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METHODS OF THE INFORMATIVENESS AND DIDACTIC COMPLEXITY ESTIMATION OF EDUCATIONAL CONCEPTS, PICTURES AND TEXTS

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Abstract:
The article analyzes the problem of assessment of the informativeness (or informational content) and the didactic complexity of various learning material elements (educational concepts, pictures and education texts). The informativeness of learning material elements (LMEs) is considered equal to the number of concepts to be used for its presentation or the description. Under the didactic complexity of LME it is offered to understand the value proportional to the time or amount of the efforts demanded by the 5–class Russian schoolchild for his/her studying this LME. As all educational information is presented in a verbal form, to define the complexity of LME it is necessary to decompose LME into separate concepts, to estimate their separate difficulty, and then to summarize it. The article considers: 1) the estimation of difficulty of experimental and theoretical studying of a concept using the method of paired comparisons; 2) spreading out cards with scientific concepts on them in order of increasing complexity; 3) the calculation of the objects and links in the picture taking into account their abstractness degree; 4) the determination of terms (concepts) number in the text, accounting their complexity. Uniform criteria for estimation of the words (concepts) complexity in educational texts on natural-science disciplines are elaborated and the abstract-ness scale is constructed. The received results can be used to assess the complexity of textbooks in natural sciences. The developed estimation method of didactic complexity of the physics textbooks includes: 1) the estimation of the physics complexity of the textbook summing up the complexity of the physical objects, phenomena, experiments, statements and theories; 2) the measurement of mathematical

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complexity of the textbook by counting the number of formulas (considering their complexity) and drawings presenting mathematical abstractions (a vector, power lines, graphs); 3) the calculation of the total index of the textbook didactic complexity. With the help of this method 16 Russian physics textbooks for school and university have been analyzed, their distribution within the characteristics space "*physical complexity - mathematical complexity*" has been studied.

Keywords: complexity, concept, content analysis, didactics, educational text, expert assessment, training, training material, qualimetry

1. Introduction

Development of the training theory and technique assume measurement and accounting of didactic characteristics of various learning material elements (LMEs): concepts, fragments of the theory, text blocks, pictures, tasks, educational experiments, etc. The main didactic characteristics of the LME are: 1) informativeness (or informational content), that is the quantity of information included in this LME; 2) the didactic complexity characterizing the amount of efforts and time which are necessary for a pupil to assimilate this LME. The problem of "*measurement*" of weakly formalizable properties of didactic objects is closely connected with the use of mathematical methods in pedagogy, the content analysis of textbooks, the complexity assessment of tasks, concepts and educational texts (Davis & Sumara, 2006). At the same time, it is necessary to mind the principle of incompatibility: high precision of measurements (estimates, predictions) is incompatible with high complexity of the studied system (Zade, 1976). Really, if an object consists of a large number of the diverse elements connected with polytypic links, then it is almost impossible to construct its model precisely corresponding to the original. As L. Zade writes, in the analysis of difficult systems it is necessary *"to sacrifice accuracy in the face of stunning complexity"* (Zade, 1976).

The problem of the complexity assessment of the educational text and its components has the great practical importance. V.P. Bespalko notes that pupils, comparing various subjects, intuitively "*react*" to the degree of abstractness of the studied issues, therefore the complexity criterion of the educational text, first of all, is its theoretical nature and abstractness degree (Bespal'ko, 1988). It depends on a ratio between the pupil's experience and the content of a training material. The greater the complexity and lower the level of the pupil's knowledge, the more difficult is the training material for the student and the less is its theoretical availability. Ya.A. Mikk claims that "*scientific character of material without availability is senseless: there is no sense to train if pupils cannot acquire the training material*" (Mikk, 1981).

2. Method and materials

The paper analyzes the concept, pictures and chemical formulas found in textbooks and methodical manuals on astronomy, biology, chemistry, physics, as well as books on the basics of electrical engineering and electronics, which are intended for schoolchildren. To evaluate the informativenees and didactic complexity it was applied: 1) the paired comparisons method; 2) the method of the objects arrangement on increase of the estimated quality; 3) the method of the content analysis of the object verbal description. Counting concepts and symbols was carried out using the computer programs that analyze a text files. The methodological basis of the research is work by V.S. Avanesov, B. Bitinas, G.V. Glass, J.C. Stanley, M.P. Karpenko (Karpenko, 2008), L. Leont'ev, O. Gohman (Leont'ev & Gohman, 1984) (mathematical methods in pedagogy), L.Ja. Aver'janov (Aver'janov, 2007), V.P. Bespalko (Bespal'ko, 1988), B.E. Zhelezovskij, F.A. Belov (Zhelezovskij & Belov, 2011), Ya.A. Mikk (Mikk, 1981), M.D. White, E.E. Marsh (White & Marsh, 2006), I.V. Oborneva (textbooks content analysis). This article is development of the ideas stated in (Mayer, 2014; Maier, 2015; Mayer, 2016).

