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Metacognitive and cognitive abilities in reading comprehension among Russian upper secondary and undergraduate students: Explanations from different points of view

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Abstract: The study was aimed at identifying the characteristics of upper secondary and undergraduate students' ability to learn when working with explanatory learning texts, depending on the level of their logical thinking. The experiment involved 669 third- and fourth-year university students (future philologists [*n* = 351], teachers [*n* = 90], psychologists [*n* = 96], and soil scientists [*n* = 132]) and 121 upper secondary students. We used two methods to identify spontaneous strategies for understanding the text: 1) "Select the main sentences" (Mal'skaya & Sidel'nikova, 1984); and 2) "Search for contradictions" (Korotaeva, 2000). We also diagnosed logical thinking, using the following methods: 1) tasks for equalizing variables in the process of confirming and testing hypotheses; 2) "the plant problem" (Kuhn & Brannock, 1977) and 3) the Badelly reasoning test. Our sample showed that understanding of the text is significantly related to the level at which the subject forms logical operations. There was a weak positive correlation between the ability to highlight the main thing and the ability to detect contradictions in the text. The ability to highlight the main thing was significantly and positively associated with the formation of certain logical operations. The study also revealed differences in the quality of work with the text and the mastery of logical techniques between students of different specialties, with the lowest results observed in students of pedagogical specialties. The university students' ability to highlight the main sentences was also compared with that of high school students (Grade 10, mean age 17.3). The results are discussed from two different theoretical standpoints: the Cognitive approach and the Cultural-Historical Activity approach.

Keywords: reading comprehension, explanatory learning text, logical thinking, undergraduate students, upper secondary students

Metakognitivne in kognitivne sposobnosti ruskih srednješolcev in dodiplomskih študentov pri bralnem razumevanju: razlage z različnih gledišč

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Povzetek: Namen študije je bilo identificirati značilnosti učnih sposobnosti srednješolcev in dodiplomskih študentov pri delu z razlagalnimi učnimi besedili v odvisnosti od ravni njihovega logičnega mišljenja. V eksperimentu je sodelovali 669 študentov tretjega in četrtega letnih univerzititnega študija (bodoči filologi [*n* = 351], učitelji [*n* = 90], psihologi [*n* = 96] in geologi [*n* = 132]) ter 121 srednješolskih učencev. Za identifikacijo spontanih strategij razumevanja besedila smo uporabili dve metodi: »izberi glavno poved« (Mal'skaya in Sidel'nikova, 1984) ter »poišči neskladnosti« (Korotaeva, 2000). Poleg tega smo logično mišljenje diagnosticirali z uporabo naslednjih metod: nalog za izravnavo spremenljivk v procesu potrjevanja in preverjanja hipotez, »rastlinskega problema« (Kuhn in Brannock, 1977) ter Badelleyevega testa sklepanja. Rezultati pri naših udeležencih kažejo, da je razumevanje besedila pomembno povezano z ravnjo posameznikovih logičnih operacij. Sposobnost označevanja najbomembnejšega dela besedila in sposobnsost zaznave neskladij v besedilu sta bili nizko pozitivno povezani. Študija je prav tako pokazala razlike v kakovosti dela z besedilom in obvladovanju logičnih tehnik med študenti različnih študijskih smeri, pri čemer so najnižje rezultate dosegli študenti pedagoških smeri. Sposobnost študentov za označevanje glavnih povedi smo primerjali s sposobnostjo srednješolcev (10. razred, povprečna starost 17,3 let). O rezultatih razpravljamo z dveh teoretskih gledišč: kognitivnega pristopa ter pristopa kulturno-zgodovinskih dejavnosti.

Ključne besede: bralno razumevanje, pojasnevalna učna besedila, logično mišljenje, dodiplomski študenti, srednješolci

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In the conditions of modern education, the ability of students to independently assimilate information from scientific texts has become extremely important. This was especially evident in distance learning during the COVID-2019 pandemic, when each student had to become an active subject of his/her educational activity, internally motivated to obtain scientific knowledge, mastering ways of processing information and regulating their own cognitive activity. In this regard, the study of the psychological processes underlying comprehension of the texts becomes very relevant (Brown et al., 1983; Hattie, 2008; Lennon, 2010; Thiede et al., 2003).

Modern cognitive research shows that text comprehension is a complex process that is supported by a whole range of cognitive and metacognitive skills (Kintsch, 1998; Snow, 2002; Wooley, 2011). In Russian Cultural-Historical Activity Theory (CHAT), the process of text comprehension is considered a special type of activity, which includes actions of different levels, and some of them can be considered as cognitive and metacognitive (Il'yasov & Galatenko, 1988; Korotaeva, 2014). However, the question of the interconnection between metacognitive and cognitive skills in educational text comprehension cannot be considered to have been solved, either at the empirical or theoretical level.

In this paper, we present the results of comparing the formation of cognitive and metacognitive skills in university students, and also compare similar parameters in upper secondary school students. We also suggest how these results could be interpreted differently from different approaches.

Cognitive and metacognitive components in text comprehension: Cognitive approach

In modern cognitive psychology based on Constructivism (Duffy & Jonassen, 1992; Vianna & Stetsenko, 2006), the reading comprehension process is considered, first, as the active construction of a mental representation of the text's ideas (Wooley, 2011). This process is two-sided: the quality of comprehension is influenced by the characteristics of the information presented in the text, as well as by how this information will be integrated with the reader's prior knowledge.

Traditionally, Cognitivism distinguishes three types of mental models or levels of text representation (Gernsbacher & Kaschak, 2013; Kintsch 1998; van Dijk & Kintsch, 1983).

The first is the surface-level representation, which is a verbatim representation of the wording used in the text. Usually, such a representation is forgotten after a few days. The second level of representation is a text-based model, in which the reader builds the structure of the text itself: the sequence of the described content, the connections between its individual parts, etc. At the third, deepest level, a situational model is built. This integrates information from the text into the system of the reader's previous knowledge; it does not preserve verbatim descriptions from the text or the sequence of its parts, but is a more flexible structure, a representation of the content of the text. The situational model is structured around five dimensions: the protagonist, the time, the space (what relationships among characters, objects, and events are described), causality (which events are connected by causal connections), intentionality (how much the described content coincides with the goals and desires of the protagonist; Gernsbacher & Kaschak, 2013). In fact, a true understanding of the text is the construction of a situational model, since it is here that integration with prior knowledge takes place. The linguistic mechanisms of this process are widely discussed in the literature (for example, whether the construction of a situational model is based on language structures, motor activity, or imagination – see, e.g., Kosslyn, 1994), and we will not dwell on them.

What about psychological structures?

In the literature, two systems of psychological processes involved in the process of text comprehension are discussed.

