourage their participation. Also, providing clear instructions and offering opportunities for students to ask questions can help improve interpretation and ensure better student concentration on learning (Siddiquei & Kathpal, 2021).

To overcome the challenges posed by online teaching, biology teachers utilized various methods and educational aids to ensure that their students receive quality education. Xie and Yang (2020) argue that study materials for distance learning should be designed to promote students' autonomous learning and assist teachers in their instruction while saving their time. Based on these findings, we can state that biology teachers employed various teaching methods and

techniques during online education in the period of the COVID-19 pandemic. However, they aimed to preserve as many methods commonly used in face-to-face teaching as possible. According to Tan (2013) informal online educational interactions have a positive impact on students. These interactions create pleasant experiences, support learning, and enhance social engagement among students. According AlAdwani and AlFadley (2022) teachers used platforms such as YouTube, PowerPoint Moodle and MS Teams during online teaching.

In the field of biology, laboratory exercises are an essential part of learning, allowing students to gain practical experience and develop critical thinking skills. However, after the implementation of social distancing measures, traditional laboratory sessions became challenging to conduct. Nevertheless, teachers responded by adopting innovative approaches to ensure that students receive quality education despite the limitations imposed by the pandemic. For example, some institutions incorporated virtual simulations into online laboratory teaching and active learning exercises (Alvarez, 2021). Others created and taught online cell biology laboratories (Delgado et al., 2021). These approaches enabled students to continue their studies while staying safe during the pandemic. Another method employed by biology teachers was the use of virtual laboratories. In our case, virtual laboratories were composed of videos in which the instructor performed the experiments, allowing students to familiarize themselves with the protocols and procedures. They could then carry out the experiments at home through special homework assignments. Liu et al. (2022) noted that a virtual laboratory in the form of computer simulation enabled students to conduct experiments and observe samples online. Although virtual laboratories could not fully replace hands-on practical exercises, they provided students with an opportunity to learn and practice their skills in a safe and controlled environment.

Although there are several proven methods for teaching experimental design and data analysis online, nothing can fully replace the experience of working in a laboratory or in the field. Similarly, Frey (2008) points out that practical exercises cannot be completely replaced during online teaching, and therefore teachers should choose an appropriate teaching approach and technology to substitute laboratory work.

Similar findings were also published by Babinčáková and Bernard (2020) in their research focused on experimental chemistry teaching. Their study highlighted prevalent forms of presentations, video sharing, and home experiments adapted for household implementation. However, we can state that while the pandemic presented challenges for laboratory exercises in biology, the creativity and adaptability of educators ensured that students could continue their education.

From the perspective of accessibility of study materials, teachers had to ensure that their study material was accessible to all students, including those with disabilities (Perrault, 2007). In this case, factors such as font size, color contrast, and alternative text for images had to be considered. One of the most popular methods was the use of pre-recorded lectures and presentations on online platforms such as EduPage, where students had unlimited access to them. In our research it was also confirmed that the availability of materials was addressed through the use of EduPage and e-mail communication. Similarly, to our research, Csachová and Jurečková (2020) also mention the most commonly used application for communication with students, the website [www.edupage.sk](http://www.edupage.sk), followed by student email addresses.

According to the study by Siddiquei and Kathpal (2021), motivation plays a crucial role in creating value for digital education for both employees and students. Therefore, teachers must design homework assignments that are engaging and challenging enough to keep students motivated while providing them with appropriate support and resources. In our case, the tasks consisted of simple questions aimed at understanding and reinforcing the subject matter. However, Muldayanti et al. (2022) stated that online platforms such as Google Classroom or Moodle were mainly used for assigning and collecting homework. They also noted that the online format for solving projects and tasks was suitable for most respondents due to its flexibility, speed in task completion, and motivation driven by the requirement to submit assignments for final evaluation. Additionally, distance education requires more self-discipline and motivation than a traditional classroom environment.

## **RQ2 - How were Students Assessed/Tested on Their Knowledge during Online Biology Teaching?**

During the pandemic, students' opinions on testing varied significantly. Some students found it difficult to adapt to online education and felt unprepared for tests. Others discovered that online testing was more convenient and less stressful than in-person exams (Fontaine et al., 2020).

Testing students' knowledge during the COVID-19 pandemic posed a challenge for educators. As a result, many schools had to adjust their testing methods to the new online environment and utilize alternative forms of assessment such as quizzes, assignments, and projects that could be completed remotely. Since students were taking exams from home, it was challenging to monitor their behavior and ensure they did not access unauthorized materials or receive assistance from others (Noorbehbahani et al., 2022). Some students took advantage of this situation and engaged in cheating during exams, which affected the accuracy of test results



and undermined the integrity of the education system (Holden et al., 2020). Additionally, teachers may use open-ended questions that require critical thinking skills rather than simple regurgitation of information, making it more difficult for students to cheat (Xiong & Suen, 2018). Overall, cheating during online exams is a complex issue that requires innovative solutions from educators.