3. Discussion

The main objective of this paper is the development and use of the method of the assessment didactic complexity (DC) and the quantity of information (QI) of different LMEs (concepts, pictures, chemical formulas). Let us name the didactic complexity of LME as the dimensionless value proportional to the amount of efforts and time of studying to be used by the 5th class pupil (or the person who graduated school long ago) to understand and acquire this LME. DC depends on degree of LME abstractness that is its isolation from the pupil's daily experience.

From the theory of systems (Lavrushina & Slugina, 2007) it is known that the complexity of any object characterizes the degree of its variety and depends on: 1) the quantity of the elements entering it; 2) the difficulty of elements; 3) the number of links between them. The universal unit of the QI or DC measurements of LME is a word or a concept (term). Fig. 1.1 and 1.2 present the structure of two systems which consist of identical quantity of elements and have approximately equal volumes. In the first case, the system is represented by four unconnected graphs, and in the second case – by one related graph. It is clear, that the complexity of the second system is higher. If we talk about two LMEs consisting of concepts (or judgments), then to understand and assimilate LME–1 (fig. 1.1) it is enough to be able to operate with three various concepts at the same time, and to understand LME–2 (fig. 1.2) it is necessary to keep ten concepts in mind simultaneously. It is known that it is more difficult to construct one skyscraper, than a number of one–storey lodges. To understand and learn how to use the formula consisting of a large number of symbols is more difficult, than to deal with several simple equations (fig. 1.3 and 1.4).

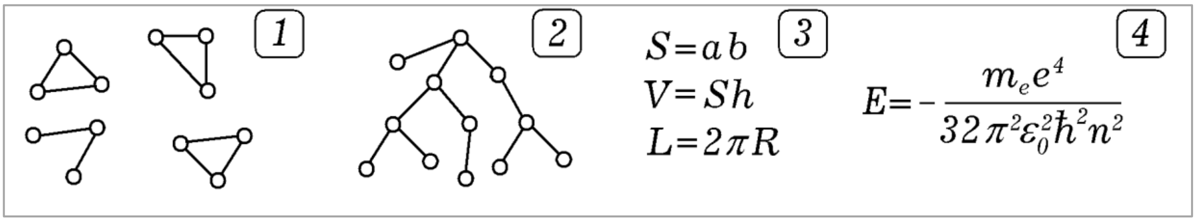

Figure 1: Complexity and volume of learning material elements

So, DC of the LME (information block) depends on the complexity and quantity of the elements forming it (concepts, judgments, theoretical models) and links between them. As all educational information is representable in a verbal form, for estimation of LME complexity it is necessary to decompose the text to separate concepts, to estimate their difficulty, and then to summarize them. Let us consider that for the simplest concept DC s_i =1, and for more difficult terms DC s_i is more than 1 (for example, 2, 3 or 5). Then the didactical complexity of the LME is equal to $S = s_1 + s_2 + \cdots + s_n$, where n – quantity of concepts in the text which replaces this LME. If all concepts have complexity $s = 1$, then $S = n$.

Table 1: The didactic complexity of the concepts designating physical devices

	CONCEPTS	A	B	S		CONCEPTS	A	B	S
1	Ruler	0,000	0,000	0,000	15	Inter. combust. engine	0,523	0,563	0,568
2	Thermometer	0,121	0,117	0,124	16	Radio receiver	0,140	1,000	0,596
3	Pump	0,215	0,068	0,148	17	Spectrometer	0,748	0,485	0,654
4	Weighing-machine	0,187	0,126	0,164	18	Transformer	0,551	0,699	0,654
5	Dynamometer	0,271	0,117	0,203	19	Electric generator	0,505	0,757	0,660
6	Stop watch	0,093	0,369	0,242	20	Cathode ray tube	0,514	0,777	0,675
7	Magnifying lens	0,252	0,301	0,289	21	Semiconduct. diode	0,551	0,796	0,704
8	Refrigerator	0,093	0,505	0,313	22	Geiger counter	0,794	0,660	0,760
9	Areometer	0,486	0,194	0,356	23	Electron. lamp diode	0,785	0,699	0,776
10	Aneroid barometer	0,430	0,301	0,382	24	Mass spectrograph	0,907	0,621	0,799
11	Capacitor	0,542	0,272	0,425	25	Diffraction grid	0,738	0,854	0,833
12	Telescope	0,439	0,573	0,529	26	Cyclotron	0,963	0,874	0,960
13	Psychrometer	0,664	0,388	0,550	27	Michels. interferometer	0,907	0,942	0,966
14	Ammeter	0,467	0,602	0,559	28	Nuclear reactor	1,000	0,913	1,000