The first is the system of cognitive processes. These occur simultaneously at different levels. First is the literal level: the understanding of separate words/sentences (when lexical information is used to construct a situational model). Second is the inferential level: establishing logical connections (when a series of sentences is integrated into a holistic picture, connected logically or based on a more global picture). The third process is actual thinking, the level of problem solving (Gernsbacher & Kaschak, 2013; Wooley, 2011).

One of the important issues on which authors differ is related to how logical coherence is established: whether the reader constructs only partial consistency or includes it in a broader context. Studies using the Constructivist approach (e.g., Graesser et al., 1994) suggest that it all depends on the reader's purpose: he will construct coherence depending on what he is reading and why he is trying to understand the text. More and more research shows that readers always choose what to read from the text and how deeply it needs to be understood; in addition, much depends on the genre of the text (Graesser et al., 1998; Zwaan, 1994).

At the same time, successful text comprehension requires the involvement of metacognitive structures or metacognition. This is the second system of psychological processes. The term "metacognition" was suggested in the 1970s by J. Flavell, and denotes a person's knowledge of their own cognitive processes, which is primarily associated with the management of their own cognitive activity. As the two main components of metacognition, Flavell distinguishes metacognitive knowledge (knowledge about the features of one's own thinking, about the tasks and requirements they impose, about strategies) and metacognitive regulation (metacognitive experience or strategies; Flavell, 1979). Some authors consider metacognition as the highest level of cognitive activity or a type of thinking of the second and higher order (see, for example, Karpov, 2015).

Metacognitive strategies of regulation are of the greatest importance among metacognitive processes, in relation both to problem solving and text comprehension. These strategies have three main functions: *planning*, *monitoring*, and *evaluation*.

Planning requires an understanding of the task and the organization of the material. It includes the selection of the necessary strategies for working with the text and the allocation of resources. **Monitoring** requires tracking your progress towards solving a problem and identifying

difficulties, determining which strategies are best suited and how to organize conditions for their implementation. For example, the strategy of tracking one's own understanding ("comprehension monitoring strategy") is quite popular, aimed at monitoring how much a person understood the text after reading it through and asking himself questions (Livingston, 2003). In addition, such strategies as highlighting (underlining) important parts in the text, various mnemonics, etc., are widely used. **Evaluation** strategies are related to the overall assessment of the quality of text understanding and problem solving (Chamot & Robbins, 2007).

The question of which criteria should be used to separate cognitive strategy from metacognitive strategy, and, more broadly, metacognition and cognition, is widely discussed in the literature (Georghiades, 2004; Nelson & Narens, 1990; Veenman & Spaans, 2005). According to J. Flavell (1979), metacognitive strategies differ from cognitive ones not so much in content as in the functions they perform. If cognitive strategies are aimed at implementing the cognitive process, then metacognitive strategies are aimed at monitoring it. When working with an educational text, the reader needs to identify elements that are significant for his understanding, regardless of the form in which they are presented; to monitor the switching of attention between semantic blocks; and to compare the content of the verbal and visual codes used in the material. Thus, in our case, metacognition is the process of monitoring the reader's own cognitive effectiveness when working with the text (Flavell, 1979). Metacognitive and cognitive strategies are closely intertwined and depend on each other, so that any attempt to explore one without taking the other into account is nonproductive (Zhang & Zhang, 2015).

Studies on the role of the metacognitive component of the reading process suggest that strategies for monitoring one's own cognitive actions at different stages of working with the material (before, during, and after reading) are a necessary condition for successfully understanding the meaning of the text (Paris et al., 1984; Pressley & Ghatala, 1990). In addition, researchers report that metacognitive knowledge is the basis for the competent choice and application of reading strategies for the most complete understanding of the material (Artelt & Schneider, 2015), and the indicator of the level of their formation correlates with assessments of the ability to learn from a scientific text (Dotsevich, 2014). Another important factor determining the effectiveness of the reading process is called "metacognitive strategic awareness", which includes: 1) the knowledge component, which is a combination of several types of meta-knowledge (declarative, procedural, knowledge of the conditions of activity), which provides conscious monitoring of the reading process; 2) the component of self-regulation of reading activity; 3) the monitoring component, in the form of a program for determining the effectiveness of the reading strategies used (Evdokimova, 2018).

In the Cognitive approach to text comprehension, it seems to us important, first, to distinguish *the levels of understanding* (surface, text, and situational model), which allows us to approach description of the result of understanding more comprehensively, and, second, *the levels of the process itself* – literal, inferential, thinking and metacognitive, which are obviously connected with different text comprehension difficulties. However, the specific relationship between cognitive and metacognitive levels and their role is not sufficiently clarified. It is only clear that they implement different functions, but they are often the same processes (for example, you can ask questions about the text both to understand it and to monitor this understanding!).

We also see that the Constructivist paradigm has been changed in its discussion of the importance of setting goals for understanding its process. During the last 20 years, another important aspect of text comprehension has been discussed widely: the possibility of using texts to solve real-life problems – so-called reading literacy. According to the authors of the concept (Organisation for Economic Co-operation and Development [OECD], 2010), reading literacy is a person's ability to understand and use written texts, reflect on them, and engage in reading to achieve their goals, expand their knowledge and capabilities, and participate in social life. This functional aspect of the comprehension of educational texts (precisely as a means of human activity) brings the indicated approach closer to the Cultural-Historical Activity approach, which will be discussed below (Zukerman & Ermakova, 2004).

Cognitive and metacognitive components in text comprehension: The CHAT approach

According to Cultural-Historical Activity Theory, learning is an active and conscious process in which the student is an active subject (Gal'perin, 1989; Leont'ev, 1947). The main units of analysis in educational psychology, based on the ideas of CHAT, are the concepts of activity and action. Action [Russian: *deistvie*], according to Gal'perin (1989), is the leading component of the learning process, because learning is a continuous sequence of actions: reading and writing, listening and understanding, counting, adding and subtracting, performing grammatical, mathematic analyses, etc. It should be noted that Gal'perin does not mean *any* action, but *purposeful* action that leads to the solution to a particular problem (we also can call it a means of purposeful action). Another component of learning are concepts that must be acquired through action or as part of different actions (Gal'perin, 1989). He states that we can speak of three components of any action: orienting (developing a goal, a plan for implementation, and tools for checking the results), executing, and monitoring (Gal'perin, 1966). The main component of the orienting part is the **orientation basis of action** (OBA), which is what the subject focuses on when performing the action. OBA includes an understanding of the goal (object) of an action, the sequence in which it is implemented, as well as the characteristics of the material, the tools used, and much more (Gal'perin, 1989). In fact, Galperin describes both the cognitive and the metacognitive (the level of orientation and monitoring of actions). OBA may seem very close to the mental model, but there is a fundamental difference. According to Galperin, it makes sense to study not every learning action, but only effective ones – actions that are reasonable (against the actions, which only imitate teacher's actions), conscious (contrary to an inability to explain what I'm doing), generalized (can be applied to a wide class of

tasks), reflexive, and mastered (Engeness, 2021). Moreover, OBA has a specific function (and is assigned precisely to this function): planning and regulation of action.

