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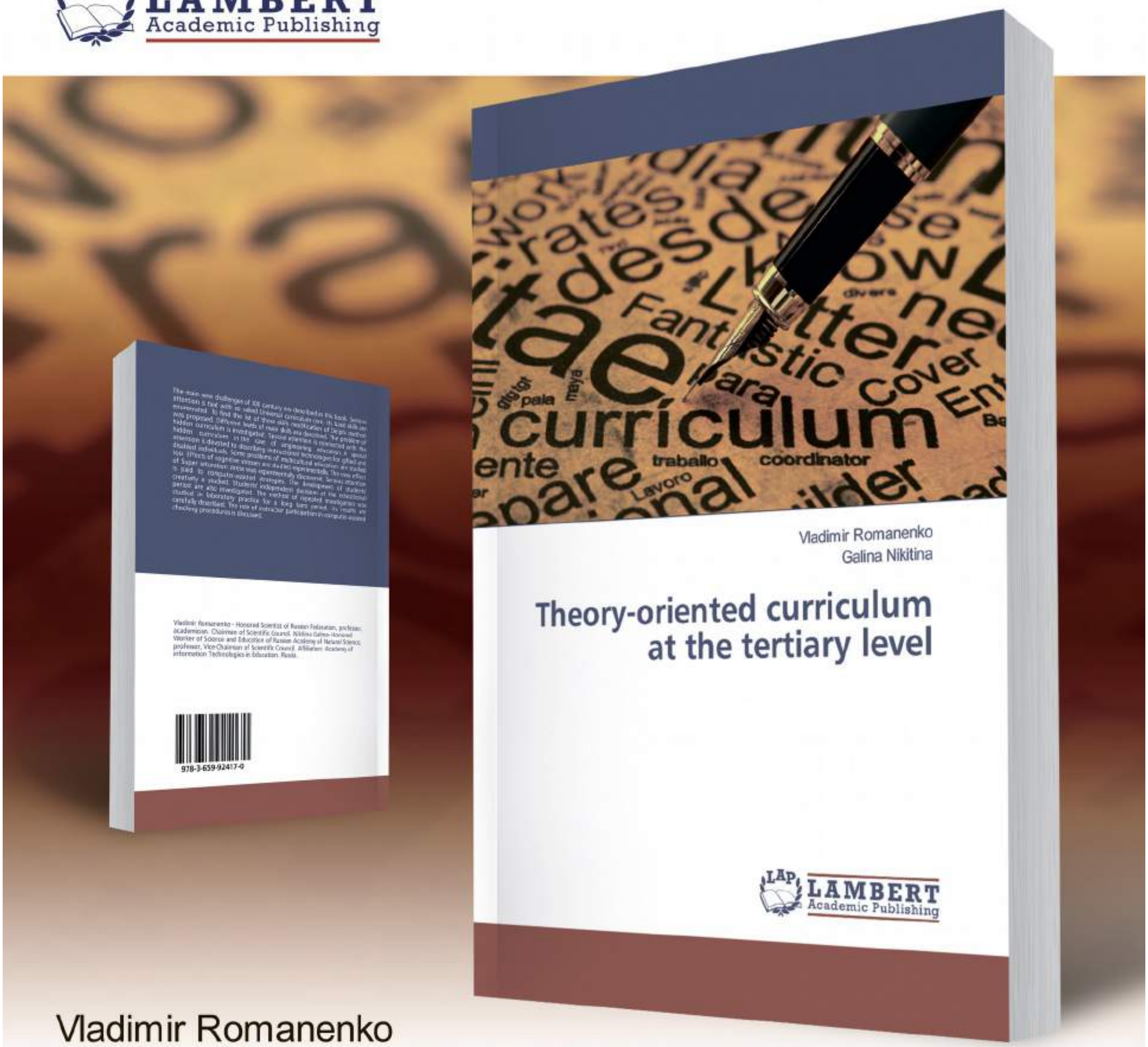

Vladimir Romanenko
Galina Nikitina

Theory-oriented curriculum at the tertiary level

The main new challenges of XXI century are described in this book. Serious attention is tied with so called Universal curriculum core. Its basic skills are enumerated. To find the list of these skills modification of Delphi method was proposed. Different levels of main skills are described. The problem of hidden curriculum is investigated. Special attention is connected with the hidden curriculum in the case of engineering education. A special attention is devoted to describing instructional technologies for gifted and disabled individuals. Some problems of multicultural education are studied too. Effects of cognitive stresses are studied experimentally. The new effect of Super saturation stress was experimentally discovered. Serious attention is paid to computer-assisted strategies. The development of students' creativity is studied. Students' independent decisions at the educational period are also investigated. The method of repeated investigation was studied in laboratory practice for a long term period. Its results are carefully described. The role of instructor participation in computer-assisted checking procedures is discussed.