4. Estimation of didactic complexity of concepts

Any natural science has empirical and theoretical components, therefore for estimation of didactic complexity of concepts it is necessary to consider: 1) the complexity A of experimental studying of the object designated by this concept; 2) the complexity B of its theoretical studying. The concept can designate a really existing object (e.g. electron), the phenomenon or process (e.g. cell division), an idealized object (e.g. ideal gas), the value (e.g. concentration of molecules), the law, principle or postulate (e.g. Mendeleyev's law). For estimation of LME complexity, we can use the method of pair comparisons (Devid, 1978; Mayer, 2014). For this purpose let us choose 25–40 concepts which complexity changes within a wide range, and perform their paired comparison separately of characteristics A and B. The values A and B are normalized so that they fill the interval [0; 1]. On the basis of normalized values A and B we calculate the DC $S' = (A^2 + B^2)^{0,5}$. The turning-out results allow to estimate DC and to range concepts according to their complexity. Table 1 shows the normalized results of DC assessment of the concepts designating the physical devices (error 0.1).

The alternative approach to the concepts complexity estimation consists in the use of *"the cards method".* The experts are given: 1) the cards with the estimated concepts; 2) the scale of didactic complexity 0–1–2–3–4–5 drawn on a sheet of paper; 3) a sheet with a task which is formulated as: "*Imagine a 5–7 grades pupil to whom you explain the essence of this or that concept from the list. The greater the complexity, the more time and effort must be used for the explanation. It is necessary to place the cards with the names of concepts in order of increasing complexity*." The expert, comparing objects in pairs, places them on a scale depending on their complexity. After that, for each i–th object it is defined its coordinate x_i with an accuracy of 0.1. Knowing x_i (i =1, 2, …), for each expert it is calculated normalized complexity of all the objects $S'_i = (x_i - x_{min})/\ (x_{max} - x_{min})$ lying in the interval [0; 1], where x_{min} , x_{max} – the minimum and maximum assessment used by the expert. For each concept the all expert's examination, results are averaged. The resulted values of complexity S on an interval scale are given in table 2.

Table 2: The didactic complexity of the natural-science concepts

1	Water	0,000	15	Tropic	0,326	29	Nuclear forces	0,664
2	Liquid	0,053	16	Oxide	0,389	30	Gene	0,695
3	Sea	0,064	17	Gravitation field	0,431	31	Logarithm	0,715
4	Gas	0,074	18	Alkali	0,432	32	Cell	0,726
5	Air	0,095	19	Electron	0,453	33	Universe	0,758
6	Iron	0,106	20	Mole	0,463	34	Orbital	0,770
7	Addition	0,136	21	Galaxy	0,568	35	Alkanes	0,779
8	Plant	0,137	22	Fats	0,568	36	Aldehydes	0,779
9	Animal	0,147	23	Black Hole	0,577	37	Limit	0,789
10	Multiplication	0,221	24	Plasma	0,578	38	Chromosome	0,865
11	Saturn	0,262	25	Carbohydrates	0,579	39	Electro-magn.field	0,905
12	Speed	0,262	26	Atomic nucleus	0,612	40	Integral	0,958
13	Pulse	0,294	27	Cosine	0,652	41	Derivative	0,958
14	Comet	0,305	28	Sine	0,652	42	DNA	1,000

Table 3: The abstractness scale for the natural-science concepts

	Mathematics	Chemistry	Physics	Biology	Geography
1	Words, used in everyday life				
2	addition, subtraction, area, multiplication, division, perpendicular, circle	substance, solution, mixture, burning, filtration, evaporation	gas, liquid, crystal, water, lightning, scales, weight, spring, stop watch	dog, cat, flower, horse, fly, plant, animal, soil, bird, caterpillar, wood, skeleton	sea, mountain, river, continent, earthquake, volcano, clouds, sand, clay
3	integral power, root, function, graph, vector, direct proportionality	chemical reaction, indicator, chemical element, valence, electrolysis	electric field, magnetic field, fild strength, energy, amount of heat, voltage	brain, heart, lungs, artery, reflex, thinking, digestive system, blood system	poles, equator, latitude, longitude, meridian, parallel, continent, monsoon
4	sine, arccosine, nonintegral degree, vector sum, square equation	valence electrons, mole, alkali, molecules H_20, H_2SO_4, KCl, NaOH	molecule, atom, semiconductors, electron, hole, EM-wave, intensity	cell, amoeba, bacteria, autotrophs, cell division, erythrocytes, cell nucleus	polar belt, tropic, ozone layer, Earth kernel, troposphere
5	derivative, integral, logarithm, scalar product of vectors	benzene ring, ribose molecule, molecule of glucose, fat, protein, alkane, phenol	nucleus of atom, proton, nucleon, antiparticles, quarks, meson, gamma rays	DNA, RNA, chromosome, codon, natural selection, evolution, gene	
6	Nabla operator, tensor, functional variation, rotor, partial derivative	molecules DNA, RNA, nucleotides, amino acids	wave function, Schrödinger equation, orbital, quantum number, spin		

For creation of the abstractness scale, the uniform criteria for estimation of complexity of words (concepts) in educational texts on natural-science subjects have been elaborated. If this or that word (proper or common noun) is included into the dictionary on physics, mathematics, chemistry, biology or geography, then it is a scientific term. Let us imagine that the analyzed text is read by the statistically average pupil who has successfully finished the 5th class of the 11–year Russian secondary school. The didactic complexity of the words entering the text is proposed to be determined according to table 3.

