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Preconceptions in Physics Among Pupils in Primary School

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Abstract. Significant attention has been devoted to research of the physics preconceptions among primary school children. However, the theoretical anchoring of the term preconcept is often insufficient and commonly used research techniques do not take into consideration the complexity of this phenomenon in many cases. In this study, we present a complex research approach based on the understanding of preconception as disposition. We identified problematical tasks from the TIMSS international survey focusing on 4th grade pupils based on clear criteria. In total, 11 multiple-choice tasks out of 97 analysed were identified as problematical which were most frequently related to the concepts of heat and heat transfer (4 tasks), state of matter (2 tasks) and gravitation (2 tasks). Moreover, an additional survey of 100 high school students aged 15-17 years were carried out using the same tasks in order to understand how physics learning has affected the identified preconceptions. We have also gathered data from students who studied beforementioned concepts in distance learning. Thus, it is possible to compare results (affected preconceptions) from distance and non-distance education. We have found that some of the incorrect preconceptions are corrected during the physics learning but other persist among significant number of pupils. It may have significant consequences for the effectivity of physics teaching at higher stage because of teachers do not expect such extent of fundamental misunderstanding among students. Further research focusing on identification of such incorrect preconceptions and ways how to overcome them in practice is thus highly needed.

THEORETICAL BACKGROUND OF PRECONCEPT RESEARCH

The concept of preconcept is not yet firmly anchored in our environment and there is no consensus in foreign literature in the definition of this concept [1]. Similarly, different authors understand the relationship between preconcepts and misconceptions differently. Misconcepts are also a relatively frequently used term in this context [1]. In subject didactics, there is a common approach where preconcepts are understood in accordance with the original meaning of this concept by Piaget as ideas [2]. According to Nachtigall, misconception is a "misconception of physics phenomena" that appear in pupils, students and older people who already completed physics education. These misconceptions occur during teaching due to the interaction and mixing of preconcepts with what students learn [2]. Other authors use the term misconcepts in the sense of, independently of school teaching, erroneously created preconcepts [1]. Also other authors understand preconcepts as ideas [3]. On the other hand Štěpáník and Slavík understand preconcepts as dispositions ("dispositional units" for solving certain types of situations or tasks), i.e. the pupil's individual disposition to use a shared cultural background or knowledge system [4]. The quality of the preconcept determines the quality of the relevant functional literacy. Ideas depend on the preconcept, but are not identical with it, because they provide a functional connection between the preconcept (disposition) and a specific,

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spatial-temporal action. For the purposes of our research, we use the dispositional understanding of the preconcept updated by the idea, which we approach using a suitably chosen task. Although the concept of preconcept as an idea and as a disposition are significantly different from a theoretical point of view, the representatives of both approaches agree that preconcept is a subjective prerequisite for solving a certain type of problems. In addition, these approaches are consistent in the view of some important properties and manifestations of preconcepts. For example, they agree that students' preconceptions often correspond to obsolete scientific theories from the past, demonstrating the importance of knowledge of the historical development of the field [1]. Preconcepts are also understood as firm structures characterized by "durability and resistance to change" [1,5]. Although we understand these concepts slightly differently from the prevailing trend in subject didactics, we can find a number of common properties that ensure the comparability of our results with previous research focused on the determination of scientific or specifically physics preconcepts.

DIAGNOSTICS AND RESEARCH OF PHYSICS PRECONCEPTIONS

In the Czech and foreign literature, considerable attention has been paid to the research of preconcepts or, more generally, to pupils' conceptions of the curriculum in the field of natural sciences. In 2004, extensive meta-analysis of these researches, which included 180 studies published in major Czech and foreign journals, was conducted. It was found that in terms of natural sciences, the greatest attention was paid to physics with almost a third of the analysed contributions, followed by chemistry. The research was most often focused on high school students and pupils of the 2nd grade of elementary school, followed by university students, pupils of the 1st grade of elementary school and the least attention was paid to science preconcepts of children from kindergartens.