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PREFACE

The famous Moravian educator John Amos Commenius (Yan Amos Komensky) was the first theorist who clearly formulated the idea that the system of education is divided into four parts (Comenius, 1967; Lukaš, M. & Munjiza, 2014). Since then, the College and the first years of University education have been referred to as the tertiary educational level. There are many reasons why the training process at the elementary and secondary schools is studied more extensively than at the tertiary level. The educational strategy at the pre-graduate and post-graduate periods is closely connected with future practical activities of students. Therefore, this strategy is more certain than at the tertiary level. As a result one can say that the educational strategies at the tertiary level should be given the maximum attention. The new challenges of XXI Century affected the whole world system of education. They made serious corrections to the main ideas of the instructional practice at the tertiary level. Some of these ideas were discussed at the annual conferences at the Latvia University of Agriculture. All materials of these discussions and some additional articles are the basis of this book. A number of these materials were previously published in Russian. However, we are not going to give references to these Russian articles. If necessary, we shall refer to our books (Nikitina &Romanenko, 1992; Romanenko et al., 2008). In this book we focus attention on the computer-assisted learning and new methods of information search. We believe that such a joint analysis will make it possible to identify several new approaches for instructional practices. The authors also proposed the classification and ranking of skills that are essential for the engineering background. This classification has additional independent value.

It has been an established intellectual tradition that the process of education at all four levels has to be described as a set of methods on the creation of theoretical knowledge and a set of particular professional skills. With this approach all personal behaviours of students and teachers are excluded from consideration. The affect of information from environment on the instructional process was also excluded. Therefore, the greatest part of theoretical studies of instructional practice has some serious restrictions. A more general approach requires description of the instructional process as a triad:

STUDENT BEFORE INSTRUCTION→INSTRUCTIONAL ACTIONS→STUDENT AFTER INSTRUCTION

It is well known that the principal behaviour of any process, which can be called technology, may be presented in the form of a triad (Romanenko & Nikitina, 2015). Therefore, the theoretical investigations of instructional strategies should be started with an analysis of the general properties of technological transformations of various nature. We shall devote the first chapters of theoretical part to them. As additional novelty, we shall discuss some new ideas which allow us to justify a set of long term experiments and different independent observations in several countries. The majority of them is devoted to STEM disciplines. Additional results are connected with pre- and post-graduate practice. Special attention will be paid to computer-assisted learning.

We are very grateful to Professor Sergei Abramovich (SUNY USA), Professor Larisa Maļinovska (Jelgava University of Agriculture, Latvia) and Ph. D. Yana Edquist (Chicago, USA), and Ph. D. Latinka Hitova (Sofia, Bulgaria) who helped us during the entire period of our work.

The readers can order a paper copy of this book on the website of the publisher.

THEORETICAL PART

CHAPTER 1. GENERAL DESCRIPTION OF TECHNOLOGIES

1.1 UNIVERSE AND MODELS

The Universe is such a complex system that its behaviours may be known only partially. Despite this, its perception by humans is possible as a result of modelling. One who defines modelling as a simplified description takes into account only some of the properties. The loss of a number of important properties in the description of nature is the cost for simplification of studied problems. Therefore, a number of different models are necessary for study of each serious problem. The process of human learning is tied to several models that take into account different theoretical points of view (Frigg & Hartman, 2011; Romanenko & Nikitina, 2009). The best known of them are: theory of systems (Bertalanaffy, 1974), theory of human activity (Vygotsky, 1978; Vygotsky, 1986), theory of global evolution (Gould, 1981; Chaykovsky, 2008). The general theory of technologies is one of them. There are three important questions in the field of education, natural sciences, and sociology. The first question is «WHAT IS IT?”, and the second is “HOW TO DO IT?”. The last, third question is “WHY IS IT SO?”. (Romanenko & Nikitina, 2012a). The answer to the first question is given in physics and engineering. The answer to the second question can be found in the field of chemistry and other types of processing. Processing is defined as a path of fabrication or transformation of different objects we need. One can transform objects by different ways. If the object under transformation is a person or a group of humans, such transformations cover areas of medicine, politics, and education as well. The processing can sometimes create objects we really need. Human knowledge develops unevenly over time, and in different areas.

Nevertheless, one can interpret observed behaviours of the Universe and generate different conclusions and predictions based on various models. However, the models simplify the reality. Each model can investigate and describe a restricted set of the observed reality. These restrictions are the cost of exact conclusions given with the help of the model usage. The best investigation of Universe behaviours could be found in the zone where several models interact with each other. The practical value of each model depends on the level of its integration. A low level of integration allows us to give a concrete forecast for real situations. Yet, the generality of given predictions is not high. The increase of this level allows one to generate more general conclusions. At the same time, these conclusions are less linked with the real problems.

We shall illustrate this point with a simple example. One wants to build a new lecture hall. It is necessary to find the illumination in the middle of this housing. For this purpose, one needs to know all dimensions of the hall, a number of windows and all behaviours of different light sources. In addition to this evident data, the designer has to find the information about geographical and climatic characteristics, building orientations and possible shadows from neighbouring structures. All this data has to be introduced in the computation model, which enables the designer to find how many electrical bulbs of a given power can provide the necessary illumination. Unfortunately, this result will be correct only for a specific town or village. For instance, the results found for the city of London are not correct for Mexico City. If one wants to study illumination for a rural area in Lithuania or Ukraine among others, he or she has to explore different models. The integration of these models has to be of higher level. With the help of this model the designer can find useful results about illumination of large areas. This data is less general than in the previous case. Therefore, the cost of enlarging of a described area is a loss of specific practical recommendations given by a more general model (Romaneko & Nikitina, 2009).