What is learning, and more specifically learning from texts, according to the CHAT approach? Learning is a change of actions (their content and properties) in the educational process. The process of such change is often described as a special activity – learning activity or self-change activity (El'konin, 1966; Il'yasov, 1986). It should be noted that even within the CHAT approach, there are two different interpretations of learning activity (especially when using texts). One of these positions is closer to the cognitive interpretation, and the other is further from it.

Thus, according to the first position, that of Il'yasov and Mal'skaya (1979), it is important to distinguish between actions that are assimilated in the learning process (including through texts) and learning itself as a special activity for the assimilation of these actions. The actions performed in learning are those subject-specific actions (reading/writing/mathematical operations, etc.) that the curriculum requires. They are the object of the activity – what needs to be mastered and what will change in the learning process. These actions can be understood as subject-specific cognitive processes.

The learning itself takes place on two levels:

1. The actual learning activity as a specific activity. It has three components:
   - The orienting basis of the learning activity ("knowledge about the subject, product, means, actions, and operations of this activity"). The key for text comprehension here is construction of a program for future activities to understand the text, based on the generalized characteristics of typical assimilable material: knowledge about the logical structure and components of scientific knowledge presented in educational texts of different types, and knowledge of the structure of educational actions for understanding any material and working through it (Il'yasov & Mal'skaya, 1979). In the language of cognitive psychology, effective text comprehension is based on metacognitive knowledge (about the task/strategies) and metacognitive strategies for planning, selecting resources, etc.
   - The second component is the learning process itself (the executive part of learning). The executive part of the activity of text comprehension includes this activity itself – in this case, the activity of understanding, which is represented by two types of actions, *clarification* and *elaboration*. In particular, for the effective assimilation of the material from the texts, the student should have formed such actions of clarification (understanding) as thematization (highlighting the topics and assigning them to logical types of content – for example, the facts, theories, methodology, etc., underlying the search for the essential in the text), systematization of the material (establishing logical relationships between fragments of content), drawing up a plan, as well as determining the clarified content (taking notes, drawing up diagrams, etc.), etc., and actions of working through (consolidating) the learned material. All these actions are essentially metacognitive; they are aimed at improving understanding and its appropriation.
   - The third component is the monitoring part of the activity, which includes actions aimed at obtaining information about the progress of implementation. The monitoring part of the learning activity is designed to provide quality assessment and correction (if necessary) of the entire process of assimilation of content in the process of reading. Here we are talking about metacognitive strategies for monitoring and evaluation; in fact, this is an analogue of metacognitive strategies for planning, regulation, and evaluation.
2. The second level of learning activity is that of more general cognitive actions. These are divided into two groups: "the first includes cognitive actions on the empirical and theoretical levels of cognition and their constituent operations (actions for understanding the material), and the second are actions related to memorization (arbitrary, involuntary, indirect, direct)" (Il'yasov, 1986, p. 135).

So, if we are talking about text comprehension, then according to Il'yasov and his colleagues, for effective understanding, it is important not only to be able to perform the actions referred to in the text and regulate their implementation, but to understand how text comprehension itself works, what kind of activity it is, and to perform and regulate it.

A fundamentally different (but also CHAT!) approach to understanding both the learning process and the specifics of text comprehension is presented in the works of G. A. Zukerman, E. V. Chudinova, and E. V. Vysotskaya, based on the ideas of Davydov (Chudinova & Zaitseva, 2014; Zukerman & Kleshch, 2017). From their point of view, learning is not a separate activity that needs to be formed as a meta-disciplinary activity. Full text comprehension requires both prior knowledge and the ability to think conceptually in this particular field of knowledge. So, "only the student's own purposeful subject-specific actions allow him to construct a system of guidelines that serves as support for further text comprehension" (Chudinova & Zaitseva, 2014, p. 45). This refers to actions for the construction and transformation of learning models (methods of action). If the initial basic concepts for students' text comprehension were natural or naïve concepts, it will be impossible to talk about any understanding. In the works of E.V. Vysotskaya and her colleagues (Vysotskaya et al., 2020), the condition for full comprehension of educational texts is their specially developed content, which describes the purposeful transformation of natural material in accordance with the tasks of human activity ("from an ear to a loaf", "from a stem to a shirt", "from ore to iron"). This makes it possible for students to simulate the process of creating a thing that a person needs (what happened, how it happened, what the action was) based on the analysis and transformation of the text itself (Vysotskaya et al., 2020). The task of building a model, therefore, directly mediates text comprehension. In Russia, there is a specific curriculum (the El'konin-Davydov educational system) built on providing the conditions for children to understand why certain concepts were created

in the history of mankind and what their main functions are. Students who are educated according to the El'konin-Davydov curriculum, where conceptual, theoretical thinking is specially cultivated, demonstrate significantly higher levels of understanding of informational texts (Sidneva et al., 2020; Zukerman & Kleshch, 2017).

This version of CHAT emphasizes the important fact that the text itself is only a reference point for some action and should be considered in conjunction with the subject matter and conceptual apparatus of the particular science. This approach is close to the idea of functional literacy, described in detail in the framework of the justification of the international PISA studies (OECD, 2010; Zukerman & Ermakova, 2014). In this sense, the study of comprehension of the educational texts – how they acquire the function of reference points for the student's subject-related actions – is productive from the standpoint of CHAT. What logical skills might be behind the understanding of the text according to this theoretical paradigm?

For us, possible action can be that of "understanding" a definition: the action of concept recognition (Gal'perin & Talyzina, 1957). The essence of this action is not to understand, to comprehend the elements of the definition, but to use it as a reference point for recognizing situations and objects described by the concept that is defined. Thus, it is in this action that the criterion for "understanding the definition" is the use of its elements as reference points for future recognition action. Formally, the action of summing up the concept is a logical action, and the extent of its formation is easy to check. But can we say that those who have a well-formed grasp of the concept use more effective strategies for text comprehension? This is one of the questions that we hoped to find an answer to in this study.

Summarizing the comparison of the cognitive approach and the CHAT approach, we conclude that in fact there are only two methodological positions in relation to text comprehension. In the first case, the text is considered as an "independent" object of analysis and students need to be taught to understand it. In the second case, the text is considered as a mean of solving other problems; it may or may not change the person's previously acquired knowledge and skills. The emphasis on the first or second model sets different strategies for the teacher's work with text comprehension. But even at the diagnostic level, in our opinion, it is possible to "grab" a particular strategy for text comprehension, whether the text will really be perceived in its orienting function (as something that explains something, as an answer to a question) or will be perceived as a specific object in itself. In this sense, methods can help that track how the reader correlates what is described in the text with reality, whether he sees contradictions in the explanation of this reality in the text, whether he can use the features of objects specified in the texts to recognize real objects.