The analysis of research methods used in the given studies, the selection of which is influenced by factors such as the age of the participants, the scope of the research or its targeting, brought very important findings [6]. Interviews with pupils, conceptual mapping and didactic tests were most often used. On the contrary, less common techniques were the analysis of pupils' creations, a questionnaire, observations and a case study.

A larger number of studies focused on the research of physics preconceptions of primary school pupils was published after 2004, when the above-mentioned meta-analysis was prepared. Nezvalová et al. used an ad-hoc didactic test to conduct a research of science preconcepts in 5th grade elementary school students [7]. They found that the preconcepts of heat, temperature, density and state of matter seem to be the most problematic [7]. Škoda and Doulík carried out research focused on pupils' conceptions of selected concepts from physics and chemistry in pupils of 5th, 7th and 9th grade of elementary school [8]. They used the technique of conceptual mapping in semi-quantitative adjustment so that it was possible to perform statistical processing. They found that in the quality of the created concept maps it is not possible to trace the differences between the monitored years. Šťastná in her work carried out a questionnaire survey based on interval scales, while for the given basic concepts of physics and chemistry she found out how the affective dimensions of the given preconcept for 5th, 7th and 9th grade pupils is changed [9]. In foreign studies, we can mention the research which was focused on grasping the concepts of strength and movement in 4th graders [10]. The research included answers to ten multiple-choice questions and subsequent justification of the choice of answer. It was found that the preconceptions of students are not in accordance with the instrumental practice of the field, especially in the subjects of the law of inertia, frictional force and free fall.

Based on the above-described meta-analysis, Doulík concludes, that preconcepts are not comprehensively diagnosed as a multidimensional entity and current diagnostics is mainly focused qualitatively and does not include a larger number of probands [6]. These limitations also apply to research carried out after the implementation of this meta-analysis. The second of these limits can be overcame by the use of secondary analyses of the results of international research surveys, which are carried out on very large samples. This approach is presented by Neidorf et al. [11], who used the results of the TIMSS and TIMSS Advanced surveys in the field of mathematics and physics to determine pupils' concepts in pupils attending in the Czech equivalent 4th grade of elementary school, 8th grade of elementary school and the last year of high school. The research design allowed them to determine to some extent how resilient pupils' initial misconceptions are. It was found that in the field of gravitational force in some countries, incorrect preconceptions persist even after the teaching of the relevant thematic unit [11].

OBJECTIVES AND DESIGN OF THE RESEARCH STUDY

The goals of our research study as well as its design are based on the above-mentioned diagnostics of the preconcept as a multidimensional dispositional entity. The specific objectives are set as follows:

1. To determine which physics preconcepts for 4th grade primary school pupils are problematic. We use detailed analysis of physics tasks from the international survey TIMSS.
2. To find out to what extent the problematic preconcepts are affected (or "corrected") during the course of education.
3. To find out what effect distance learning implemented during a pandemic had on the success of pupils.

As a part of the research, secondary analyses of tasks from TIMSS intended for pupils in the 4th year of primary school and a selection of problematic tasks were performed according to clear criteria listed in the next part of the article. Furthermore, the same problematic tasks were assigned in person to secondary school students who have already completed several years of physics education and their success was determined in comparison with 4th grade students who have not yet encountered the subject targeted education at school. In the case of one of the secondary schools, the same test was given to the same pupils at the time of distance learning (with an interval of about 1 year after full-time testing) and differences in the achieved results were analysed. Due to the descriptive nature of the research, particular hypotheses were not formulated and statistically tested.

METHODOLOGY

Analysis of Tasks from TIMSS and Definition of Problematic Tasks

We analysed a total of 97 tasks assigned in the international comparative survey TIMSS in 2007, 2011 and 2015, which, according to our assessment, fall into the field of physics, which were released by the end of 2018. With regard to our understanding of preconcepts, tasks meeting the following criteria were defined as problematic:
1. The task concerned a subject that pupils typically do not discuss until the end of the 4th year, according to the relevant report of the Czech School Inspectorate. In solving the task, students had to rely on intuition or other sources of information than from formal education.
2. More than 25 % of pupils selected or reported some of the incorrect options, indicating that the pupils did not choose the answers completely randomly and some incorrect option received a significantly higher proportion of answers than the other options.