The taxonomy of different models was also described in (Romanenko &

Nikitina, 2011). The level of models' generalization was studied in this issue as well. The higher level is attributed to the models, which cover all possible theoretical and practical situations of human practice. These models are called global. The theory of systems, theory of manifolds, and the theory of information are examples of these general theoretical models. These theories are all of an interdisciplinary nature. One of these theories represents the general theory of technologies. This theory is a focus of this chapter.

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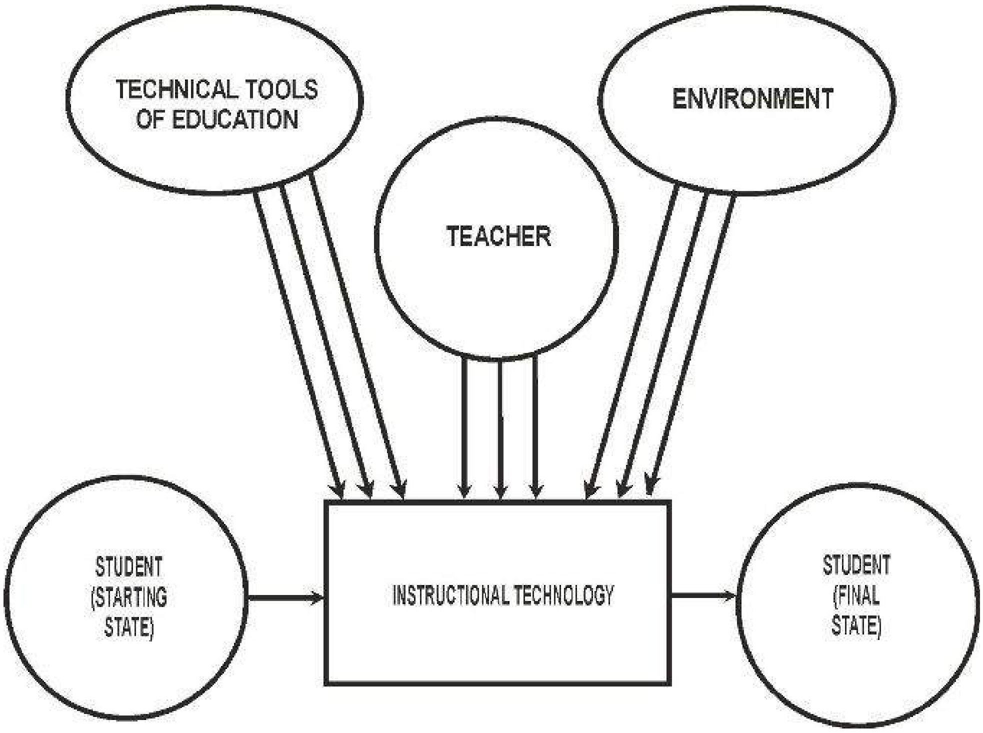

Fig. 3. Full representation of the input information flows and its main external sources for the general sketch of educational strategy.

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1.3 THE OPEN AND CONFINED INSTRUCTIONAL TECHNOLOGIES

There are two dimensions affecting a position of the border between different technological zones. Both of them are presented on the axis in Fig.5. One of them is the complexity of technology. The other one is the magnitude of uncertainty of a transformation process. Each technology is a prediction of transformation results. These predictions cannot be fully complete. For instance, it is easy to say what result will be achieved on a car or TV receiver assembly line. Yet, the scheduled actions of steel melting are connected with a higher uncertainty. If we take a number of actions that lead to highly probable results and divide it by a total number of actions, we determine the so called coefficient of uncertainty. If this coefficient is less than 50%, the technology transforms into a set of recommendations. One knows that human behaviour has a higher uncertainty than behaviour of different things, matters, and goods. A creative part of the recommendations poses the largest amount of uncertainty. In view of this, in the area of human technologies all predictions are fuzzy.

From theoretical analysis of this chapter one can say the following. First of all, instructional actions should be considered as a typical technological process. Therefore, average psychological behaviours of both teacher and student have to be included in modern theoretical analysis. Secondly, the instructional system in many cases has active interactions with the environment. In the first approximation these interactions are connected only with information flows. If this interaction is significant one can say the instructional technology is open. If this interaction is negligible one can say instructional technology is confined. The teaching of some subjects, mathematics and chemistry among them, is confined. In opposite, the information from TV, books, and movies creates active interaction flows from the environment which affect instructional technologies. As a result, these instructional actions one can interpret as open. Moreover, average behaviours of students under strong external information affectation, changed the coefficient of uncertainty and sometimes moved instruction actions from technological zone into the zone of recomendations.