Although in educational practice (especially in higher educational institutions) we specify effective strategies for working with educational and scientific texts, in most cases the teacher relies on the student's internalized reading experience, which he or she has developed by the time of university study, which does not take into account scientific data, and especially does not teach working with texts. Another important factor is the inadequate reading competence of both in-service teachers and pre-service teachers, which is evidenced by studies of the effectiveness of their use of strategies for reading explanatory texts (Dotsevich, 2014; Korotaeva, 2019).

In this study, we try to assess the level of metacognitive strategies for working with explanatory texts among university students and 10th-graders and assess how this level is related to their logical skills. With regard to logical skills, it seems to us that it is fundamentally important, in addition to concept recognition, to study hypothetical-deductive thinking, in particular the logical method of equalizing variables. This method (Baldina, 1987; Il'yasov, 1986) is described by certain actions. The first action is *the selection of variables*. But it makes sense to measure this ability only in connection with the second one: implementation of the equalization rule (to determine whether a certain variable affects the result, it is necessary to compare situations with different values of this variable so that the remaining variables in these situations are equalized, that is, taken with the same values). We will call this *equalization ability*. The third is the action associated with application of the rule of logical inference from the compared situations: if the results of the action of variables in the compared situations are the same, then the analyzed variable does not affect the result. If the results of the variables' actions in the compared situations are not equal, then the analyzed variable affects the result. We will call this *the ability to identify the influencing variable*. Studies have shown that there can be one more ability (Baddeley, 1968) that can play an important role. This is *reasoning ability*, the ability to draw a logical conclusion from the above assumptions.

The aim of this study was to find methods for each of these types of actions, and to compare students' hypothetical-deductive thinking with their text comprehension. So, the specific purpose of the research was to analyse the relations between the stated metacognitive and cognitive skills. In addition, we aimed to find out if these skills varied across age groups (upper secondary students and University students), as we supposed that the University required higher levels of such skills from the students, because of much more independent work with the explanatory texts.

Research questions

General research question: how are the spontaneous metacognitive strategies of students' text understanding related to the level of their hypothetical-deductive thinking?

Specific research questions

1. What are the relationships between the metacognitive ability to select the most important thing in a text and the characteristics of hypothetical-deductive thinking (the ability to identify an influencing variable, equalization ability, reasoning ability, and recognition ability)?
2. What are the relationships between the ability to find a contradiction in an explanatory text and the formation

of hypothetical-deductive thinking (ability to identify an influencing variable, equalization ability, reasoning ability, and recognition ability)?
3. What are the differences in above mentioned characteristics between upper secondary students and University students?

Specific research hypotheses

1. Metacognitive ability to select the most important thing in a text positively correlates with the characteristics of hypothetical-deductive thinking (the ability to identify an influencing variable, equalization ability, reasoning ability, and recognition ability).
2. Ability to find a contradiction in an explanatory text positively correlates with the formation of hypothetical-deductive thinking (ability to identify an influencing variable, equalization ability, reasoning ability, and recognition ability).
3. University students will show higher levels of metacognitive and cognitive skills comparing with upper secondary students.

Methods

Participants

The experiment involved third- and fourth-year Lomonosov Moscow State University students (future philologists [n = 351, mean age 21.2, 17.7% were men], psychologists [n = 96, mean age 21.8, 23.7% were men], and soil scientists [n = 132, mean age 22.1, 57.3% were men]) and fourth-year preservice teachers from Moscow City Pedagogical University [n = 90, mean age 21.3, 10.9% were men]. It was a random sample of students, all of respondents were studying in regular study groups and the participation in the research was a part of the course "Pedagogy and psychology". We did not have a special task of comparing students of different specializations, these specializations were taken to get a greater spread between the indicators. The comparison between the specializations was not a research question, only an addition to the results obtained.

Other subgroup of the respondents consists of upper secondary students (Grade 10), from a public school in Moscow [n = 121], mean age 17.6, 46.3% were boys). It was an ordinary public Moscow school without any specific programs.

The total number of respondents was 790.

Procedures

All the measures were administered in person by the researchers. The tests were given in the same order to all the participants.

Assessment of reading comprehension

1. **The "Select the main sentences" method** was designed by O.E. Mal'skaya and A.A. Sidel'nikova (Mal'skaya & Sidel'nikova, 1984). It assesses the metacognitive ability to select the most important thing in a text. We gave the students a text and asked them to select the main sentences of this text and write their numbers (see Appendix 1). It is an explanatory text, which includes some definitions, facts, explanations of the facts, historical dates, and some insignificant statements. We calculated how many significant sentences each respondent selected (a number from 0 to 8) and how many sentences from each category (facts, explanations, definitions, history, and statements). The method is described in detail in *Appendix 1*. The definitions presented in the text were not real definitions, because they did not *define* anything, but only *gave a name to* something. This allowed us to track whether the respondents were really building a situational model of what is described in the text or were only guided by external characteristics of the text (a definition is something that looks like a definition).
2. **The "Search for contradictions" method** was designed by Korotaeva (2000). It assesses the ability to detect problems in an explanatory learning text describing a scientific experiment (*Appendix 2A*). The problem is contradiction between a fact and its explanation. The instruction is to read the text and try to understand it as well as possible. Six questions are then asked that require reproduction of what is described in the text. The answers to some of the questions contradict each other. The method evaluates what students do with the contradiction:
   – detect it (the student writes that the text is incomprehensible and that there is a contradiction);
   – remove it (in answer to a question, the student changes a fact to fit an explanation or an explanation to fit a fact);
   – reproduce it (the student does not notice the contradiction, answering questions by reproducing the wording of the text).

   This method evaluates whether students are trying to build a situational model of what the text describes, whether they see the reality behind the text. For upper secondary students, the short version of the method was used, in which less information was presented; but in principle the two can be compared, since the contradiction remains in both (see *Appendix 2A*, version for university students, and *Appendix 2B*, version for upper secondary students).

Assessment of logical skills

We assess the characteristics of hypothetical-deductive thinking through the following abilities: equalization ability, ability to identify the influencing variable, and reasoning ability. Separately, we assess recognition ability (only with upper secondary students).

1. Equalization ability **(**Baldina, 1987**).** Three tasks were presented that evaluate equalization ability. It was necessary to determine which types of variables should be varied, and which should be left unchanged when evaluating the influence of an independent variable on the dependent one (for example, evaluating the influence

of size/material on the bounce of balls). These tasks were proposed by Baldina (1987) and Il'yasov and Kostrova (2014), and are described in detail in *Appendix 3*. The maximum score for all three tasks is 3 points. For upper secondary students, we used only two tasks; for them the maximum was 2 points.