A summary of the fulfilment of the above criteria can be seen in Table 1, which also lists the international codes of problematic tasks that meet both of the above criteria. These 11 tasks were further analysed.

TABLE 1. Selection of problematic tasks from the TIMSS survey

	TIMMS 2007	TIMMS 2011	TIMMS 2015
The total number of analysed tasks in the survey	31	32	34
Number of tasks meeting the 1st criterion	18	20	20
Number of tasks meeting both the 1st and 2nd criteria	2	5	4
Selection of researched tasks (international code)	S03 – 08 S04 – 07	S06 – 05, S07 – 05, S05 – 09, S01 – 06, S07 – 09	S05 – 10, S05 – 08 S02 – 08, S07 – 04

Solving Problematic Tasks by High School Students

The 11 problematic tasks selected above were assigned to 47 pupils from two classes of the 2nd year of the Masaryk Grammar School in Pilsen and 53 pupils from two classes of the 1st year of the Secondary Industrial School of Electrical Engineering in Pilsen (further as SPŠE). The participants age was 15–17 years. The tasks were assigned by physics teachers and the authors of this study as a potentially evaluated individual work, students had 10 minutes to answer. Pupils were not informed in advance that these were tasks from the TIMSS survey intended for the 4th year of elementary school. The results were analysed in terms of the frequency of individual answers, attention was also paid to possible differences between the grammar school and the secondary industrial school. In the case of SPŠE, testing was repeated online one year later via the Microsoft Teams platform during distance learning during a pandemic. 50 pupils took part in the repeated testing, in addition to the correctness of the answers, the time of completing the test and its effect on success was also monitored.

RESULTS

We will present the results of the research in individual problematic tasks. This approach is in line with our strategy of approaching preconcepts through learning tasks. The synthesis of the findings obtained for individual tasks and their connection with the relevant preconcepts will be performed in the light of the findings from the literature in the following section Discussion and conclusions. On this point let us state an interesting finding that during online testing in distance learning, high school students took an average of 223.5 seconds to complete the 11-item test (standard deviation: 44.1 seconds, range 131–305 seconds). A weak negative correlation was found between the filling time and the success in the test, when the relevant Pearson correlation coefficient was -0.21.

Task 1 (S03 - 08), assigned in 2007

Students had to decide what is the main reason why they can see the Moon. The answer options were:

A) The moon reflects light from the Earth. B) The moon reflects light from the Sun. C) The moon emits its own light. D) The moon is bigger than the stars.

The relative frequencies of answers of Czech 4th -year pupils in the TIMSS survey and high school pupils in our research (broken down by secondary school and the form of the test assignment) are shown in Table 2.

TABLE 2. Comparison of answers for task 1

Answer variant	A	**B**	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	6.0	34.1	25.3	30.8
Relative frequency among grammar school pupils (n = 47) (%)	0.0	97.9	2.1	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	0.0	92.4	3.8	3.8
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	2.0	96.0	2.0	0.0

Note: The correct answer is marked in bold and/or red, the sum does not have to give 100 %, because some students did not answer. The same is true for Tables 3-12.

Task 2 (S04 - 07), assigned in 2007

The assignment of this task was as follows:

In which case does the object move because a gravitational force acts on it?

A) The girl hits the ball with a bat. B) The boy pushes the box on the floor.

C) The girl hammers a nail into the wall. D) The boy falls from the tree to the ground.

TABLE 3. Comparison of answers for task 2

Answer variant	A	B	C	**D**
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	38.3	7.9	10.3	38.5
Relative frequency among grammar school pupils (n = 47) (%)	0.0	0.0	2.1	100
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	7.6	0.0	1.9	90.6
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	6.0	0.0	0.0	94.0

Task 3 (S06 - 05), assigned in 2011

The task was: *Which of the following sentences describes condensation?*

A) The liquid changes to a solid. B) The solid turns into a liquid.

