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DEVELOPING COMMUNICATION COMPETENCE IN DIGITAL LEARNING ENVIRONMENTS FOR PRIMARY SCIENCE STUDENTS

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Abstract. *Effective natural science teaching in primary schools helps students to form and change their conceptions about nature and natural processes. This is only possible through communicating about learners' existing misconceptions and the process of transforming them into correct scientific concepts – using a socio-constructivist learning approach. The aim of this study was to find out what happens when the natural science teaching/learning process moves into digital learning environments. Immediately after the end of the Covid-induced school lock down, a sample of 183 first-, second- and third-grade teachers in Slovenia were asked to report about what happened in their science classes during the 11-week school lock down. The results reveal problems originating in very limited digital literacy competences as well as a lack of basic skills (in the first grade), and slowly emerging basic literacy in grades two and three. This had a great impact on the communication between teachers and students and between students themselves. According to research results, the problem significantly affects science teaching and is particularly urgent in didactics of chemistry and physics.*

Keywords: *basic literacy, communication competence, digital literacy, primary school, science class, socio-constructivist learning approach*

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Introduction

The starting point is the definition of learning environments as provided by the international study of the OECD on Innovative Learning Environments – ILE (OECD, 2013, p. 11), which states that a learning environment is an "organic, holistic concept – an ecosystem that includes the activity and the outcomes of the learning". It is "marked by a variety of teaching approaches, the dynamics of the learning process, the flexible roles of the main actors in this process, and the use of contemporary technologies".

All learning environment concepts are based on some paradigm or learning theory (Hannafin et al., 1997). Typically, learning theories are an interdisciplinary patchwork of education science, philosophy, psychology, cognitive science, social anthropology, organizational science, linguistics, cybernetics, architecture, social design, and, more recently, the neurology of learning, multiple intelligences, and multimedia.

Unlike teaching theories, learning theories are descriptive and explain the nature of learning. They are not limited to a single model or method but provide a basis for their selection or construction according to the circumstances. Their focus is on the learner and his or her patterns of thinking, which form the framework of his or her own learning metacognition ("learning (how) to learn"). This research focuses on those learning theories that reveal the role and importance of the learning environment. Most often, this is the case with different constructivist learning theories:

- cognitive constructivism, which focuses on the active role of the learner and learning in a real-life environment (Piaget, 1953);
- social learning theory, which includes socio-historical and cultural-historical conditions as well as situational learning and communities of practice, and treats learning as a process/product of the social context (Bandura, 1971);
- critical learning theory, which emphasizes that the existing social context is man's own construct toward which a critical attitude must be formed, and which must be constantly improved in order to create a better world (Freire, 2005).

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Constructivism has also received attention in the context of the acquisition of scientific (or STEM) competences, which we now understand as STEM literacy. A new understanding of "STEM knowledge" is coming to the fore, which refers not only to the memorization of information about the natural world and the processes that occur within it, but also to the interpretation of this information in relation to prior knowledge, experiences, and values (Cencelj et al., 2020; Kordigel Aberšek & Aberšek, 2022). Constructivism offers a fresh perspective on learning and considers the emotional, motivational, and social dimensions of learning in addition to the cognitive. Teachers must also be able to create meaningful learning environments that foster processes of active thinking, experimentation, participation, and group communication (Lamanauskas, 2009; Lamanauskas & Vilkonis, 2005).

In fact, all learning is situated (Engeström, 2009; Vygotsky, 1978), therefore learning environments occur wherever learning takes place, and one can see how different components of learning come together and intertwine in them. "Learning is any process in a living organism that leads to permanent capacity changes but is not merely a biological maturation or aging" (Illeris, 2007, p. 3). It takes place in the triangle of content, incentive, and interaction (Illeris, 2009, p. 9). Remarkable advances in cognitive neurology are revealing in increasing detail how learning processes actually occur (Bansal et al., 2019). Through learning, the learner forms mental structures that are stored in the brain in the form of mental schemas or patterns and are the elements of the learner's thought organization. "Learning is more than knowledge acquisition. It is often a process with multiple phases and different components. Inquiry, investigation, decision making, selection and deselection are all preparatory activities before we even enter the learning experience (where the learning experience is defined as the moment when we actively acquire the knowledge that is missing in order for us to complete the required tasks or solve a problem). During (and after) the learning experience, assessments or evaluations take place to measure whether the required learning has occurred. Each phase has different requirements. Preparatory learning tends to rely more on informal tools; the learning experience is most likely to use structured content and dialog with gurus; the assessment phase requires informal discussion, reflection, and self-expression" (Siemens, 2006, p. 25).