2. *Ability to identify the influencing variable*. We used "the plant problem", designed by Kuhn and Brannock (1977), modified by Baldina (1987). The task evaluated the ability to identify the influencing variable, and thus, draw a logical conclusion from the compared situations: if the results of the variables' actions in the compared situations are the same, then the analyzed variable does not affect the result. If the results of the variables' actions in the compared situations are not equal, then the variable affects the result. There were six pictures and descriptions of each; each picture showed a plant (healthy or not) and conditions (a glass of water [small or large], fertilizer [light or dark], and liquid for the leaves [yes or no]). The instruction was as follow: "Name the conditions on which the health of the plant depends".
3. *Reasoning ability.* We used Baddeley's Reasoning Test (Baddeley, 1968), which assesses the ability to reach a logical conclusion from the given assumptions. This is a method for determining the truth of statements when using various grammatical constructions (see Appendix 4 for details). The subjects are asked to read a sentence such as "A precedes B", and then to decide whether this sentence correctly describes a subsequent letter combination, e.g., AB. The test items comprised combinations of the following conditions, ordered at random: (a) positive or negative sentences, (b) active or passive sentences, (c) the use of "comes before/ after", or "follows", (d) A or B mentioned first, and (e) the letter pair AB or BA. The total number of sentences is 20; only mistakes are counted, so the higher the score, the worse the respondent's performance.
4. *Recognition ability.* We used the same procedure as in our previous studies (Sidneva et al., 2020). The participants were asked to read the definition of the concept and to perform 10 tasks afterwards. The first concept and first definition were familiar to most respondents ("straight line") and the other one ("enclave") was unfamiliar to most. After the definition, the following instruction was given: "In each problem you need to put '+' if it is a straight line/enclave, '–' if not, and '?' if there is not enough information to decide. Please explain all your answers". Two groups of tasks were given in random order for each definition: (a) problems with all the necessary and sufficient conditions to answer the question (regular tasks), and (b) problems that do not provide all the necessary conditions (provocative tasks). We used a very similar method in our previous research (Sidneva et al., 2020). We evaluated the answer as correct if it was justified by the information supplied (the attributes specified in the definition). If students give the correct answer (+, –, or ?) and justify it with reference to the given definition in any form, we encode it as 1. If they give the wrong answer, or the correct answer but justify it with reference to something else ("I know it", "My Mom told me", etc.), we encode it as 0. If students give the wrong answer but justify it with reference to the given definition, it was also 0. The total score was evaluated on a scale of 1 to 10, depending on the number of tasks that were solved correctly.

Results

Descriptive statistics

Means and standard deviations for the ability to select the main sentences are presented in Table 1.

Predictably, the upper secondary students coped with selecting the main thing in the text much less successfully than university students (see Table 1; differences with university students in the overall level of ability to highlight the main thing are significant at the level of $p < .001$, Student's *t*-test). There are also significant differences in the selection of facts (university students selected them more often, $p < .001$), definitions (university students were less likely to consider proposed definitions as significant, $p < .05$), and upper secondary students were also significantly more likely to select historical facts and declaration proposals as essential sentences ($p < .05$).

Table 1

Means and standard deviations for the method "Select the main sentences"

	Total number of selected significant sentences (0–8)		Facts (0–5)		Explanations (0–3)		Definitions (0–5)		Historical date (0–1)		Declarations (0–2)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
All respondents	4.37	1.73	2.32	1.43	2.05	0.90	2.90	1.68	0.19	0.40	0.52	0.65
All university students ($n = 669$)	4.48	1.77	2.41	1.46	2.07	0.90	2.84	1.70	0.18	0.39	0.50	0.65
All upper secondary students ($n = 121$)	3.83	1.41	1.88	1.17	1.94	0.91	3.18	1.54	0.27	0.45	0.64	0.63
Philologists ($n = 351$)	4.44	1.79	2.39	1.47	2.05	0.89	2.90	1.70	0.14	0.36	0.48	0.64
Pre-service teachers ($n = 90$)	4.21	1.78	2.51	1.38	1.70	1.02	2.62	1.65	0.40	0.49	0.83	0.74
Psychologists ($n = 96$)	4.95	1.77	2.76	1.39	2.19	0.87	2.51	1.73	0.20	0.40	0.33	0.54
Soil scientists ($n = 132$)	4.42	1.64	2.12	1.46	2.30	0.76	3.06	1.65	0.10	0.30	0.43	0.60

Table 2
Means, standard deviations, and frequencies for assessment of equalization ability among upper secondary students (n = 121) and university students (n = 669)

			Frequencies (%)			
	M	*SD*	0	1	2	3
All upper secondary students (*n* = 121)	1.60	0.66	9.9	16.5	73.6	
All university students (*n* = 669)	2.28	1.21	20.6	1.5	6.6	71.2
Philologists (*n* = 351)	2.57	0.95	10.5	1.4	8.3	79.8
Pre-service teachers (*n* = 90)	1.37	1.46	52.2	0.0	6.7	41.1
Psychologists (*n* = 96)	1.30	1.46	54.2	2.1	3.1	40.6
Soil scientists (*n* = 131)	2.86	0.51	1.5	2.3	4.5	90.9

Table 3
Means, standard deviations, and frequencies for assessment of mistakes in identifying the influencing variable (the plant problem) among upper secondary students (n = 121) and university students (n = 669)

			Frequencies (%)			
	M	*SD*	0	1	2	3
All respondents (*n* = 787)	1.41	0.68	7.6	42.0	40.6	2.7
All upper secondary students (*n* = 118)	1.99	0.60	0.0	18.2	62.0	17.4
All university students (*n* = 669)	1.30	0.64	9.0	46.3	36.8	
Philologists (*n* = 351)	1.37	0.60	6.8	49.6	43.6	
Pre service teachers (n = 90)	1.13	0.71	18.9	48.6	32.4	
Psychologists (*n* = 96)	1.15	0.66	15.6	54.2	30.2	
Soil scientists (*n* = 132)	1.28	0.65	10.6	50.0	39.4	

Table 4
Means and standard deviations for assessment of mistakes in reasoning (Baddeley's Reasoning Test) among university students

Group	*M*	*SD*
All university students (*n* = 669)	3.45	4.52
Philologists (*n* = 351)	2.17	3.40
Pre-service teachers (*n* = 90)	8.70	5.07
Psychologists (*n* = 96)	3.40	4.20
Soil scientists (*n* = 132)	3.33	4.38

The results of the "Search for contradictions" method show that in the entire sample ($N = 704$), only 9.2% detected a contradiction in the text, 12.7% removed a contradiction, and 46.1% simply reproduced the contradiction, not caring that the answer to one question contradicts another. We found significant differences between university and upper secondary students: upper secondary students are significantly more likely to simply rewrite information from the text in their answers to the questions without caring that it is contradictory: 81.1% of upper secondary students who performed this technique did this ($n = 36$, $\chi^2 = 13.9$, $df = 2$, $p < .001$). Unfortunately, only 29.8% of high school students managed to complete this test in the allotted time, so we took into account only their results. It is possible that in this regard it is incorrect to draw a conclusion about the difference in this parameter between upper secondary students and University students.