The words, which are not scientific terms and are used by the average schoolchild in everyday life ("*rolls*", "*warm*", "*flows*"), have DC $s = 1$. They are used for the description and explanation of various natural phenomena, especially at elementary school too. Scientific terms with DC $s = 2$ have a low degree of abstractness, are studied in 1–5 classes, used by the average pupil in everyday life and do not require explanations ("*sphere*", "*air*", "*evaporation*", "*soil*", "*plant*", "*Moon*"). The terms with average or not very high degree of abstractness have DC $s = 3$ or 4. DC $s = 5$ is in following cases: 1) the terms have very high abstractness and denote objects and processes consisting of a large number of components (or particles) which the pupil in principle cannot observe (e.g. "*sodium atom*" as a system of 11 protons, 12 neutrons and 11 electrons; "*chromosome*"); 2) the mathematical terms that designate difficult functions and transactions: e.g. potentiation, logarithming, differentiation, integration, finding of a limit, scalar product of vectors. Such terms as "*the nabla operator*", "*functionality*", "*molecule DNA*", have DS $s = 6$.

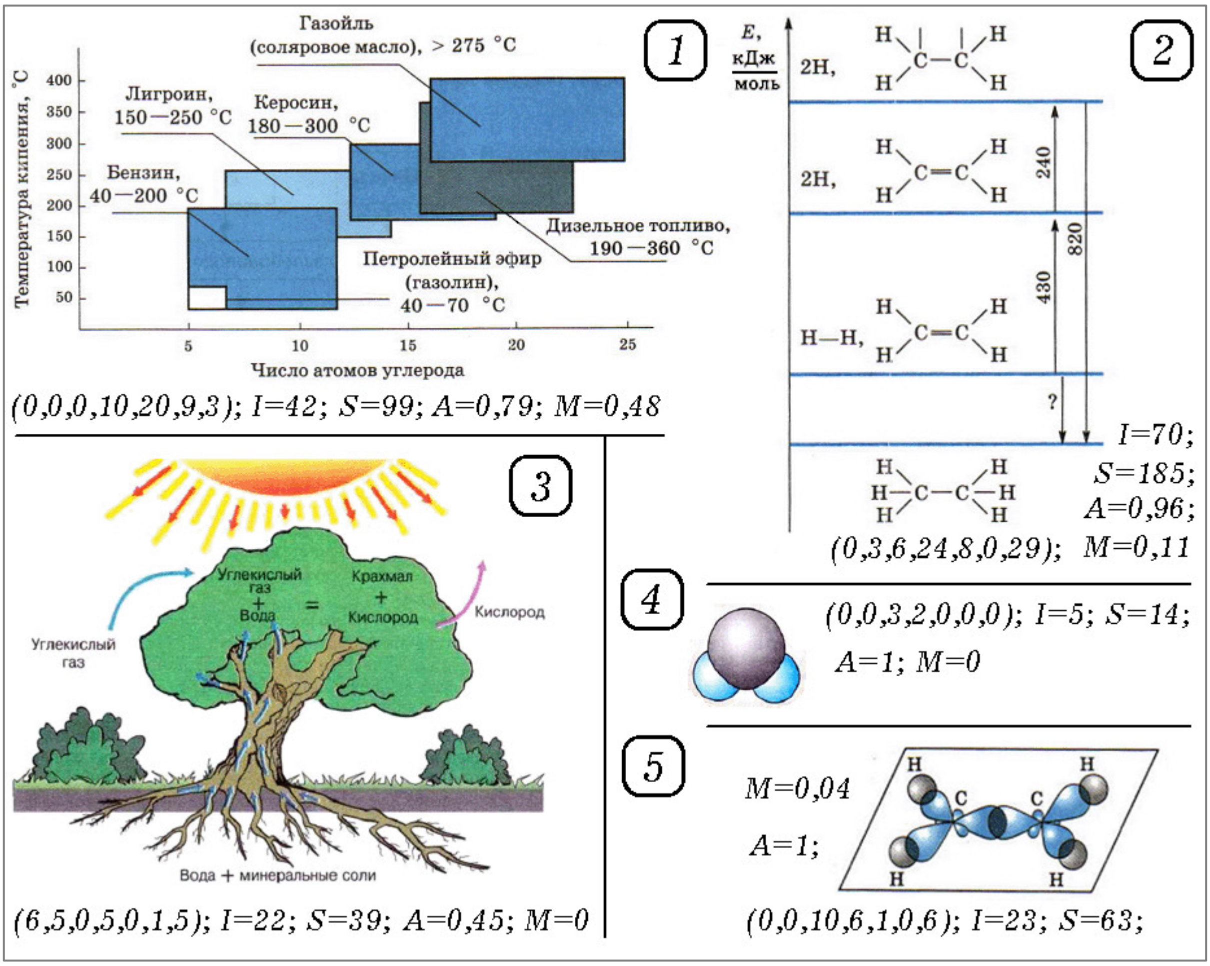

Figure 2: The estimation results of didactic complexity of pictures

5. Estimation of the informativeness and didactic complexity of pictures

For DC assessment of a picture, we can replace the picture with a full, but extremely short description and count the quantity and complexity of the used concepts (Maier, 2015). Another approach demands estimation of quantity and the abstractness degree of the depicted objects and links between them. Let us list some examples of such links: the interaction the Sun – the Earth, the thread connecting two bodies, the relationships of cause and effect, the perpendiculars lowered on coordinate axes. The abstractness criterion of an object (or links) is the impossibility for the pupil to observe this object (link) or another object similar to it directly, to sense it. For DC assessment of the picture it is necessary to define: 1) the number x_1 of the physical objects images which the pupil can observe, sensing it directly; 2) the number x_2 of physical links which the pupil can observe (e.g. the galvanometer is connected to the coil; the microphone is located opposite the loudspeaker; the acid is poured in a flask; the thermometer is lowered into the liquid, etc.); 3) the number x_3 of images of the really existing physical objects which the schoolchild cannot sense and needs to imagine (e.g. an atom, an electron, a chromosome, an electro–magnetic field); 4) the number x_4 of links which the pupil cannot sense and needs to imagine them (e.g. chemical links, an attraction of electrons to an atomic nucleus, the abstract links represented in the form of arrows); 5) the number x_5 of the mathematical abstractions (the mathematical formulas and designations, geometrical figures and bodies, vector, coordinate axes, schedules); 6) the number x_6 of the legends (inscriptions), that denote the objects (phenomena) which the pupil can observe (legends *"the Sun"*, *"petrol"*, *"cell"*); 7) the number x_7 of the legends, that designate the objects (phenomena) which the pupil cannot sense and he/she needs to imagine them (e.g. legends $"HNO_3"$, *"quarks"*, *"leukocytes"*).