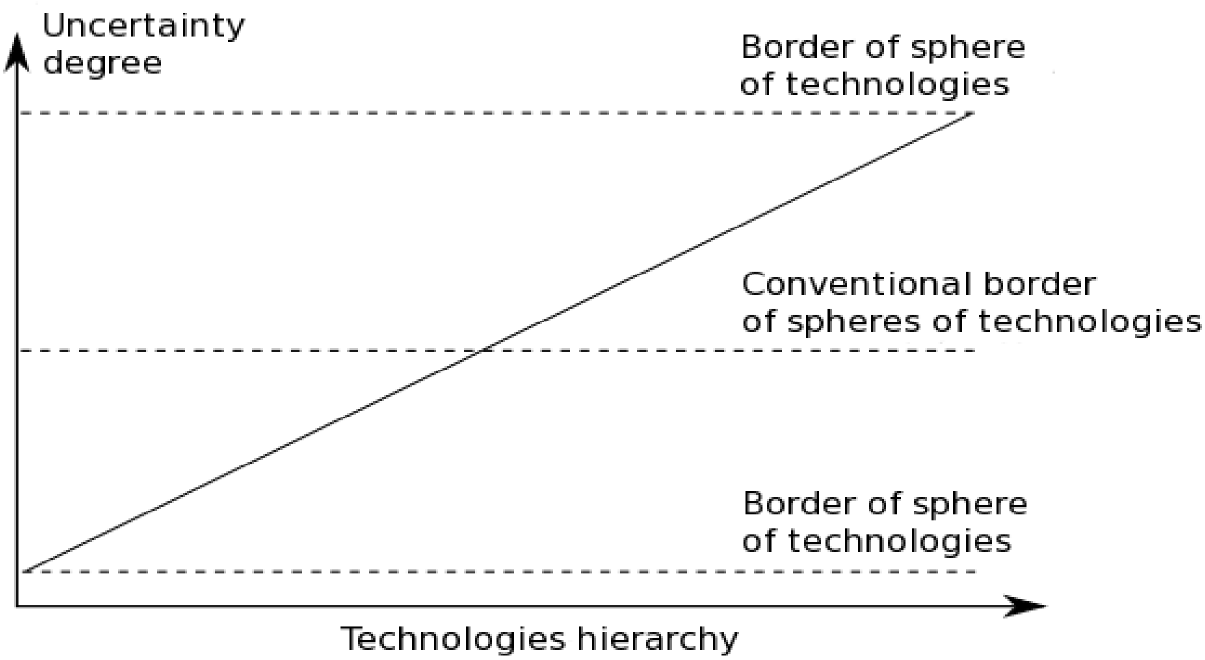

Fig.5. Position of the border between different parts of technological zone.

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2.2 XXI CENTURY AND ITS EDUCATIONAL CHALLENGES

Educational system is built to meet the demands of the social environment. The changing environment creates new educational demands. Therefore, educational institutes have to constantly upgrade their curriculums. The sensitivity of curriculum to the surrounding environment is described with the so called elasticity index E_j (Romanenko & Nikitina, 2012c):

$$E_j = \frac{(\Delta P_i)}{(\Delta q_j)} = \frac{(P_i^2 - P_i^1)}{(q_j^2 - P_j^1)} \qquad (2.1)$$

If any parameter of the environment q_i changes, it changes any value of curriculum denoted as P_i .The changed values are measured at different moments of time: t_1 and t_2 . The integral changes of all possible q_j for many centuries were not high. In the past, it was permitted to introduce educational changes slowly. The new curriculum generated under these processes was stable for a long time. The history of science and technique says that changes in environment have had serious acceleration during the last several decades. This period is the time of intensive creation of new knowledge. Such intensity transforms the evolution character of education, upgrading it into a revolutionary. It is not enough to restrict investigations of curriculum changes with traditional study of elasticity indexes. The new challenges create new responses. The main goal of this presentation is to identify new challenges and outline several ideas that enable us to find effective solutions of educational practices at the tertiary level.

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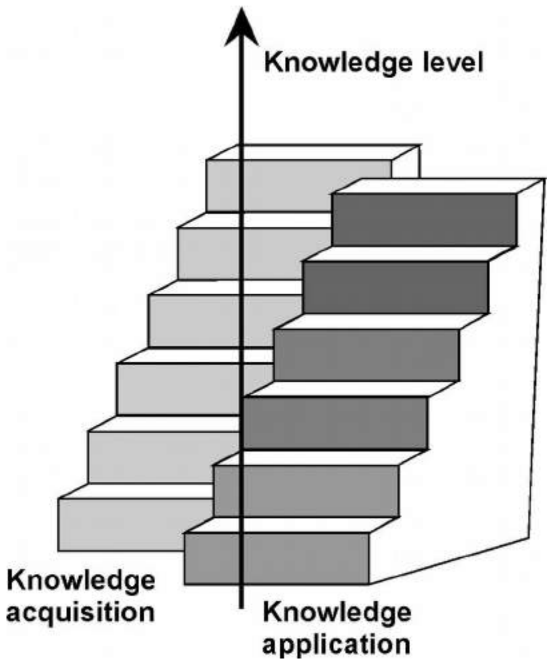

Fig. 9. Staircase of growing knowledge

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6.2 EDUCATION AND STRESS; PROBLEM OF OPTIMAL CURRICULUM

As evolution in general, an individual development does not always go evenly. Sudden revolutionary changes cause stress in their participants and observers. Accordingly, stress accompanies the process of the personal development and the learning process. Every child experiences stress when he (she) learns of the death of his (her) parents. Another typical stress of growing up can be the discovery that adults do not possess absolute knowledge. Our further attention will be devoted to the Cognitive stresses which are specific for learning on the tertiary level. The learning of the Universe is gradual. This is because Nature is infinitely complex. We can learn it only by using simplifying models. As we move from one level of education to another, all used models of cognition both of Nature and Social life are replaced step by step with new ones. These replacements are frequently unexpected. They are associated with the need to change the individual thesaurus of a student. At its core, this transition may be similar to what Thomas Kuhn called Scientific Revolution (Kuhn, 1996). Using the terminology of this author, one can say that a change in studied models causes an individual paradigm shift. Of course, what more often happens in instructional practice is that the paradigm shift covers only a small area of knowledge. One can speak about shifts of individual paradigms or microparadigms. At the tertiary level, a stress situation is usually complicated with the fact that new models come up in the taught material when students move to new subjects. This, in turn, is accompanied by the appearance of new lecturers and instructors. This frequently can enhance the power of cognitive discomfort.