Jonassen and Land (2000) found that neurological discoveries suggest significantly different ontological and epistemological arguments for learning in comparison to communication theory, behaviourism, and cognitive theories: learning is an activity that takes place within a goal-directed and integrated activity system. Learning is a closed-end process of intention, action, and reflection, and therefore the learning process is not just about obtaining knowledge, but about making it meaningful for one's own use. A socio-dialogical process requires a referential social environment and exists not only in individual thought, but also in public discourse, social relationships, and material ideas.

In the cross-section of learning concepts presented in the OECD publication *The Nature of Learning* (Dumont et al., 2010), there is a strong emphasis on the learning environment as a concept that has a major impact on perceptions of learning. DeCorte (2010) emphasised that high quality learning environments promote constructive learning based on the recognition of students as key actors in the process of knowledge acquisition; and self-regulated, conceptual, and cooperative learning that refers to the relationships among all actors in the learning environment.

Today, constructivism is the dominant view in teaching and learning. It refers to a new understanding of teaching and learning and to the changed role of teachers and learners. The latter is an active subject, while the teacher *encourages* rather than *transfers* knowledge. In other words, learning is a self-regulating process of constructing thoughts that takes place in interaction, and the teacher supports the learning process by selecting learning materials and methods that are appropriate to the learning process. Therefore, learners construct their own knowledge rather than passively receiving it from the teacher (Darmody et al., 2010).

Such an understanding of learning is adopted by the "model for designing a constructivist learning environment" (Jonassen, 1999), which refers to a pedagogical approach in which reality in the learning environment is not just some textbook "illustration" or other, but a source of open questions, genuine problems, and a realistic reason for undertaking projects. In this model, related examples and information sources support understanding of the problem and imply possible solutions; cognitive tools help learners interpret different aspects of the problem; conversational or collaborative tools enable learning communities to negotiate and construct meanings; and social and contextual supports serve to implement the entire model. Clearly, creating a context for presentation and an educational space for manipulation in which learners can communicate about their learning process, is a challenging task. It remains to be determined whether learning environments created under distance education conditions can meet these requirements. As the current research showed, options of instructors and learners range from negative or reserved (Kerndl & Kordigel Aberšek, 2016) to quite positive (Lamanauskas et al., 2022). "Naturally, satisfaction with online learning depends on many different factors, such as students' motivation, the

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system of study, organization, the socio-cultural environment, the quality of teacher's work" (Lamanauskas et al., 2022, p. 239) and it also depends on students' digital literacy competence and the topic they are learning about.

Learning Environments in Primary Science Classes

The advantage of constructivist-oriented physical learning environments that focus on learners' interest in discovery and encourage collaboration, anticipation, assumption, work with objects, inquiry, research, and innovation, are widely recognized (Dangel, 2013). The role of teachers is to provide a context for such practices, as indicated by physical indicators such as seating arrangements, wall panels, the general layout of the classroom, etc.

Analysing a large sample of British primary school students, aged 5 to 11, the HEAD (Holistic Evidence and Design) study found that for students of this age, the classroom environment is significantly more important than the school environment as a whole (Barrett et al., 2015, p. 15; Barrett et al., 2017, p. 436). In addition, the results of the PISA 2012 survey, which showed that up to 25% of differences between schools in learning outcomes can be explained by differences in the quality of their learning environments, clearly indicate that this is primarily true for physical environments in the classroom (OECD, 2013). When it comes to teaching and learning processes, STEM teachers most often choose between a traditional and student-centred, constructivist approach to the learning environment.

According to Brown (2008), in constructivist-oriented learning environments, learners play an active role in gathering experiences as a basis for their own reasoning. Learners are able to develop their own understanding of subject content because they are interested and excited about it. Although the teacher leaves the stage and is less visible, their role in such teaching is more demanding, both in terms of planning and supporting learning and in terms of formative assessment. Constructivist teachers plan and design learning environments that encourage learners to engage in problem solving, social negotiation, discovery, creativity, communication, and research.

Learning Environments for Teaching Primary School Science Constructively

Effective primary science teaching supports students to form and modify their ideas about nature and natural processes. Effective teaching at an early age also enhances learners' curiosity, motivates them to explore the world in productive directions, and develops active thinkers. This interpretation of learning primary science is based on conceptual development, according to which students take steps towards the concepts. "Learning science is also interpreted as students becoming members of a classroom-based science community – one in which they develop scientific competences and learn what it means to engage in inquiry-oriented practices" (Skamp & Preston, 2018, XVI).