### **RQ3 - What is the Opinion of Students on the Advantages/Disadvantages of Online Biology Education and its Use in the Future based on the Experiences Gained during COVID-19 Pandemic?**

Within the third round of questionnaire survey, we focused on the advantages and limitations of online education, as well as students' opinions on the future use of online learning. According to the respondents, the biggest positives included independence, flexibility in learning, no need for waking early, and having ample free time. The flexibility of education as a foundation for good time management has been identified as a positive aspect in several studies (Kies, 2018; Mukhtar et al., 2020). The major negatives mentioned were spending a lot of hours in front of the computer, difficulty in maintaining attention, internet connectivity issues, and lack of social contact. In this case, our results align with multiple studies that have highlighted the importance of interaction among students and between students and educators as a basis for effective learning. Harjule et al. (2021) note that parents expressed concerns about increased screen time for their children from the perspective of greater exposure to harmful internet content, decreased physical activity, and lack of socialization. In a survey of 1,406 university students in asynchronous online courses, students claimed to be more satisfied and learned more when a significant portion of the course was based on discussions, possibly because discussions facilitated increased student-student and student-teacher interaction (Shea et al., 2001). Internet connectivity problems also had a negative impact on online learning (Milla et al., 2021). Technical support has been identified as one of the factors responsible for satisfaction with online classes (Nambiar, 2020; Wang et al., 2021; Yang & Cornelius, 2004) also identify motivation as the biggest challenge for students' learning. Similarly, Mishra et al. (2020) reveal that some students had difficulty concentrating during online lectures. In online education, it is important to pay attention to the fact that students may have difficulty maintaining their attention, especially when lacking feedback from teachers or peers and being exposed to external distractions that can divert their attention.

The sudden transition to online education resulted in an extended screen time, which could lead to lifestyle changes and adversely affect students' health (Chu & Li, 2022). According to a study by Hawamdeh et al. (2022) and Siddiquei and Kathpal (2021), the prevalence of back

pain increased among students during the COVID-19 pandemic. This is likely due to prolonged sitting in front of a computer screen without proper ergonomic support. Extended sitting can lead to poor posture and strain on the lower back muscles. Since students were spending more time attending online courses and completing tasks on screens, it was important for them to take frequent breaks and practice proper posture to prevent back pain. Additionally, spending long hours on the computer for lectures, assignments, and exam preparation could contribute to feelings of burnout, negatively impacting academic performance and students' mental health.

Absence from classes could also occur due to these reasons. With the transition to online education, many students struggle to attend classes regularly. This can be attributed to various factors such as lack of motivation, technical issues, or personal and health problems (Siddiquei & Kathpal, 2021). On the other hand, some students may simply use the online format as an excuse to skip classes without consequences. It is important for educators to address this issue and find ways to encourage student participation in online learning, such as implementing strategies like setting clear attendance expectations, providing engaging course content, and offering opportunities for interaction and collaboration among students. By addressing the underlying causes of student absences in online education, educators can create a more effective learning environment in these challenging times.

Finally, we also investigated whether students could envision a combination of in-person and online teaching for biology in the future. The most commonly mentioned response was "yes, but practical exercises should be conducted in person." These findings are consistent with our research among teachers, who, like students, consider online education suitable only for theoretical biology topics. However, laboratory exercises will not be suitable for online education because biology is learned through hands-on experiences (Babosová et al., 2022).

### **Limits of Study**

The limitation of our research is the absence of questions about gender, age, and region. We can assume that the lack of knowledge about these factors may hinder the creation of more accurate relationships and could contribute to a different statistical analysis of respondents' answers. For example, gender may play a role in differences in education, preferences, or perception. Similarly, different age groups of students may have different needs and experiences, which could influence the research results. Regions may have varied approaches to education and conditions during the pandemic period.

The low response rate to the questionnaires could have also resulted in a selection bias and inadequate

representation of a range of opinions and experiences. Some teachers we contacted did not distribute the questionnaire to their students. These teachers mentioned that they have a lot of work with online teaching, or education is suspended at their school, and they provide study materials to students in printed form. Teachers who did not distribute the questionnaire to their students may have had a different attitude or experience with online education, which could have influenced the research results.

Although we tried to create questions suitable for students at all levels of schools, some questions may have been challenging for students at different levels of education. Tertiary students had difficulty answering certain questions, where the study of biology, especially practical exercises, is more intensive than in primary or secondary schools.

Although the participation of elementary and university students in the research was limited, our findings sufficiently revealed how these students worked and how studying during the pandemic differed. It is important to keep in mind that students at different levels of schooling have varying abilities and knowledge in the given field.

Despite these limitations, our research has yielded important findings. We found that the majority of students expressed their willingness to continue with combined education in the future, which can contribute to improving the education system. Our results can serve as guidelines for further research and contribute to understanding how students adapted to and managed education during the pandemic.

## CONCLUSIONS

In conclusion, it can be said that the COVID-19 pandemic has had a significant impact on learning biology from the perspective of Slovak students in primary, secondary, and tertiary schools. The sudden transition to online education brought several challenges for both students and teachers, including limited access to resources, lack of direct interaction, and difficulties in maintaining motivation and engagement.

Despite these challenges, it is evident that technology has played a crucial role in enabling online education during these times. It is crucial to continue evaluating the effectiveness of online education methods and exploring innovative ways to enhance student engagement and success in biology education.

Ultimately, through collaboration between the teaching community and students, we have been able to overcome several obstacles and move forward, embracing a combination of online and in-person education for the benefit of all involved.

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