Gradual complication of the studied models inevitably causes cognitive stress. Careful examination of the curriculum suggests that this phenomenon is inherent in the teaching of all subjects. For this reason, to completely get rid of cognitive stress is impossible. An experienced instructor usually knows well in which points of the taught material the cognitive problems will come up. These critical points may be shifted within certain limits. Sometimes, it is possible to overcome all cognitive stress with the help of discussions in reciting classes or by special explanations at the lecture time. Yet, very often the problem is more serious. Let us consider two examples.

In Physics, which is taught in high school, the students frequently solve the problems about a balance of the two loads hanging on a cord thrown through a block. At the first stage the rotation of the block is neglected. On the next level the students study the main laws of a rotating body. In this case, the solution of the same problem on equilibrium of two loads on the block is different. It is not very difficult to alleviate the discomfort and the attendant stress. This is enough for a short discussion. The second example is connected with teaching of foreign languages. It is well known that the study of a language requires constant expansion of vocabulary. Translation of words into another language is ambiguous. However, at the early stages of learning one can usually focus only on one meaning of the word. As a result, the overwhelming majority of trainees have an impression that there is one-to-one correspondence of words in different languages. The ambiguity of translation and its dependence on the context is usually surprising. The consequence of this frequently creates Cognitive stress. A set of interviews confirmed this suggestion. In contrast to the previous example the stress in this case occurs in different students at different times. This time depends on many individual circumstances. A more careful approach in this case is required as a consequence of overcoming cognitive stress.

It is not difficult to understand that the facts and novelties in instructional technologies, which affect the perception of the new material, are very diverse. In this field much depends on the psychology of a student and of his (her) background. An experienced teacher is usually able to identify these critical moments. They may be called focal points of the instructional program. The most important of them is well known. One example is the transition to the study of quantum phenomena in Physics and Chemistry. These points are available in many academic disciplines. For this reason, the question arises about how to allocate these difficult moments in the

General schedule. As a result, the problem arises of optimisation of the schedule. For this point the idea of optimal curriculum can be considered one of the most important practical problems.

Students can have cognitive stresses in classrooms, lecture halls and elsewhere. Modern education is becoming a more open system in comparison with previous times. Over the last decades students can find a lot of information from TV, Internet and popular books. This process is not under serious control. Most students do not have experience in the estimation of the reliability of found information. Dealing with erroneous and contradictory information often leads to creation of cognitive problems and stresses. To overcome them one needs to organize special trainings in the area of independent work with information flows. Based on our own experience, we can suggest that the best way to solve these problems is with the help of personal training.

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Table 1. The main engineering skills and abilities which have to be developed in the hidden processes (Published in 1992).

№	**Engineering skills and abilities**	**№**	**Engineering skills and abilities**
1	Systematization of results	11	To be familiar with personal computer
2	Streamlining of experimental data	12	Statistical planning data of experiments
3	Estimation of experimental data statistical description	13	Estimations of measuring equipment descriptions
4	Presentation of results in the diagram forms	14	To make use of dimensions method
5	Optimal results presenting	15	To know literature data search methods
6	To know simple computing methods	16	To know methods of literature data storage

7	To know methods of numerical and graphical problems solving	17	To know modern literature data searching systems
8	To use nomograms	18	To write short resume
9	To find jumping out result	19	To know the main library indexation systems
10	To be familiar with methods of graphical derivation	20	To formulate main results of own work

For practical use of the information which was obtained as a result of the expert's survey one needs to answer two questions. The first one should cover how the KSAO's enumerated in Table 1are really developed across instructional strategies. The second question is more complicated. It is well known that technical progress has rapidly accelerated over the recent years. It changes the KSAO's to be developed in the Universities. To answer this challenge, the authors did the same exercise for the determination of a standard set of KSAO's again after some time. The answers to these questions will be discussed in the following sections.

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7.5 SOME ADDITIONAL METHODS FOR FINDING THE SET OF MADATORY KSAO'S

It is also useful to complement Modified Delpi method with additional independent investigations. To this end the USSR State Specialist Qualifications lists were carefully studied (Nikitina & Romanenko, 1992). We studied Qualification list for Civil Engineers and 8 lists for different chemistry professions. For every speciality we collected special experts groups. So, for the study of the qualification list for Civil Engineers the experts' group consisted of 20 persons which were split into 5 subgroups: deputy directors of building firms, chief designers, chief process engineers, leading experts and University teachers. All of them were the residents of the town of Murmansk (Nikitina & Ovcharenko, 1988). Similar experts groups were created for all chemical professions. Yet, in this case most experts were invited from research institutions.