As Brockett (2011) and Murphy (2012) pointed out, learners' conceptions are the essential starting point for learning science in primary classes. These conceptions differ from scientifically correct concepts, and are often referred to as *alternative conceptions* because they refer to "experience-based explanations constructed by learners to make sense of a range of natural phenomena and objects (Wandersee et al., 1995). Other terms used to describe these non-scientific concepts include "misconceptions", "everyday" or "intuitive" or "naïve" ideas, or "preconceptions". These alternative ideas come from everyday experiences with the world; they may be adopted from misinformation from peers, family, and the media. In addition, language can also influence misconceptions, when scientific terms have different meanings than those used in everyday speech (Taber, 2015). In recent years, misinformation is often due to the World Wide Web with its fake news and advertisements, because it is difficult for children to know what a reliable source of information is.

Learners' alternative concepts are often resistant to change. Learners may reject new ideas, they may simply add new ideas (which they encountered in science classes) to their existing ideas, or they may change their existing ideas, but not necessarily in accordance with scientific interpretations of phenomena or events, which means that the outcomes of formal science learning may lead to a range of unintended conceptual learning outcomes (Leach, 2015). With a social constructivist approach in primary science classes, the rejection of new concepts and the formation of parallel scientific concepts can be reduced or even avoided. The didactic approach in primary science classes should focus on the group (in the classroom), on the learning process (which should be based mainly on the learner's interaction with their social environment), and on language, whose first function is to enable communication among learners or between learners and the teacher (Bachtold, 2013).

Knowing all this, while considering the circumstances of the shift in learning environments from "face to face" to "distance/remote", a key question arises: is it possible to provide appropriate learning environments for

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achieving a central goal of primary science curricula, i.e., science literacy? The second relevant set of questions would be the following:

- What happened to the already changed teaching approach that occurred over the last two decades as teachers moved from the traditional to the socio-constructivist teaching/learning paradigm, from presenting science through explanations, reading texts, watching videos, or observing teachers conduct experiments to guiding students in an active, extended inquiry?
- Were teachers successful in exploring students' existing alternative conceptions related to selected natural science phenomena, or not? The answer to this question is of utmost importance because knowledge of students' alternative conceptions is critical in determining the science-teaching approach to be used in a primary science class.

It is important to find out what actually happened to primary science classes *when teaching and learning moved to digitally supported learning environments.*

To address this central topic, the aim of this study was to provide answers to the following research questions:

1. What digital learning environments did teachers use for teaching science when were they forced to make a shift from "face to face" to digital learning environments?
2. How many natural science curricular goals were achieved in these digital learning environments?
3. What natural science curricular goals were not achieved with digital learning environments?
4. What are the reasons for not choosing certain specific natural science curricular goals during the distance-learning period in digital learning environments?

Research Methodology

General Background

The research was conducted in the week in which Slovenian students returned to school – in February 2021. In Slovenia, the Covid school lock down lasted 11 weeks, and it provided the opportunity to examine what happened in primary school natural science teaching in terms of the social constructivist approach (in digital learning environments). For the purposes of this research, a quantitative approach was chosen in order to provide the answers to the research questions. A questionnaire was designed, tested, and sent to all compulsory school headmasters in northeast Slovenia. They were asked to distribute them to the first-, second- and third-grade teachers in their schools. There are two reasons why Slovenian schools are an appropriate sample for exploring what happened to primary-level science teaching in digital learning environments. The first reason is the level of general preparation for teaching by means of digital learning environments. Four main factors influence student performance in digital environments: two technological factors (accessibility and quality of the internet connection, and students being equipped with laptops or tablets), teachers' digital competence (their ability to teach in digital environments), and the participation of students who are already digitally competent in the process of online learning in digital learning environments. These four factors usually occur together, but not in Slovenia: in Slovenia, both technological factors were solved very quickly, and teachers were prepared to use digital learning environments. The second reason is the fact that the period of school lock down and therefore the time frame for remote teaching in digital learning environments in Slovenia was relatively long – it lasted 11 weeks, which is one of the longest periods in the world.

Sample Selection

The sample consisted of 183 randomly selected first triennium teachers in Slovenia (in the 2019/2020 school year, there were a total of 22,009 teachers in primary education in Slovenia; about 7,000 taught in the first triennium), with different length of service (Table 1). With this sample size (representative sample) we got level of confidence approx. 93% which is not ideal, but still good enough for preliminary conclusions.

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Table 1
Participating Teachers by Length of Service

	f	%
1–3 years	11	6.01
4–6 years	5	2.73
7–18 years	54	29.51
19–30 years	64	35.00
31–40 years	49	26.88
Total	183	100.0

In Slovenian schools, there are 97.4% of female teachers at the primary level and only 2.6% of male teachers, which is why a sociodemographic description was not specifically included in this research.