So, we did not find a connection between the ability to highlight the main thing and the ability to find a contradiction in the text, which is probably due also to the insufficient distinguishing capabilities of the "Search for contradiction" technique in this sample.

Descriptive statistics concerning equalization ability are presented in Table 2.

From the frequency distribution, we can conclude that 71.7% of all respondents demonstrated the logical ability to equalize variables (73.6% of upper secondary students received the maximum score for this technique and 71.2% of university students); only future teachers and future psychologists differed: half performed perfectly, and half could not cope with the tasks at all.

Descriptive statistics concerning the ability to identify of the influencing variable are presented in Table 3.

The statistical analysis shows that university students made significantly less mistakes than upper secondary students according to the χ^2 criterion ($\chi^2 = 155{,}7$, $df = 1$, $p < .001$); in fact, judging by the distribution, not a single upper secondary student coped with the task absolutely correctly, highlighting a small glass of water and a little light fertilizer as key factors. As for university students of different specialties, there were differences only between future philologists and future soil scientists and other groups (future philologists and soil scientists for some reason made significantly more mistakes; $\chi^2 = 14{,}07$, $df = 3$, $p < .05$).

Descriptive statistics concerning reasoning ability are presented in Table 4.

The analysis of differences showed that future teachers made significantly more mistakes than all the other specialties in their errors in the reasoning test (*t*-test with Bonferroni correction, $p < .001$; with soil scientists: $t = 8.39$, $df = 219$, $d = 1.15$; with psychologists: $t = 7.77$, $df = 184$, $d = 1.14$; with philologists: $t = 14.5$, $df = 439$, $d = 1.71$).

Results of the logical skills assessment

Comparing the different logical abilities, we show that two indicators – equalization ability and mistakes in reasoning – significantly negatively correlate with each other: the more developed the ability to equalize, the fewer

errors in reasoning according to the Baddeley test (r_s = –.13, p < .01 , n = 668). With mistakes in reasoning, there is also a significant positive correlation with errors in determining the influencing variable ("the plant problem" test): those who make mistakes in one test are likely to make them in another (r_s = .10, p < .05 , n = 615). No significant links were found between performance of the equalization test and errors in the selection of the influencing variable; perhaps these are still relatively independent skills: the ability to equalize and select experimental conditions is not at all related to the ability to draw a logical conclusion from already set experiments about which factor is influential and which is not. We tested this result on university students separately; on upper secondary students (since they were given only two equalization tasks, not three), the correlation is not significant.

Interesting data were obtained for the ability to recognize concepts on the part of upper secondary students (M = 1.81, SD = 2.3 for a familiar concept and M = 3.26, SD = 2.99 for a new one). In general, the correlation between these two concepts is 0.62 at p < .001, which indicates that they are still measuring the same parameter. But as expected, it was much easier for university students to summarize the new concept. It turned out that 45.5% of upper secondary students did not know how to recognize a concept that has an obvious everyday analogue, and only 5.8% of them did it completely correctly (the correct answer in 9 or 10 tasks). If the concept was new for the upper secondary students, about 29.8% of them were unable to recognize the concept, and only 4.1% did so completely correctly.

We also found out that those who select *fewer explanations* in the "Select the main sentences" method (0 or 1 out of 3) *are worse at recognizing* a new concept than the others (*t*-test for two independent samples, t = 2.00, p < .05, d = .39). Also, recognizing a new concept significantly positively correlates with equalization (r_s = 0.30, p < .01, n = 121) and significantly negatively with mistakes in determining the influencing variable according to "the plant problem" method (r_s = –.29, p < .01 , n = 118).

Research questions: Main findings

General research question: how are the spontaneous metacognitive strategies of students' text understanding related to the level of their hypothetical-deductive thinking?

In general, the results show significant links between text comprehension ability and logical thinking. The correlations are presented in *Table 5*.

Specific research question №1. What are the relationships between the metacognitive ability to select the most important thing in a text and the characteristics of hypothetical-deductive thinking (the ability to identify an influencing variable, equalization ability, reasoning ability, and recognition ability)?

We see that the ability to highlight the main thing in the text is significantly negatively correlated with the number of errors in determining the influencing variable and errors in reasoning, but we did not find a connection between ability to equalize variables and concept recognition. So, discussing the first research question, only some characteristics of hypothetical-deductive thinking (the ability to identify an influencing variable and reasoning ability) relate to metacognitive ability to select the most important thing in a text, we couldn't find any connections with equalization ability and recognition ability.

Specific research question № 2. What are the relationships between the ability to find a contradiction in an explanatory text and the formation of hypothetical-deductive thinking (ability to identify an influencing variable, equalization ability, reasoning ability, and recognition ability)?

The ability to find a contradiction in the text is also higher for those who know how to equalize and worse for those who make a lot of mistakes in reasoning; there is no connection for the other two parameters. So, discussing the second research question, only some characteristics of hypothetical-deductive thinking (the equalization ability and reasoning ability) are connected with metacognitive ability to find a contradiction in the text, we couldn't find any connections with the ability to identify an influencing variable and recognition ability.

Table 5

Correlations between the indicators of text comprehension and the formation of hypothetical-deductive thinking

	Ability to select the main sentences ("Select the main sentences" method)			Equalization ability (Tasks)			Mistakes in reasoning (Baddeley's Reasoning Test)			Mistakes in identifying the influencing variable (the plant problem)			Concept recognition		
	r	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*
Ability to select the main sentences ("Select the main sentences" method)	/	/	/	.03	.48	668	–.11**	.003	668	–.09**	.009	787	–.04	.69	121
Ability to search contradictions ("Search for contradictions" method)	.05	.12	704	.14***	< .001	667	–.10**	.008	667	.03	.48	702	.13	.44	37

**p < .01 , ***p < .001

It turns out that in general, according to our data, neither the ability to highlight the main thing in the text nor the ability to find a contradiction is related to the logical ability to recognize a concept. We analyzed the relationship between ability to highlight the main thing and the parameters of logical thinking separately for a sample of university students and upper secondary students and found that this relationship can be traced only to university students; in upper secondary students, the ability to select the main thing *is not associated* with logical skills. So, this can be considered also as one of the differences between upper secondary students and University students (third research question).

Discussion

We obtained a clear link between the ability to work with an explanatory text and the formation of individual components of logical (hypothetical-deductive) thinking in the respondents, but this connection turned out to be significant for university students, not for upper secondary students. But first, such conclusions are limited by specific of our sample. Obviously, students from Moscow State University of all specialties quite differ from students from other universities, as well as upper secondary students from one specific school can also be different from students from other schools. Second, there were a lot more participants in the undergraduate group compared to the secondary student group – it also could influence to the results. There was another limitation - all the tests were given in the same order and yes, it might have impacted on results.