Let us describe in detail the results of the study of the qualification lists for Civil Engineers. The total number of KSAO's defined by expert group was 74. After statistical testing, twenty eight (28) out of them were classified as the most important. These KSAO's were renamed in order to get rid of technical terms, and after this the experts ranged them. The experts who studied the qualifications lists of 8 chemical professions worked based on a little simpler strategy. Yet, the results were in principle similar to those obtained for Civil Engineers. All the results were compared with Table 1. No serious differences in the results were found. It is necessary to take into account that KSAO's determined with the help of qualification lists are written for graduates. The KSAO's in Table 1 are tied with competences which have to be created during the first period of education. Therefore, both methods that gave similar results can be recommended as the practical basis for curriculum modernisation. One must take into account that qualification lists are often different in various countries. Modern European situation in this field one can be found in (Köper & Zaremba, 2000). The emergence of the Unified Europe forced alignment of the Qualifications lists of different countries. Therefore, the most important result of the additional investigations discussed above is the development of various technologies in order to find the most important KSAO's which must be created in the Universities.

Similar to the development of the list of the most important KSAO's for graduates, one needs to use additional independent methods to study the degree of their real development. For this purpose the study of the mistakes made by ordinary students was supplemented by analysing the mistakes detected at different contests where the best students participated. It was obvious, that the number of mistakes found in the works of the best students was lower than in the mass experiments in the

Universities.

During the first week of the studies the average number of incorrect answers at the interview with instructor when the results of exercises were discussed, was 11.8%. Such big number was never detected in the materials of contests. Yet, the nature of the mistakes was practically the same.

More informative results were obtained when the students had to investigate problems which allow multiple ways of their solution. To this end, at the beginning of the first semester all students in reciting Physics classes were invited to find the lifting height of a given stone. Practically, no less than 95.0 % solved this task without any problems. Yet, no more than (9.0-10.5) % solved this task with the help of the Law of Energy Conservation. The others solved it using the equations of motion. This way is less effective than the usage of the laws of conservation. A set of such exercises enables us to get a real picture of development of the necessary KSAO's. The study of different mistakes and misconceptions in scientific articles enables us to estimate the real situation with graduates. This data is only approximate because many editors helped the authors to correct their manuscripts.

The results described in this chapter give the reader the information about methods of determination of the necessary sets of KSAO's and also enables us to evaluate their comprehension level. Yet, to build effective instructional strategies one must know the dynamics of their development. We shall discuss this issues in the next chapter.

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8.2 TESTING PROCEDURE

It is clear that it is necessary to have some numerical indicators for evaluation of the level of creative ability of the students in order to estimate the efficiency of the method. For this purpose, we used the so-called “mastering index" which at first was introduced in (Bespal'ko, 1977). This index P_j; for the j-th class of questions was defined to be the main relative fraction of factors that the student identified when solving questions of this class:

$$P_j = \frac{\sum_{i=1}^{N} P_{ij}}{N} \qquad (8.1)$$

Here, N denotes the total number of students in the group under study. j= 1,2,3,4 denotes the category of questions given to the student. The value p_0 is the relative fraction of correct answers given by the student number i to the question of category j.

All P_j were calculated after each class. To receive the data about the development of competencies the times dependence of every P_j was investigated. The methods used for calculation of p_0; were different for each different category of questions (different j). For example, for questions of the category 1 (j=l) this value was found as:

$$P_{i1} = \frac{n_{1i}}{n_o} \qquad (8.2)$$

Here, n_{1i}. denotes the number of negative factors found by student i and n_0 denotes the total number of these factors for the given exercise.

Special expert groups were created in order to determine the value of n_0. These groups consisted of 4-5 instructors from different technical or pedagogical universities. All of them had substantial experience in teaching Physics. It is clear that $n_{1i} \leq n_0$.

The value of p_{2i} was calculated using the expression:

$$P_{2i} = \frac{\Delta n_{2i}}{n_i} \qquad (8.3)$$

Here, Δn_{2i} denotes the number of negative factors that student *i* excluded in his report. Δn_{2i} is not divided by n_0 but by n_i. This value was different for different students, and usually, $n_i = n_{1i}$. Thus, we are interested in the fraction of negative factors found earlier by student *i* that he was able to eliminate in his recommendations. Values for p_{3i} were calculated using an expression analogous to (8.3). All students' ideas were accurately recorded during the period of final discussion. As noted above, such a discussion was the last stage of each exercise. The last coefficient – p_{4i} — was determined using an expression similar to that for p_{1i}. Students' suggestions in this area were also recorded. As mentioned above, the students could find the necessary material for solution of category four in the recommended textbooks and lecture synopses. Thus, P_4 makes it possible to estimate how students in the group considered can find the data in the literature.

Authors present here the coefficients P1 — P_4 for two typical groups of students. (P_1 and P_2 without data for control groups were also presented earlier on Fig. 11) The discussed results were received at the first stage of testing the new strategy. The experimental group consisted of 604 students. The control group consisted of a group of 313 students. The students in the experimental group were taught using the method described above, while the control group students were taught using traditional methods. In the control group, some questions of the categories described above were periodically asked during the final discussion. This allowed us to make all necessary comparisons and calculate the coefficients P_1 — P_4 for the control group. The main experimental results are presented in Figures 12 — 15. It is obvious that the described strategy is useful for the formation of creative abilities of students.