The picture can contain m conventional designations of really existing objects which the pupils can sense. For example, the scheme of an electric chain consists of abstract elements corresponding to the real objects which the pupil can observe and touch. In this case it is also necessary to increase x_1 and x_3 by $m/2$.

The general informativeness I of a picture and the abstract information quantity I_A are equal (in concepts): $I = x_1 + x_2 +\ldots+x_7$, $I_A = x_3 + x_4 + x_5 + x_7$. The abstractness coefficient A and the share of mathematical information M are given by formulas: $A = I_A/I$, $M = x_5/I$. The didactic complexity of a picture is equal to its informativeness taking into account the complexity of the elements entering it; DC is defined by the weighted sum $S = (I - I_A) + \alpha I_A = I + (\alpha - 1)I_A$, where α – the weight factor exceeding 1. As the transition to another qualitative level is connected with the increasing of the appropriate quality amount in $e = 2.72\ldots$ times, then we assume that $\alpha = 2.72$. Fig. 2 shows five pictures from school textbooks on natural sciences subjects; nearby the vector of characteristics $(x_1, x_2, x_3,\ldots, x_7)$, the informativeness I, the coefficients A, M and the didactic complexity S are given. The received values allow to compare pictures on their didactic complexity DC and informativeness QI. It is visible that fig. 2.1 is twice as informative as fig. 2.3 or 2.5, and its DC is 1.5 times more, than DC of fig. 2.5.

6. Estimation of the physics textbook complexity

For analysis of the textbook, it is possible to make a representative selection of pages, and with the expert help to estimate their average complexity. If the volume of the selection is sufficiently large (for example, 30–40 pages from 400), then the result of such assessment can be extended to the whole textbook. Let us distinguish the physical F

and mathematical M complexities of the textbook. To assess physical complexity, it is necessary to find the degree of abstractness of the used models and the level of their isolation from the pupil's everyday experience. At the same time it is necessary to consider: 1) the perception of the object with sense organs; 2) the changes of the object over time; 3) the number of the freedom degrees; 4) the space-time length of the object or process; 5) the existence of the object structure; 6) the existence of an apparent contradiction between of behavior of the object and "*common sense*". The mathematical complexity of the text depends on variety, quantity and complexity of the used formulas and figures containing mathematical abstractions.