Anyway, some other findings (see, for example, Bayat & Çetinkaya, 2020) support these results and show that the inference-making ability of upper secondary students predicted reading comprehension skill only at a medium level, but there are not many studies comparing 16–17-year-old upper secondary students with university students. The only connection that is still found for 10th-graders is that between the ability to highlight the main thing in the text and the ability to recognize a concept. The better the students distinguish the essential sentences of the text, the better they work with the definition, using it as a real tool for actions of recognition. Our previous studies confirmed this result even among fourth-graders, in spite of the fact that we used different techniques for text comprehension and assessment (Sidneva et al., 2020). As for university students, those who are better at highlighting the main thing in the explanatory text, as a rule, were better at logical reasoning (the Baddeley test) and searching for an influencing variable based on experience data ("the plant problem"). We did not find a connection between the ability to distinguish the main thing in university students, and the logical operation of equalizing variables, which can be explained by the relative ease of the tasks given to the subjects to assess their ability to equalize (71.2% of the students coped with it correctly). So, we can't say about the full answer to the first research question, that metacognitive ability to select the most important thing in a text positively correlates with all measured characteristics of hypothetical-deductive thinking. The ability to find a contradiction in the text was associated with the abilities to equalize variables and to carry out logical reasoning (it was second research question). So, in general, according to our results the spontaneous metacognitive strategies of students' text understanding related to the level of their hypothetical-deductive thinking (general research question).

What is the difference between university students and upper secondary students? Judging by the research data, upper secondary students work significantly worse with the text in terms of highlighting its main ideas. They apparently consider the most important things to be not facts and their explanations, but definitions of concepts, historical dates, and proposals that state the significance of the problem and offer some generalized, meaningless statements. Unfortunately, we did not have enough respondents who used the "Search for contradictions" method to draw a conclusion about the differences with university students, but what is there shows that practically no upper secondary nor university students coped with this task (only 1 out of 36 upper secondary students [0.8%] and 72 out of 667 [10.8%] university students found a contradiction in the explanatory text). This may be due to the fact that students rarely encounter texts in which there are contradictions. As for logical thinking, the differences between upper secondary and university students are not significant in terms of the ability to identify the influencing variable. This result is unexpected, because in our opinion, university students should face the tasks of equalizing variables more often than upper secondary students. Perhaps this is due to the specifics of the sample of university students - most of them study in the humanities. Concerning the ability to equalize variables, due to the different number of proposed tasks, it is difficult for us to compare university students and upper secondary students, but the number of those who completed all the tasks correctly is about the same for both, so here we can conclude that there are no fundamental differences. Apparently, the fundamental differences between these groups of respondents relate to working with the text.

Let us now discuss the differences among the specializations of university students. According to our data, the lowest results, both in ability to highlight the main thing and the ability to see a contradiction, were found in student teachers. The same result was obtained in our previous studies (Korotaeva, 2000, 2019). What can this be related to? In Russia, the teaching profession is not yet considered prestigious and, as a rule, those who did not score enough points on the state exam to enroll somewhere else enter the pedagogical universities.

How do the explanations of the results can be discussed from the point of different approaches? In our opinion, the key is found in the relationship between text comprehension and recognition of a concept. Why are those who select fewer explanations in the method of "Selecting the main thing" generally worse in recognizing a new concept? Why does concept recognition significantly positively correlate with equalization and the ability to find the influencing variable according to "the plant problem"? Research shows that the goal set by the reader, or the questions with which they start reading, play a fundamentally important role in reading comprehension (Freebody & Luke, 1990; King, 1994). From

our point of view, this fact plays a key role: the question or task sets the future action, and the text acts not as the object of a separate work, but as a culturally developed means or tool for finding guidelines in answering a question or solving a problem. We can explain it using the difference between a text-based model and situation-based representation (Gernsbacher & Kaschak, 2013; Kintsch 1998; van Dijk & Kintsch, 1983): the more successfully university students build a situational model of the text, the better they use it to answer questions about reality. In our opinion, this difference in explanations is important to take into account, because the practice of teaching by working with texts depends upon it.

Conclusion

In this study, the university students demonstrated that the ability to work with the scientific texts was correlated with some components of hypothetical-deductive thinking. The 10th-graders, on the other hand, showed a correlation between the ability to highlight the main thing in the text and the ability to recognize a concept. In general, the results raised a question about general theoretical framework for text comprehension as not some independent activity but part of specific actions, where any text considered as a cultural mean for completing this actions. So, further research and comparison of the results and approaches in which they were obtained are necessary.

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Appendix 1

Please read the entire text and choose from it the 8 sentences that contain the most important information, in your opinion. The sentences you have chosen do not necessarily have to be connected and form a complete narrative.

1. Transplantation is the transplantation of organs and tissues.
2. The first attempts at transplants were made by the Chinese surgeon Hia Tu in the second century.
3. The organism that gives the tissue or organ for transplantation is called a donor.
4. A recipient is an organism to which a tissue or organ is transplanted.
5. The material indicates that if the transplant is carried out on another part of the same organism, then true engraftment is possible.
6. Transplants to another part of the same organism are called autotransplantation.
7. Examples of transplants within one organism are a variety of plastic surgeries.
8. In experiments on hydra and worms, it was found that when transplanting from one individual to another, true engraftment is possible.
9. In higher animals and humans, transplants of this kind, as a rule, are not performed.
10. An exception is identical twins.
11. The effects of tissue incompatibility are associated with the fact that each organism has a specific protein composition and responds to the penetration of proteins that differ in chemical composition with an immunological reaction aimed at protecting the organism from agents that are genetically alien to it.
12. The phenomena of tissue incompatibility are especially pronounced during transplants from an organism of one species to an organism of another species.
13. Transplants from an organism of one species to an organism of another species are called heterotransplantation.
14. It was found that under the influence of the protein of transplanted tissues, special cells produced by the lymphatic system appear in the body, which act on the cells of the transplanted tissue and cause its death due to blockage of blood vessels.
15. The specificity of the results of transplants in lower animals is due to the fact that the immune reaction, being a product of biological evolution, is clearly expressed only in highly organized organisms.
16. The problem of tissue incompatibility is of great importance for practice.

Appendix 2A

Read the text.

In the world of wildlife, green plants are the main source of energy for living organisms. They have a remarkable ability to use solar energy to build nutrients. This process is called photosynthesis. For its implementation, a light absorber

is needed—chlorophyll contained in plant cells, as well as carbon dioxide and water coming from the environment. The final products of the reaction are starch and oxygen, which are necessary for the vital activity of animals and humans. We are interested in under what conditions of light radiation the photosynthesis process becomes optimal. Let's consider a few experiments.

In 1902, E. Smith demonstrated the dependence of the rate of photosynthesis on the duration of illumination. He illuminated one plant with periodic flashes, and the other with continuous light of the same intensity. It was found that the rate of photosynthesis in both cases is the same.

Another experiment was conducted in 1954 by A. Svenson. It showed the dependence of the efficiency of light rays on their wavelength. If several young plants are covered with cellophane of different colors, then a significant difference will be found in their growth. Plants covered with green cellophane grow well, and those covered with red or blue-purple grow poorly, although the intensity of the incident light is the same in all cases.