Ethical Procedures

Participants' approval was obtained in research in line with the voluntary principle. All participants were informed of the purpose of the research. The identity of participants was maintained at all stages, and the codes provided to the participants were used when citing raw data.

Instrument and Procedures

Data were collected using the online questionnaire *Learning Environments for the First Three Grades in the Time of Remote Teaching*, which included 52 questions about teachers' experiences after the Covid-19 school lock down. For the purposes of this research, 7 questions from this extensive questionnaire were relevant and were interpreted. The first part of the questionnaire contained questions about demographic data (teaching experience – length of service), and the second part collected data about teachers' experiences with remote teaching in digital learning environments during the 11-week school lock down from the perspective of different curriculum subjects.

The first question focused on what learning environments teachers used for teaching science in the distance-learning period. They selected between: videoconferences (Zoom, Teams, Meet, etc.), e-mails, online learning environments (Moodle, Mahara, 0386, Seesaw, Google classroom, E-assistant classroom, Xooltime), social networks, phone calls, and other (Mentimeter, BookCreator, Padlet, Plickers, Quizlet, Kahoot, Thinglink, etc.). A 6-point Likert scale was used (range: 1 – never, 2 – once a month, 3 – once every two weeks, 4 – up to 3 times a week, 5 – daily).

Teachers were also asked about what methods they used during videoconferences. On a 5-point Likert scale (1 – never, 2 – rare, 3 – sometimes, 4 – often, 5 – always), they rated how often they used videoconferencing for the organization of their work, for communication at the time of explanation, for communication at the time of interpretation, for communication after interpretation, for socializing, and so on.

Then teachers were asked what percentage of science curricular goals they achieved during the remote teaching period. They compared their annual teaching plan (created before knowing that the school lock down would occur in October and last until mid-January) with the realization. The percentage of curricular goals achieved was stated as follows: one fifth and less, a quarter, one third, half, two-thirds, three-quarters, and almost all curricular goals.

Next, teachers focused on the science curriculum goals that they have successfully implemented in digital learning environments, and on those for which they believed were not appropriate for implementation in digital learning environments. They listed the three didactic units that they thought were most successful, and the three didactic units that they chose not to implement. They also gave reasons why they did not select specific natural science curricular goals for implementation in digital learning environments. The teachers' responses were categorized as follows: students were not present, the curriculum is overloaded anyway, the goal is too demanding for digital learning environments, no digital learning resources available, distance learning requires a different didactic approach, students' limited digital competence, my own limited digital competence. The teachers' responses were interpreted by comparing the social sciences with the natural sciences.

The questionnaire was piloted on a sample of 15 primary-level teachers. The same teachers responded to the same questionnaire again after a two-week period. The results confirm the reliability of the questionnaire. The

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results were thoroughly reviewed, thematically and methodologically edited, and differences and errors were addressed. Subsequently, the final version of the questionnaire was prepared. The reliability of the rating scales was checked using Cronbach's alpha coefficient (α) and was found to be acceptable for the observed variables (Nunnally, 1978): the scale reliability for learning environments for teaching science in the distance-learning period was: α = .702, and for methods used by teachers during videoconferences Cronbach's alpha coefficient was: α = .714. The validity was evaluated through two expert evaluations (both experts are active in the field of research in digital learning environments, primary science class and statistical analysis). Objectivity was ensured in the implementation phase: the survey took place in an online environment that allowed to avoid stimuli, closed-end questions were preferred, and the proportion of personal interpretation was deliberately controlled in the evaluation phase of the open-end questions.

Data Analysis

Quantitative data of primary school teachers from first (6-year-olds) to third (8-year-olds) grade was collected. After verifying that the data were correct, a quantitative analysis was conducted, which analysed the data according to the following phases: encoding, definition and organisation of the data, and interpretation of the results. The programme IBM SPSS was used for statistically processing the data. The sample is presented with basic statistics. To compare the results obtained with the 5- and 6-point Likert scales, null and alternative hypotheses were established. The Friedman test was used to test whether there were significant differences in the learning environments teachers used to teach science in the distance-learning period (6-point Likert scale) and in the frequency of using different teaching methods during videoconferences (5-point Likert scale). If the Friedman test confirmed the presence of the statistical differences between the learning environments and in the use of different teaching methods during the videoconferences, the Chi-square test was used to test whether there were statistically significant differences in the frequency of use within each individual learning environments (6-point Likert scale) and within each individual teaching method used during videoconferences (5-point Likert scale). The mean of the responses given for each variable was also calculated. The mean value was calculated based on the frequency of responses on the Likert scale for the individual learning environment and, in a next step, for the frequency of using different teaching methods during the videoconferences. The higher the value, the more frequently the teachers used the individual learning environment or the more frequently they used different teaching methods. Based on the results obtained, the mean values of all learning environments were compared. The share of science curricular goals reached during the remote teaching period was presented using basic statistical interpretation, a Chi-square test was conducted to measure the possible differences among observed variables. Science curricular goals that teachers did/did not implement are presented tabularly with basic descriptive statistics for comparison. The reasons why teachers didn't select natural science curricular goals in digital learning environments were statistically tested using the Chi-square test.