Under the physical complexity of textbook let's take the value F, that is equal to the sum of the complexity of the considered physical objects, phenomena, experiments and physical theories (postulates, ideas, consequences). The physical complexity of the textbook is estimated as follows:

1. To analyze the contents of the i-th textbook, if necessary, to view separate chapters, and to assess the general complexity A_i of the studied objects, the phenomena, and also physical theories according to a scale 1–2–3–4–5: $A_i = 1$, if the physical objects and phenomena considered in the textbook can be perceived by sense organs of the person (water, a spring, a stopwatch, reflection of light), and their explanations are obvious and don't require imagination; $A_i = 3$, if objects and the phenomena which are discussed in the textbook can be observed in a physical laboratory (an oscillograph, photo-effect, electrolysis) or there are explanations for understanding of which the pupil must imagine the molecules, atoms, gravitational and electromagnetic fields; $A_i = 5$, if the experiments considered in textbook are non-reproducible in the conditions of training (nuclear reaction, the accelerator of elementary particles) and/or there are arguments that are contrary to "*common sense*" (wave-corpuscle dualism, relativity of simultaneity). The values of $A_i = 2$ and 4 are the intermediate.

2. To select $n = 10$–15 pages of the textbook which are uniformly distributed throughout the text (for example, if in the textbook of 420 pages, it is possible to select 40, 80, 120, 160, … 400 pages). The selected pages and two next pages (40–41–42, 80–81–82, 120–121–122, …) are analyzed, the level of the physical information complexity on every three pages is estimated on the scale considered above. As a result, for each of the three pages we give the marks B_{ij} ($j = 1, 2, \ldots$), which are entered in a table similar to tab. 4. Average value B_i^{av} for i-th textbook is calculated by the formula $B_i^{av} = (B_{i1} + B_{i2} + \ldots + B_{in})/n$, where n – the number of selections.

3. To calculate physical complexity of the i–th textbook on the formula

$$F_i = 0{,}25\,\frac{A_i - 1}{4} + 0{,}75\,\frac{B_i^{av} - 1}{3{,}25}.$$

The coefficients are selected so that it was possible to correct a contribution of estimates A_i and B_i in the general assessment of physical complexity.

Table 4: Assessment F and M (textbook Physics–11, V. A. Kasyanov)

Numbers of pages		40-42	80-82	120-122	160-162	200-202	240-242	280-282	320-322	360-362	400-402	Average
Physical complexity of text	A_j	2	2	3	4	5	2	2	3	5	5	3,30
Number of the formulas	N_j^F	13	6	12	8	2	12	10	5	4	5	7,70
Complexity of the formulas	K_j^F	2	2	2,5	1	1	2	1,5	2	1,3	1	
Number of pictures with the mathematical information	N_j^P	0	3	3	1	1	1	0	1	2	0	
Mathematical complexity of text	D_j	26	18	36	10	4	26	15	12	9,2	5	16,12

The mathematical complexity of the textbook is characterized by complexity and variety of the mathematical models used for the description of the studied phenomena and the solution of physical problems. Indirectly it can be defined by counting the number of formulas (taking into account their complexity) and pictures in which the mathematical abstractions (vectors, power lines, graphs) are represented. Mathematical complexity of the textbook is defined as follows:

1. To analyze the mathematical formulas presented in i-th textbook, and estimate the general level of their complexity (showing the level of the pupil's knowledge who is capable to understand these formulas): $C_i = 1$ – only arithmetic operations are used; $C_i = 2$ – formulas with square roots and/or powering; $C_i = 3$ – formulas with trigonometrical functions; $C_i = 4$ – logarithms and limits are used; $C_i = 5$ – formulas with differentials, derivatives, integrals, complex numbers; $C_i = 6$ – in the formulas the operators containing derivatives are used (nabla, Poisson's brackets, etc.).

2. To select n =10–15 pages of the textbook which are uniformly distributed throughout the text. The selected pages and two following (altogether 3 pages) are analyzed; the number of formulas N_{ij}^F, considering their complexity K_{ij}^F, and the number of pictures N_{ij}^P that contain mathematical information (vectors, graphics, frame of reference) are counted. One picture containing mathematical abstractions is equated to a formula with complexity 2. To calculate the mathematical complexity of each of the three pages; for this purpose the number of formulas is multiplied by their complexity, and the result is added to the number of pictures multiplied by the weighting factor 2: $D_{ij} = N_{ij}^F K_{ij}^F + 2N_{ij}^P$. After that for every i–th textbook the average value D_i^{av} and average number of formulas on three pages are calculated as:

$$D_i^{av} = (D_{i1} + D_{i2} + \dots + D_{in})/n, \qquad N_i^F = (N_1^F + N_2^F + \dots + N_n^F)/n.$$

3. To find the complex indicator of mathematical complexity of the textbook

$$M_i = \frac{1}{4{,}09}\left(0{,}5\frac{C_i - 1}{5} + \frac{N_i^F}{11} + 2\frac{D_i^{av}}{34}\right).$$

The weight coefficients allow to correct the contribution of these estimates to the general assessment of mathematical complexity which should fill the interval [0; 1].