From the data on these figures one can see that mastering indexes really allow us to follow the development of several important students' KSAO's directly in the learning strategy. The curves on these figures are clear and convincing. The results are repeated for long term experiments over 15-year span. About 800 students in experimental groups and 450 in the groups which were taught in a traditional way took part in the final experiments. This made it possible to collect the data from about 19 000 student interviews.

On average, in the span of fifteen years, the data indicated that a percentage of male students in different groups varied in the range 45%-50%. In particular 40% of male students were in the 18 to 25-year range, 55% in the 26 to 30-year range, and only 5% were over 30-year old. No correlation between gender/age and educational growth of the students was found. From the study of some interviews, the coherence between the creativity of a student and the cultural level of his or her parents emerged. This statement, however, was not studied in detail. So, we can say it is not a fully confirmed observation. Its further investigation is impossible due to hardly changed cultural situation.

The first finding of described experiments confirms the effectiveness of the new instructional strategy for practical exercises both in labs and reciting classes. It is worth noting that the graphs in all four figures in this section have similar shapes

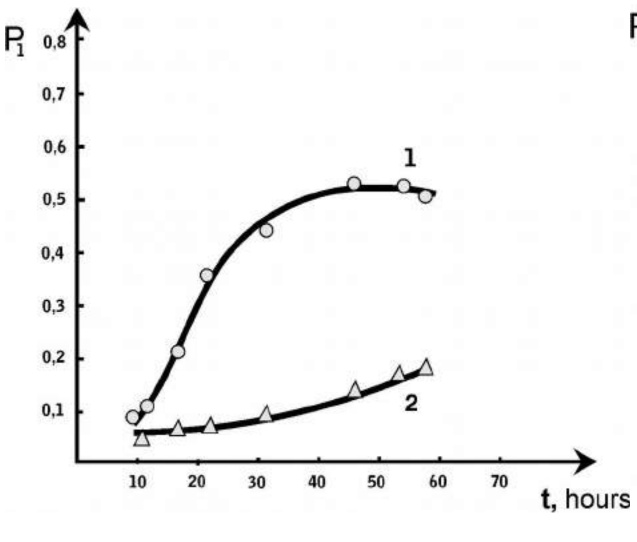

Fig. 12. Time dependence of P_1

1- *Experimental group*

2- *Control group*

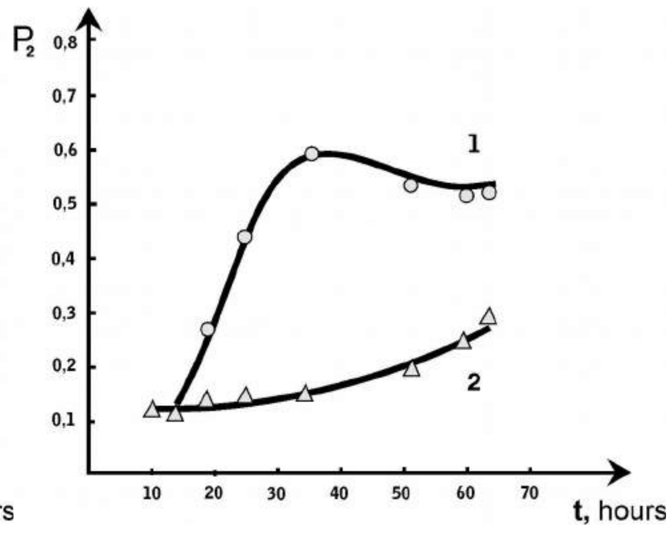

Fig. 13. Time dependence of P_2

1- Experimental group

2- *Control group*

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Table 2. The time expenditures studies for two instructional strategies.

Type of self-training	Experimental group				Cheking-group			
	Top students	Ordinary students	Weak students	Average time	Top students	Ordinary students	Weak students	Average time
Preliminary study	15.0	40.0	45.0	1.00	27.0	54.0	19.0	1.42
Experimental work	10.0	72.0	18.0	1.58	10.8	64.9	24.3	1.64
Result treatment	15.0	20.0	65.0	1.90	0.0	19.0	81.0	2.31
Summary				**5.28**				**5.37**

(Amounts of students in %, time in hours)

At the next stage the mistakes in students' lab reports in five Universities were studied in detail. The 392 students were under investigation. The principal result of this stage indicates that the average number of mistakes in the reports and their distribution by types are practically the same in all five Universities. Based on this result the further study was done in one University only.

h active participation in a master/apprentice type of a learning environment.

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9.6 TANSFORMATION OF INSTRUCTORS ACTIONS FROM ANCIENT TIME OF PERSONAL CONTACTS TO COMPUTER MEDIATED ACTIVITIES

Learning in the computer environment seriously changed demands to teachers. In some cases, some people believe that over time, the use of computers and other forms of computer-assisted activities allows one to almost completely get rid of teachers. Such ideas are periodically repeated in the history of education. To verify this it is enough to read (Richmond, 1965). In reality, this problem arises with every serious major change in pedagogical technologies. Historical experience shows that in all such situations the significant changes of instructional strategies refer only to the role of instructors. At these moments instructors' activities require new content. As a result some new competencies are necessary for successful work of university faculties.