Research Results

The first question regarding science teaching in distance learning period focused on the learning environments that teachers chose for science classes. The null hypothesis H_0 was stated: All types of learning environments are used equally often. An alternative hypothesis H_1 stated: All types of learning environments are not used equally often. A non-parametric Friedman test of differences was conducted. Differences are statistically significant (χ^2 (6) = 451.97, p = .001). Based on the results, H_0 was rejected. The use of learning environments for distance science education is unevenly distributed.

Table 2
Learning Environments (LE) for Teaching Science in the Distance-Learning Period (Lock Down)

Learning Environments	$\bar{x}$	χ^2	*df*	*p*
Videoconferencing	5.4	202.11	5	.001
Email	4.1	54.39	6	.001
Online learning environment	3.9	270.39	6	.001

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Learning Environments	$\bar{x}$	χ^2	*df*	*p*
Social networks	1.5	586.96	6	.001
Phone calls	2.5	106.96	6	.001

Because it was found that the use of learning environments for teaching science in the distance-learning period was unevenly distributed, the individual learning environments using Chi-square test were further examined. The answers presented in Table 2 indicate that on a daily basis, most teaching/learning sessions were held in Zoom, MS Teams, or another videoconferencing environment. Moodle, Mahara, Seesaw, Xooltimme, Google classroom, and e-assistant classroom were used almost as frequently. The data showing the use of email, social networking, and phone calls reveals the fact that some students could not successfully participate in online science classes and that they could do so after some assistance. The frequency of individual communication channels used daily, such as e-mail (teacher – students, teacher – parents), could indicate problems in performing science didactic units in digital learning environments (which could be solved individually), but also communication between teachers and students or students (peers) among themselves could indicate that a social constructivist approach to science teaching was used. Individual communication channels could be used for asking questions, communicating problems, and suggesting/comparing solutions.

From this perspective, the results presented in Table 2 suggest further exploration: *What methods did you use during the videoconferences*? The null hypothesis H_0 is: Teachers use different work methods equally frequently during videoconferences. The alternative hypothesis H_1 is: Teachers do not use different work methods equally frequently during videoconferences. A Friedman test of differences showed a statistically significant Chi-square value (χ^2 (6) = 309.96, p = .001). The null hypothesis was rejected, which means that teachers use different work methods unequally during videoconferences. Accordingly, this research focused on which methods teachers used more frequently than others. The results are presented in Table 3.

Table 3
The Frequency of Using Different Teaching Methods During Videoconferences in Distance Learning Period (Lock Down)

Frequency of Using Different Teaching Methods	$\bar{x}$	χ^2	*df*	*p*
Organization of learning work	4.0	119.09	5	.001
Communication at the time of explanation	3.0	23.31	5	.001
Communication at the time of interpretation	4.0	72.47	5	.001
Communication after interpretation	2.4	74.87	5	.001
Socializing	2.7	30.65	5	.001
Other	2.1	59.00	5	.001

As the results in the Table 3 show, videoconferencing was most commonly used for "*organization of learning work*", and for "*communication at the time of interpretation*". Both teaching methods were used equally often with the sample mean 4.0. Only one tenth of teachers reported giving traditional "lectures" daily. 15.8% taught frontally for 4 hours per week or more, and about one-third did so sometimes (1-2 hours per week). The data that teachers used videoconferencing for *"communication at the time of explanation"* indicates the possibility of implementing more advanced didactic approaches that include dialogues between students and the teacher, and between peers. 33.9% of respondents reported that they always communicated with students *"in time of interpretation"*, and 21.3% reported that they did so at least 4 hours per week. This optimistic interpretation seems less correct when considering the data on the use of videoconferencing for "*communication after interpretation*". Only 3.8% of teachers always provided the opportunity to communicate about students' new knowledge, what beliefs they held prior to instruction, and how and why they changed their viewpoints (and the same number did so 4 hours per week). More than half of teachers provided this opportunity 1-2 hours per week or less. Insight into what happened during videoconferencing time (besides teaching, organization, and socializing) can be derived by reading what teachers listed under the "*Other"* response. Only 19.7% of teachers provided information in this section. They mentioned "feedback on work, joint discussion of solved tasks", "overview of completed activities", "instructions and

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explanations" "allowing students to ask their classmates questions about the topic", "games and fun experiments for motivation" … The remaining 80.3% of the sample gave no answers.