How do scientists explain these phenomena? It is known that the process of photosynthesis is a chain of reactions that occur in two phases: light and dark. The light phase involves the absorption of the energy of the sun's rays and its transformation into the form of chemical bonds. The second phase is called dark, since it proceeds without the direct participation of light. At this time, the synthesis of nutrients is carried out on the basis of those intermediate chemical compounds that were obtained in the first phase. It was found that the speed of photosynthesis is limited by the speed of the dark phase; the formation of an intermediate chemical compound during the light phase occurs much faster than its use in the dark phase.

The results of the experiment demonstrating the dependence of the efficiency of light rays on the wavelength also confirm logical reasoning. Let's imagine the process of photosynthesis taking place in plants under green cellophane. Indeed, green cellophane passes mainly green light. Chlorophyll is also green; the green rays of the spectrum are reflected by it, not absorbed. Therefore, the energy of green light is not used in photosynthesis. It is obvious that in the process of photosynthesis, the most important parts of the spectrum are those that are most distant from the green part of it, since they are absorbed by chlorophyll. These can be red rays located at one end of the spectrum, and blue-violet rays at the other end.

Do you understand everything in the text? If not, underline the fragment that you don't understand.

1. What substances are the product of photosynthesis?
   a) carbon dioxide
   b) water
   c) starch
   d) oxygen

2. Under which cellophane do young plants grow better?
   a) under red
   b) under green
   c) under blue-purple

3. What is the difference between the lighting conditions of the two plants in the experiment of E. Smith?
   a) weak and strong intensity
   b) discontinuity and continuity of lighting

4. Chlorophyll mainly absorbs
   a) red rays
   b) green rays
   c) blue-purple rays

5. Which parts of the spectrum are most important in the process of photosynthesis?
   a) red
   b) green
   c) blue-purple

6. If one plant is illuminated with periodic flashes, and the other with continuous light, then:
   a) the speed of photosynthesis will be different
   b) the speed of photosynthesis will be the same

7. Green cellophane passes mainly:
   a) red color
   b) green color
   c) blue-green color

Appendix 2B

Read the text.

In the world of wildlife, green plants are the main source of energy for living organisms. They have a remarkable ability to use solar energy to build nutrients. This process is called photosynthesis. For its implementation, a light absorber is needed—chlorophyll contained in plant cells, as well as carbon dioxide and water coming from the environment. The final products of the reaction are starch and oxygen, which are necessary for the vital activity of animals and humans. Scientists were interested in what conditions of light radiation the process of photosynthesis becomes optimal. In one of the experiments, scientists observed the growth of plants covered with cellophane of different colors. Plants covered with green cellophane grew well, and those covered with red and blue-purple grew poorly, although the intensity of the incident light was the same in all cases. How can the results of this experience be explained? Imagine the process of photosynthesis occurring in plants under green cellophane. Indeed, green cellophane transmits mainly green light. Chlorophyll is also green; the green rays of the spectrum are reflected by it, not absorbed. Therefore, the energy of green light is not used in photosynthesis. It is obvious that in the process of photosynthesis, the most important parts of the spectrum are those that are most distant from the green part of it, since they are absorbed by chlorophyll. These can be red rays located at one end of the spectrum, and blue-violet rays at the other end.

Do you understand everything in the text? If not, underline the fragment in the text that you do not understand. Answer the questions.

1. What substances are necessary for photosynthesis?
   a) carbon dioxide
   b) water
   c) starch
   d) oxygen

2. Under which cellophane do young plants grow better?
   a) under red
   b) under green
   c) under blue-purple

3. What substances are the product of photosynthesis?
   a) carbon dioxide
   b) water
   c) starch
   d) oxygen

4. Chlorophyll mainly absorbs:
   a) red rays
   b) green rays
   c) blue-purple rays

5. Which parts of the spectrum are most important in the process of photosynthesis?
   a) red
   b) green
   c) blue-purple

6. Green cellophane passes mainly:
   a) red light
   b) green light
   c) blue-purple light

Appendix 3. Tasks for assessment of equalization ability.

Task 1: You know that not all balls bounce equally high: some are better, others are worse. They can be of different sizes, large or small, and can be made of different materials, for example, rubber and plastic. Their bouncing ability may depend on both the size and the material. Answer the questions below. Circle the letters of the correct answers in the appropriate fields.

1. What kind of balls should I take to check the connection of bouncing ability with size?
   a) a large one made of rubber and a small one made of plastic
   b) made of rubber and plastic, both large
   c) a large one and a small one, both made of rubber
   d) a large one made of plastic and a small one made of rubber

2. What kind of balls should I take to check the connection of bouncing ability with material?
   a) large and small, both made of rubber
   b) made of rubber and plastic, both large
   c) a small one made of plastic and a large one made of rubber
   d) large and small, both made of plastic

Task 2: Barley was sown in three fields. No barley grew in any of the three fields. There were no weeds in the first field; the plowing was good and there was insufficient moisture. The second field had weeds, good plowing, and insufficient moisture. There were no weeds in the third field; there was poor plowing and insufficient moisture.

What do you think caused the barley crop failure in all three fields? Circle the letter of the correct answer in the corresponding field of the Answer Form.

a) weeds
b) poor plowing
c) insufficient moisture

Appendix 4. Baddeley's Reasoning Test

You are asked to evaluate the truth of a number of statements describing the relative position of the two presented letters A and B. After each statement is its letter expression A-B or B-A, and you must decide whether each statement correctly describes the corresponding pair. For example, if the letter B is on the right side of the letter A, then it should be said that „the letter B accompanies the letter A". If, for example, the letter B is on the left side of the letter A, it should be said that „the letter B anticipates the letter A". In addition, when solving problems, it is necessary to take into account that verbs can be used both in the passive form („accompanied", „anticipated") and in the negative form („does not accompany", „does not anticipate").

		True	False
1. A does not accompany B	A–B		
2. A is anticipated by B	A–B		
3. A is not accompanied by B	B–A		
4. A anticipates B	B–A		
5. B is not anticipated by A	B–A		
6. B does not accompany A	A–B		
7. A accompanies B	B–A		
8. B is anticipated by A	B–A		
9. A does not anticipate B	B–A		
10. A is accompanied by B	B–A		
11. A is anticipated by B	B–A		
12. A is not accompanied by B	A–B		
13. A anticipates B	A–B		
14. B is not anticipated A	A–B		
15. B is anticipated by A	A–B		
16. A is not anticipated by B	B–A		
17. A does not anticipate B	A–B		
18. B accompanies A	B–A		
19. B is not accompanied by A	B–A		
20. B does not anticipate A	A–B		
21. B is accompanied by A	A–B		
22. B does not accompany A	B–A		
23. A is accompanied by B	A–B		
24. B does not anticipate A	B–A		
25. A is not anticipated by B	A–B		

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