C) The solid changes to a gas. D) The gas changes to a liquid.

TABLE 4. Comparison of answers for task 3

Answer variant	A	B	C	**D**
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	20.4	39.8	4.1	31.2
Relative frequency among grammar school pupils (n = 47) (%)	0.0	12.8	0.0	87.2
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	1.9	37.7	1.9	58.5
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	0.0	20.0	2.0	78.0

Task 4 (S07 - 05), assigned in 2011

The question was asked as follows: *We will use a metal and a wooden spoon to stir the hot soup in the pot. After a few minutes, we feel that the metal spoon is warmer than the wooden one. What is the explanation for this phenomenon?*

A) Metal is always warmer than wood. B) Metal conducts heat better than wood.

C) Metal conducts electricity better than wood. D) Metal heats water better than wood.

TABLE 5. Comparison of answers for task 4

Answer variant	A	B	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	30.7	45.9	8.7	13.7
Relative frequency among grammar school pupils (n = 47) (%)	0.0	100.0	0.0	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	1.9	98.1	0.0	1.9
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	0.0	100.0	0.0	0.0

Task 5 (S05 - 09), assigned in 2011

The task was assigned as follows: *Put the hot boiled eggs in a cup of cold water. What happens to the temperature of the water and the eggs?*

A) The water is cooled and the eggs are heated. B) The water is heated and the eggs are cooled.

C) The water temperature remains the same and the eggs cool. D) Both the water and the eggs are heated.

TABLE 6. Comparison of answers for task 5

Answer variant	A	B	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	5.5	28.4	38.2	25.2
Relative frequency among grammar school pupils (n = 47) (%)	2.1	91.5	6.4	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	1.9	60.4	30.2	5.7
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	2.0	76.0	20.0	2.0

Task 6 (S01 - 06), assigned in 2011

The question was asked as follows: *A piece of ice was placed in a glass of water. Which picture best describes where the ice will be? In the case of option A, the whole cube floated on the surface, in B it was about 90% immersed, in C the whole cube was submerged and floated in and in D it was at the bottom of the glass.*

TABLE 7. Comparison of answers for task 6

Answer variant	A	B	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	12.8	52.2	5.6	28.6
Relative frequency among grammar school pupils (n = 47) (%)	0.0	97.9	2.1	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	3.8	90.5	3.8	1.9
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	0.0	98.0	0.0	2.0

Task 7 (S07 - 09), assigned in 2011

The question was: *What causes an object to fall to the Earth's surface when you release it from your hand? A) magnetism B) gravity C) air resistance D) pushing your hand*

TABLE 8. Comparison of answers for task 7

Answer variant	A	B	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	25.9	51.5	9.0	10.2
Relative frequency among grammar school pupils (n = 47) (%)	0.0	97.9	2.1	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	0.0	96.2	0.0	3.8
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	0.0	100.0	0.0	0.0

Task 8 (S05 - 10), assigned in 2015

In this task, students had to determine which of these materials conducted heat best. The options were as follows: *A) wood B) metal C) glass D) plastic*

TABLE 9. Comparison of answers for task 8

Answer variant	A	**B**	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	36.7	41.6	6.4	9.0
Relative frequency among grammar school pupils (n = 47) (%)	0.0	100.0	0.0	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	1.9	94.3	0.0	3.8
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	0.0	100.0	0.0	0.0

Task 9 (S05 - 08), assigned in 2015

In this task, students had to decide in which of the two circuits with two connected batteries, the light bulb will light. In circuit 1, the batteries were connected minus to each other, while in circuit 2, minus the first battery was connected to the plus of the second battery. The options were as follows:

A) the bulb only lights up in electrical circuit 1 B) the bulb only lights up in electrical circuit 2