The third research question examined the percentage of science curriculum objectives that teachers were able to achieve during the remote teaching period. Teachers were asked to compare the annual teaching plan they had created before they knew that the school lock down would occur in October and last until mid-January, with the realization of their plan.

Table 4
Share of Science Curricular Goals Reached During the Remote Teaching Period (lock down)

Curricular Goals Reached	*f*	%
One fifth of curricular goals and less	2	1.1
A quarter of curricular goals	4	2.2
One third of the curricular goals	13	7.1
Half of the curricular goals	21	11.5
Two-thirds of the curricular goals	19	10.4
Three-quarters of the curricular goals	41	22.4
Almost all or all curricular goals	54	29.5
No answer	29	15.8
Total	183	100.0

The results in the Table 4 reveal that less than one third of teachers reached the realization of all science curricular goals they had planned before they knew they will need to change the learning environment from face-to-face to digital learning. Slightly more than one-fifth achieved the realization of three-thirds of the science curricular goals and nearly the same number of teachers (21.9%) reported that they were able to achieve half or less than half of the science curricular goals.

The results presented in Table 4 show statistically significant differences in share of science curricular goals reached during the remote teaching period (χ^2 (7) = 98.05, p = .001) and require closer examination. To provide insight into what was happening with the teaching/learning of science in digital learning environments during the school lock down, teachers were asked to list three science curriculum goals that were – in their opinion – implemented particularly successfully, and three science curricular goals, they decided not to implement in digital learning environments. The answers to this question are of great importance because they reveal a problematic situation in the field of natural science didactics at the primary level. Why is this so? In Slovenia, the school subject *Science* on primary level covers curricular goals, connected with social and natural sciences. Under these circumstances, the answers to the question: *Which curricular goals did you implement successfully, and which did you skip*, reveal which special didactic did not offer suitable solutions: didactic approaches, and didactic materials in distance learning environments. The answers show the gap between the existing didactic approaches in natural science teaching and the didactic approaches that teachers would need to know additionally in digital learning environments.

Table 5
Science Curricular Goals that Teachers did/did not Implement

Science Curricular Goals	Goal 1		Goal 2		Goal 3		Total	
	f	%	*f*	%	*f*	%	*f*	%
				Implemented				
Social sciences	7	10.5	10	14.9	9	13.4	26	38.8
Natural sciences	20	29.9	11	16.4	10	14.9	41	61.2
Total	27	40.0	21	31.3	19	28.3	67	100.0

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Science Curricular Goals	Goal 1		Goal 2		Goal 3		Total	
	f	%	*f*	%	*f*	%	*f*	%
				Not implemented				
Social sciences	8	17.4	3	6.5	0	.0	11	23.9
Natural sciences	18	39.2	11	23.9	6	13.0	35	76.1
Total	26	56.6	14	30.4	6	13.0	46	100.0

Note. Social sciences = history, geography, philosophy, sociology; Natural sciences = chemistry, physics, biology, technology, and engineering.

The results presented in Table 5 show that the didactic problem of digital learning environments is more urgent in natural science special didactics than in social science special didactics. Of the unachieved science curricular goals, only 11 belong to the social science fields. On the other hand, teachers' answers reveal they felt helpless in implementing natural science curricular goals in digital learning environments. The list of unachieved science curricular goals includes 35 topics from the field of chemistry, physics, biology, and technology and engineering.

This research also focused on why teachers did not select natural science curricular goals in the digital learning environments. The results revealed statistically significant differences (χ^2 (6) = 66.23, p = .001). Nearly half of the teachers surveyed (44.0 %) responded that they did not select natural science curricular goals because distance learning requires a different didactic approach. 16.5 % and 15,2 % of teachers cited limited student digital literacy and overly challenging curricular goals for implementation in digital learning environments, while less than one-tenth of teachers cited reasons such as "my own limited digital competence" (7.6 %), "no digital resources available" (7.6 %), "students were not present" (6.3 %) and "the curriculum is overloaded anyway" (2.6 %).

Discussion

The results of the present study may be considered inconsistent with some previous studies. They (as well as other recent research results) do not share the optimistic view of the connection between constructivism and online learning design in natural science teaching – an optimistic view that was typical of educational science before the Covid-conditioned school lock down. Even more, they broaden the focus to educational problems that were hardly mentioned in the research, problems related to natural science teaching on primary level, where students' prior knowledge and competences in general literacy and digital literacy are not sufficiently developed to use them in a communication process needed in the social constructivist teaching/learning paradigm.