4. To define the general complexity of the textbook $S_i = (F_i^2/2 + M_i^2/2)^{0,5}$.

Table 5: Didactic complexity assessment of various physics textbooks

i	The name of the physics textbook	Physical complexity			Mathematical complexity				Comp-lexity
		A_i	B_i^{av}	F_i	C_i	N_i^F	D_i^{av}	M_i	S_i
1	Physics–7 (Peryshkin A.V., 1999)	1	1,40	0,09	1	0,40	0,45	0,02	0,07
2	Physics–8 (Peryshkin A.V., 2000)	2	1,85	0,26	1	1,90	3,80	0,10	0,20
3	Physics–9 (Peryshkin A.V., Gutnik E.M., 2003)	4	2,67	0,57	3	3,00	6,09	0,20	0,43
4	Physics–10 (Myakishev G.Ya.,Bukhovtsev B.B., Sotsky N. N., 2004)	4	2,09	0,44	3	12,63	20,20	0,62	0,54
5	Mechanics–10 (Balashov M.M., Gomonova A.I., etc., 2002)	1	1,42	0,10	4	7,83	22,13	0,57	0,41
6	Physics–10: Molecular physics. Thermodynamics. (Myakishev G. Ya., A.Z. Sinyakov, 2002)	3	2,86	0,55	3	8,00	18,00	0,49	0,52
7	Physics–10: Physics. Electrodynamics (Myakishev G. Ya., Sinyakov A.Z., etc., 2002)	3	2,68	0,51	5	8,82	21,50	0,60	0,56
8	Physics–11: Oscillations and waves (Myakishev G. I, A.Z. Sinyakov, 2010)	3	2,95	0,58	5	10,10	33,80	0,81	0,70
9	Physics–11: Optics. Quantum physics (Myakishev G. I, Sinyakov A.Z., 2013)	5	3,50	0,83	3	3,45	10,50	0,28	0,62
10	Physics–11 (Myakishev G. I, Bukhovtsev B. B., Charugin V. M., 2008)	5	3,22	0,76	5	1,58	4,50	0,20	0,56
11	Physics–10 (Kasyanov V.A., 2003)	4	2,50	0,53	4	7,50	15,48	0,46	0,50
12	Physics–11 (Kasyanov V.A., 2004)	5	3,30	0,78	5	7,70	16,12	0,50	0,66
13	Physics (Pinsky A.A., Grakovsky G. Yu., 2008)	5	2,96	0,70	4	11,10	26,73	0,70	0,71
14	Course of physics. T.1. Mechanics, molecular physics (Savelyev I.V., 1989)	4	2,54	0,54	5	10,08	41,10	0,91	0,75
15	Course of physics. T.2. Electricity and magnetism. Waves. Optics, (Savelyev I.V., 1988)	4	2,92	0,63	6	9,92	45,69	1,00	0,84
16	Course of physics. T.3. Quantum optics. Nuclear physics... (Savelyev I.V., 1987).	5	4,25	1,00	6	10,00	30,50	0,78	0,90

The following textbooks have been subjected to the content analysis: 1) Peryshkin A.V. Physics–7, 1999; 2) Peryshkin A.V. Physics–8, 2000; 3) Peryshkin A.V., Gutnik E.M. Physics–9, 2003; 4) Myakishev G.Ya., Bukhovtsev B.B., Sotsky N.N. Physics–10, 2004; 5) Balashov M.M., Gomonova A.I., etc. Mechanics–10, 2002; 6) Myakishev G.Ya., A.Z. Sinyakov Physics–10: Molecular physics. Thermodynamics, 2002; 7) Myakishev G.Ya., Sinyakov A.Z., Slobodskov B.A. Physics–10: Physics. Electrodynamics, 2002; 8) Myakishev G.I, A.Z. Sinyakov Physics–11: Oscillations and waves, 2010; 9) Myakishev G.I, Sinyakov A.Z. Physics–11: Optics. Quantum physics, 2013; 10) Myakishev G.I, Bukhovtsev B.B., Charugin V.M. Physics–11, 2008; 11) Kasyanov V.A. Physics–10, 2003; 12) Kasyanov V.A. Physics–11, 2004; 13) Pinsky A.A., Grakovsky G.Yu. Physics, 2008; 14) Savelyev I.V. Course of physics. T.1. Mechanics, molecular physics, 1989; 15) Savelyev I.V. Course of physics. T.2. Electricity and magnetism. Waves. Optics, 1988; 16) Savelyev I.V. Course of physics. T.3. Quantum optics. Nuclear physics. Physics of a solid body. Physics of an atomic nucleus and elementary particles, 1987.