C) the bulb is lit in both electrical circuits

TABLE 10. Comparison of answers for task 9

Answer variant	A	**B**	C
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	32.1	43.2	6.0
Relative frequency among grammar school pupils (n = 47) (%)	4.2	95.8	0.0
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	17.0	81.1	1.9
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	10.0	90.0	0.0

Task 10 (S02 - 08), assigned in 2015

Aluminium foil was placed on the table and ice cubes were placed on it, which melted after a while. Pupils were asked to determine what caused the ice cubes to melt. The options were as follows:

A) The heat from the ice cubes transfers to the table. B) Heat from the table transfers to the air.

C) The heat from the ice cubes is transferred to the aluminium foil. D) Heat from the air transfers to the ice cubes.

TABLE 11. Comparison of answers for task 10

Answer variant	A	B	C	**D**
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	2.4	3.4	25.4	67.7
Relative frequency among grammar school pupils (n = 47) (%)	0.0	0.0	25.5	74.5
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	1.9	0.0	24.5	73.6
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	6.0	4.0	22.2	68.0

Task 11 (S07 - 04), assigned in 2015

In this task, students were asked to determine why a shadow is created when light from a lamp hits an object. They had a choice of the following options:

A) The object covers the path of light. B) Light passes through the object.

C) The light revolves around the object. D) The light is refracted to the side by the object.

TABLE 12. Comparison of answers for task 11

Answer variant	**A**	B	C	D
Relative frequency in the TIMSS 2007 survey in the Czech Republic (%)	56.6	11.1	3.8	26.5
Relative frequency among grammar school pupils (n = 47) (%)	76.6	0.0	0.0	23.4
Relative frequency among SPŠE pupils - full-time (n = 53) (%)	77.4	0.0	3.8	18.8
Relative frequency in SPŠE pupils - remotely (n = 50) (%)	82.0	0.0	0.0	18.0

DISCUSSION AND CONCLUSIONS

In the previous part, the answers of students in specific learning tasks are addressed. The obtained partial results need to be linked with preconcepts, which we understand as the disposition of students towards the corresponding physics concepts (preconcept is the subjective counterpart of the concept). When linking learning tasks with preconcepts, we start from the hierarchization of concepts performed in our previous study [12]. In it we distinguished between key concepts (basic building blocks of the field as cause and effect, size, matter and energy), substantive concepts (typically physics quantities), organizational concepts (typically relationships between physics quantities) and application concepts (application of a relation to a specific system or geometry). 4 of the 11 problematic tasks addressed the substantive concept of heat, while in two cases (tasks 4 and 8) the focus on the organizational concept of heat conduction is evident, in the other two (tasks 5 and 10) the organizational concept of heat exchange is targeted. The Heat concept was already mentioned as problematic in the study by Nezvalová et al. [7]. A closer look at the tasks suggests that the problem with heat conduction is that primary school pupils confuse the ability to conduct heat with a tendency to burn (task 8) and also have problems with a clear distinction between heat as a process variable and temperature as a state variable. The results of the corresponding tasks for high school students suggest that these problems are relatively well overcome during the 2nd grade of primary school. This is probably due to the fact that the combustion process is discussed in detail in chemistry and there are a considerable number of illustrative experiments for heat conduction, which make it possible to dismiss the initial misconceptions of students. The situation is different with the organizational concept of Heat Exchange, where a relatively high failure rate was achieved in the respective tasks, even for high school students. This may be related to the fact that heat exchange is (in the sense needed to solve these problems) difficult to grasp experimentally. In task 5 with cooling the egg and heating the water, where many 1st grade pupils and a significant number of high school students thought that the egg could be cooled without heating the water, we encounter a more general problem, which was previously pointed out by the organizers of 2nd grade elementary school testing from the project Kalibro [13].