In 2005, Bellefeuille et al. pointed out that technology, particularly computer technology, offers many resources that have been proven to complement constructivist practices in the classroom and distance learning. According to them, "the computer base instructional design (and web-based instruction) offers learning environments that are more inherently constructivist in nature" (p. 374).

According to Gazi (2009), the constructivist approach encourages students to manage their learning through metacognitive, self-reflective, and collaborative processes. Gazi pointed out that a constructivist-based online course enhances student learning and promotes communication, teamwork, and critical thinking.

Nevertheless, as early as 2007, Van Merriënboer (2007) pointed out the difficulty of integrating new information into students' prior knowledge in digital learning environments and using it to solve new problems. Therefore, Merriënboer developed a model to improve learning transfer. When designing an online course, the teacher can use videos, animations, or audios to arouse learners' interest and introduce a learning topic. Students can then learn more about the topic by visiting a variety of websites and resources provided by the teacher. Students selected the information, analysed it, and shared their views in the discussion session. In this context the communication between the teacher and the students, as well as between the students themselves, is essential to this learning process. A chat room or internet conferencing should be used to make real-time conversation for immediate answers and questions. The teacher can provide support and guidance to students via e-mail, instant messaging, or discussion board. And perhaps the most important rule for teaching in a digital learning environment: the teacher must provide students with the necessary skills and knowledge (Van Merriënboer, 2007).

This absence of satisfactory levels of these prerequisite skills and competencies, needed for successful communication in digital learning environments proved to be a key factor in lower learning outcomes when the school was suddenly faced with moving instruction to digital learning environments.

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In the context of Covid-19, the IEA and UNESCO, in collaboration with the European Commission (EC), conducted a study that draws a broader picture of the pandemic's impact on global education: Responses to Educational Disruption Survey (REDS). The sample consisted of 15,004 teachers (also 21,064 students and 1,581 school principals) from 11 countries, including Slovenia (REDS, 2022). The aim of the study was to find out how schools were prepared for distance learning in times of school lock down as well as during a subsequent reopening phase, and to gain insights into the effect of disruption and factors and measures that may influence the success of distance learning for students in different countries.

The results are consistent with the findings of the study: Slovenian teachers in the READ, which confirmed the readiness of the digital infrastructure. Internet connections were always available (91% of teachers, a similar result to Denmark, the participating country with the best results), 95% of students had a computer (Denmark 99%), 95% had their own smartphone. Despite this fact, the teachers' answers reveal that they were able to achieve only 28% of the curricular goals without adopting them to the new circumstances in digital leaning environments. 89% of them agreed with the statement that they limited themselves to achieving only the curricular goals that they considered "essential". Particularity important in the context of this research is the READ study result which relates to natural science teaching and learning. Only 35% of the teachers agreed with the statement that they were able to meet the curriculum goals associated with the so-called "practical skills". It is explained (in brackets) that "practical skills" are primarily natural science experiments and products produced in connection with the curriculum goals of technical education (and also arts education). 75% of teachers indicated that they were unable to communicate with students about the results of natural science experiments (and other products in the context of assessing "practical skills"), although 46% of them assigned them anyway (Meinck, et al., 2022). These three results reveal the full range of problems, which occurred around natural science teaching in digital learning environments during school closure and confirm the results obtained through this research.

The findings are consistent with the results of the NESET report (Sternandel, 2021). NESET is an advisory network of experts working on the social dimension of education and training, established by the European Commission's Directorate-General for Education and Culture. This report provides an overview of the available data on the impact of Covid-19-related school disruptions on the learning outcomes of primary and secondary school students in the EU. The report first mentions a study conducted in July 2020 in the United Kingdom based on responses from primary and secondary school teachers and principals. Sharp et al. (2020) found that 98% of teachers believed their students were behind in curriculum learning at the end of the 2019-2020 school year. Teachers reported covering an average of 66% of the usual curriculum in the 2019-2020 school year and estimated that their students were on average about three months behind, which is consistent with the findings of this research. A more detailed picture of the impact of Covid-19 on student learning outcomes is provided by a closer look at the results provided by evidence from standardised tests (Engzell et al., 2021; Maldonado & De Witte, 2020).