The calculation results of the physical complexity F, mathematical complexity M and didactic complexity S of the textbooks are presented in tab. 5. In fig. 3 distribution of textbooks in the space formed by axes F and M is represented. The numbers near points coincide with numbers of textbooks i in tab. 5. It is visible that the high school textbooks on electrodynamics, optics and quantum physics (15), (16) have the greatest complexity, and the textbooks on physics for the 7–th class (1) and for the 8–th class (2) have the smallest complexity. The last two textbooks (1), (2), physics textbook (3) for 9–th class and textbooks (9), (10) for the 11–th class have the mathematical complexity M less than 0.4. Textbooks (3), (9), (10) have the physical complexity of more than 0.4, while their mathematical complexity is sufficiently low (0.2 – 0.3). The textbook for the 10–th class on mechanics (5) has low physical complexity (0.10), but rather high mathematical complexity (0.57). In this textbook the mechanical phenomena, the majority of which can be observed in everyday life, are considered, but at the same time, rather difficult mathematical models are used. Textbooks for schools (4), (6), (7), (8), (11), (12), (13), as well as textbooks for higher education institutions (14), (15), (16) have physical and mathematical difficulties more than 0.4.

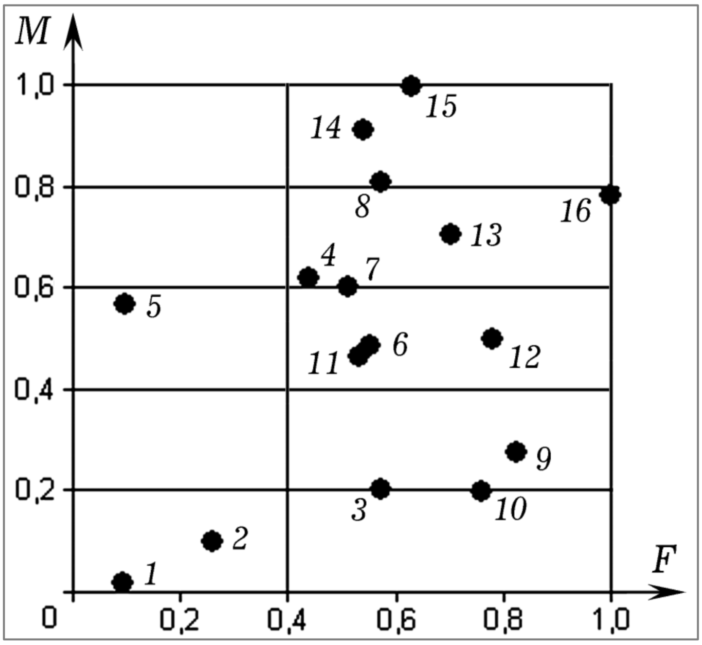

Figure 3: The distribution of textbooks in the feature space
"physical complexity F – mathematical complexity M".

The considered above method allows "*to measure*" complexities F and M of various physics textbooks quickly enough and to make a judgment what textbooks it is appropriate to use in this or that situation. At the same time the content of educational texts, correctness of logical conclusions, methodical validity of reasonings are not considered as it is initially assumed that the analyzed textbook corresponds to all standard requirements for this type of publications.

The offered technique of an assessment of physical and mathematical complexity allows to make the comparative analysis of various education texts. The results of this expertise can be taken into account while writing textbooks of new generation, and also in the work of teachers. It is well-known that pupils differ in their interests, knowledge of mathematics, and have unequal abilities to assimilate different types of information. The physical and mathematical complexity of the textbook can predict which students will acquire this or that education material better.

7. Conclusion

In this article: 1) the methods of the informational content and didactic complexity assessment of the concepts and educational pictures is considered; 2) the didactic complexity of 16 Russian physics textbooks for school and universities is assessed, their distribution in space of signs "*physical complexity – mathematical complexity*" is analyzed. For the evaluation of the concepts didactic complexity it is necessary to estimate complexity of experimental and theoretical studying of the objects or phenomena designated by these concepts, using the pair comparisons method. Another approach consists in distribution of cards with concepts in order of increasing complexity. For assessment of the complexity and informativeness of the pictures we count up the quantity of the objects and links between them, represented in the picture, and also consider their degree of abstractness. The offered methods and results of the didactic complexity estimation of educational texts can be used for an assessment of informational content and didactic complexity of the nature science textbooks and for a comparison of various paragraphs, themes, subjects and detection of the corresponding regularities of the education information distribution.

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