A high failure rate was also observed at secondary schools in the task concerning heat exchange during change of state (task 10). Here, the concurrence of two different concepts, Heat Exchange and Change of State, is probably problematic. In contrast to the situation described above with heat exchange, this is a purely qualitative problem, because about a quarter of primary and secondary school pupils did not realize that heat needs to be supplied to melt, not removed. Low success rate among secondary school pupils was also observed in another task (number 3) concerning the organizational concept of change of state, where more than a quarter of secondary school pupils (compared to 40 % of 4th grade primary school pupils) stated that the term liquification corresponds to the change from solid to liquid. This indicates a lack of mastery of terminology related to change of matter state. The above findings suggest that in the preconcept of the change of state, the wrong pupil's misconception is during the 2nd grade of primary school not fully corrected. This is relevant towards teaching at secondary schools, where this topic is addressed primarily quantitatively, while it is assumed that the qualitative level of understanding has already been achieved in previous education. In this context, the issue of the state was found to be problematic also in the previous research of preconcepts carried out by Nezvalová et al. [7].

Two problematic tasks (2 and 7) concerned the substantive concept of Gravity. In both cases, the success in testing at secondary schools was already very high, which is probably related to the fact that pupils at the 1st stage of primary school did not encounter the concept of gravity at all. Both of the considered tasks concerned only a basic understanding of what the gravity is, it is not so surprising that students are able to answer these tasks correctly after completing the relevant teaching in science and subsequently physics. It is, of course, possible that even in higher education pupils and students, there are misconceptions concerning gravity, which may be caused besides other by incorrect grasping of this concept by primary school teachers [14,16]. However, the tasks analysed by us cannot prove this fact. One of the tasks (number 11) concerned the organizational concept of Shadow. It was found that a relatively high percentage of primary and secondary school pupils link the formation of shadow to the refraction of light to the side of the object and do not use the knowledge of rectilinear light propagation correctly. This finding confirms the earlier fact obtained in the analysis of the results of the TIMSS survey in the 8th year [12] that a significant percentage of students have difficulty mastering the basics of optical imaging, which are often taken for granted in teaching and they are not given adequate attention. Without understanding them, however, optics becomes a "science of lines", in which pupils draw rays (and their behavior, for example, in a mirror or a lens) according to learned rules, although they do not understand the basic principles. It would therefore be appropriate to include in the teaching at the 2nd stage of primary school simple and illustrative experiments that would clearly demonstrate the origin of the shadow and clarify the role of refraction of light in it. Task 6 focused on the combination of the substantive concept of Density with the organizational concept of Archimedes' law. According to the findings of previous research [12], this is a problematic area, because both of these concepts fall into the so-called critical points of the curriculum. However, in this particular task of focusing on the position of an ice cube in a glass of water, there was almost no misconception among high school students. High success was also registered in the testing of secondary school pupils in tasks 1 and 9 concerning the organizational concepts of Light Sources and Connection of Power Sources. In the second case, the problem found in the pupils of the 4th year of primary school mainly concerned the application concept of battery connection in a given (for pupils) atypical arrangement. However, the partial findings presented in this study have a clear relevance towards practice, because they show that in some important concepts, even high school students have a relatively low level of qualitative understanding, which teachers must take into account when planning teaching at secondary school level as the teaching is usually already focused quantitatively. Without taking into account the low level of qualitative understanding of pupils, however, the risk of didactic formalism called disconnected cognition increases [15], when pupils learn mechanically advanced arithmetic techniques, although they do not actually understand the physics context. Therefore, in further research, in addition to a more detailed examination of these preconcepts (eg in the form of interviews with students), it is necessary to focus on this issue.

Regarding the repeated testing carried out during distance learning approximately one year after the original testing, an improvement was observed for all but one tasks in the studied group suggesting that pupils managed to take a lesson from the discussion of the baseline test results. Simultaneously it was found that pupils had needed only very little time to complete the test (approximately 20 seconds per task) in the distance learning follow-up with no significant correlation between the time needed and test results. It suggests that reading comprehension was not a relevant issue here as proposed by some in the interpretation of the mediocre results of the original in-person testing with the time limitation of 10 minutes.

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