Most of the research conducted immediately after the school lock down focused on learning outcomes in the mother tongue (spelling, reading, reading comprehension) and mathematics. Engzell et al. (2021) analysed primary school performance in these subjects in the Netherlands. Their results are particularly convincing because national tests are administered twice a year in the Dutch school system, in January/February and at the end of the school year. Thus, in 2020, these test dates fell just before and after the first nationwide school closures. Access to data from 3 years prior to the pandemic allowed for a comparison of the results and an assessment of differential learning outcomes. The results showed that Dutch primary school students made little or no progress during the 12-week full school lock down and the 11-week partial school lock down. Comparing the data with those from 2017, the results showed that students faced a learning loss of about 3 percentile points in maths and reading or .08 standard deviations, which is equivalent to one-fifth of a school year.

Similar results were obtained in French schools. Andreu et al. (in REDS (2022) have compared the results of national standardised tests in the mother tongue (French) and mathematics and compared them with results from 2019. The tests were carried out in the first and second grades of primary school students. The first-grade results in 2020 showed a massive reduction in learning outcomes in both French and mathematics. In French, test results decreased in all seven evaluated items (compare a series of letters, letters recognition, knowing the sound the letters produce, syllables manipulation, understanding text/sentences/words read aloud by teacher). In mathematics, the results decreased in all evaluated items but one (associate a number with a position). The students were less efficient than in the year before in the following tasks: compare numbers, quantify collections, and resolve problems, list full numbers, reproduce assembly. The second-grade learning outcomes decreased in seven out of the eight items for the subject "French language". Results dropped significantly in several key areas: the share of students

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who could read the text satisfactorily (down 4.8 percentage points), the share of students who could read words properly (down 4.3 points), and the share of students who could write words properly (down 4.5 points). Results in mathematics were less concerning: only one item decreased by more than one percentage point (REDS, 2022). Despite the fact that only a few studies have evaluated the impact of school closures on primary and secondary level teaching, it can be concluded (in no uncertain terms) based on the standardised test results that "the period of school closure generally has had a negative impact on student learning outcomes" (Sternandel, 2021, p. 12).

Focusing on learning outcomes in science teaching, the results of this research can be considered consistent with the Belgian study performed by Maldonado and De Witte (2020). Their study did not only focus only on the mother tongue and mathematics, but they also examined learning outcomes in all other subjects of the school curriculum. Their results showed that in the year 2020 students experienced significant learning loss compared to the previous generation in all subjects except for social sciences. In mathematics, the results showed learning losses between 0.18 and 0.25 standard deviations, and in science, a decline between 0.22 and 0.33 standard deviations. In contrast, as noted earlier, no significant decline in test scores was found in social sciences.

Conclusions and Implications

Regarding the international context of the presented research, at least two research backgrounds relevant to the present research should be mentioned. The first is the fact that the primary grade students belong to Generation Alpha, which had already been exposed to digital environments in early childhood. Consequently, one might expect a higher level of (at least basic) digital literacy competence at the age when children enter school. This would enable first grade students to successfully participate in digital learning environments. The second is the previous research study (by the same authors as in this research), which showed that playing video games and viewing YouTube images does not equip children with the kind of digital literacy that would enable them to successfully participate in the educational process in digital learning environments. At the primary level, this circumstance comes together with the lack or absence of basic literacy skills (in the first grade) and a slowly emerging basic literacy in the second and third grade. All this has a great impact on the creation of communication channels for communication between teachers and students and between students themselves in a learning community, which is essential for the science learning process. The results of the present research support the idea that the second research corpus, which points out the necessity of systematic development of digital competence in members of the Generation Alpha, seems to be right.

The absence of competences needed for successful communication in digital learning environments is a key factor for lower learning outcomes in digital learning environments, which are observed internationally – including students of the first school years. The majority of international research on primary level learning outcomes focuses on reading and writing skills and mathematics, and very little is focused on science and especially natural science curricular goals. The presented research brings deeper insight in natural science education during school lock down, when the learning process moved into digital learning environments. As the READ study showed, teachers, when instructed to 'select' curricular goals according to their own judgement, i.e., deciding whether certain goals are suitable for digital learning environments or not – have very often decided that *natural science topics 'are not suitable for digital learning environments'.* The presented results of this research showed that such decisions were made even more frequently in primary science classes, where teachers indicated that the main problem in this situation was the fact that they were unable to communicate the results of natural science experiments to their students. This result should be considered in the context of the theoretical background (as part of this research), according to which there is no other way to carry out a socio-constructivist teaching/learning process than communication about existing misconceptions, and communication about the process of searching for answers and constructing new knowledge.

As the presented research results showed, the didactics of natural sciences is facing a set of new challenges in finding methodological solutions for teaching early-level physics, chemistry, and technical sciences. The solution that teachers have used during the school closure period, i.e., to skip the natural sciences curricular topics, is simply not an answer we can be satisfied with.

Declaration of Interest

The authors declare no competing interest.

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