To find a correct answer to these problems let us briefly describe instructional actions at different times. The Ancient Greek philosophers taught very few persons at the same time. The learning technology at that time mostly consisted of a combination of discussions, monologues and very simple narrates which were predecessors of modern lectures. Certainly, there was no curriculum. The main motivation at this period was a will of each pupil to study. The philosopher could also choose its auditorium. In a small auditorium a lecturer-apprentice contacted each other face-to-face. These contacts were close and very personal. Every student could change his lecturer. It was their free choice. Respectively, a lecturer could also change auditorium at his own will. It looks like, there were no restrictions in this field. One can say it was typical education with individual contacts of lecturer-apprentice. Such instructional technology was the best for that time.

Approximately, at the V century AD the knowledge grew very fast. Its content became diverse. From this time each student had to get information from several lecturers. Moreover, effective instructional technology required classes with several students. The cost of this was a loss of close personal contacts of lecturer-student. It was a starting point of serious contradiction: each lecturer had to teach several students simultaneously and take into account difference in their personal behaviours. Two ways of overcoming this contradiction were known. The first one was the orientation on average model of students' possibilities and their background. This way step by step brought the education strategy to its modern form.

The second way was very specific and rare. In this case a group of qualified teachers was created for a specific period time to give personal lessons to one person only. Certainly it was very expensive. Only notable or wealthy families could afford to give such education to their children. Some additional problems associated with socialization of the students, who got such education, were frequently created as a result of this strategy. As additional development way, a mixed education system was widely spread as well. In this case the first educational level relied on individual teachers. The education at the next levels used group classes. Over the last decades of the medieval period a famous teacher Jan Amos Komensky radically rebuilt all educational process in the Western World. After this all education technologies were based on standard curriculum, different forms of classes and many other novelties. These novelties launched all modern educational technologies. In these technologies each faculty was in touch with a group of students. Consequently, individual contacts of lecturer-apprentice were diminished.

After the medieval era the development of education technologies was closely tied with creation of special tools and different techniques. Starting from a simple piece of chalk the special educational technique stage by stage began using different recorders, movies, radio sets, TV devices and so on. New tools influenced not only the technologies. At the same time, the requirements to instructors' skills changed too. Moreover, the skeleton of instructional technology was rebuilt little by little. As it was written the instructional strategy may be presented in a triad form (Fig. 1). We recall here that educational triad consists of an initial object (input) and a final one (output). In the case of educational systems, the input and output parts of the triad are students. The middle part is traditionally defined as method. In confined instructional strategies (Section 1.3) the description of information flows ignores the interaction with environment. Contrary to this, information from TV, books, and movies creates active interaction flows from an environment – Fig. 3. These flows influence the instructional technologies. As a result, in this case instructional strategies cannot be defined as confined. Movies, TV, and books transform most of confined technologies into a non-confined form. These transformations started dramatically in the middle of XX century. Nowadays, computer-assistant instructional technologies, open internet access and especially "youtube lections" transformed teaching of all subjects at all possible levels into open ones.

Open instructional technologies and a new form of independent students' home training impose new requirements to instructor's actions in a classroom and lecture hall. As it was mentioned some passionate professionals proclaimed full replacement of lecturers' with recorded TV and youtube pieces. Despite serious criticism of these crazy ideas one can say that nowadays, PC-assisted technologies are a new challenge. Our further discussion is one of the first attempts to find correct answers to a set of questions which are created by this challenge.

Creating new knowledge and information about different concepts is the core of lectures for all taught subjects. Lecturer builds his or her theoretical material taking into account average students' KSAO's. Therefore, real text, examples and some emotional actions will be focused on a specific audience. It can be realised only with active and constant feedback. It is hardly possible to check students' reaction and their understanding of material taught without direct observation of the listeners' behaviour. There are a lot of small, yet, very important factors which can significantly influence the perception of information taught. Therefore, each experienced lecturer constantly adapts his or her words¸ intonations and examples. Answering students' questions, stimulating activity examples and different mini-problems help a lecturer find optimum strategy for increasing the audience attention. To this traditional management of instructional strategy nowadays situation added the necessity to control the increased flow of external information. Recently it was enough to know the main printed books connected with a studied area of knowledge. Yet, free access to Internet, information exchange in social nets and watching different TV educational programmes made this informational flow poorly controlled. One can say a common modern lecturer practice is combined with active tutorial work in the field of managing independent students' informational search. It is evident, lecturers are still the main persons in realisation of such instructional strategies. The professional lecturer's competence is significantly expanded as a result of extensive use of computer and Internet teaching assistance. It is obvious, that different recorded lectures can never replace a lecturer in the new education strategies. In our opinion, this is the first and yet the simplest answer to a set of new educational challenges. We shall illuminate all these questions in the next sections.

9.7 TEACHERS PARTICIPATION IN COMPUTER-ASSISTED CHECKING PROCEDURES AND CREATING STUDENTS' ABILITIES TO MAKE INDEPENDENT DECISIONS

It is well known that one of the major advantages of computer-assisted learning is a possibility to save an instructor from routine operations. On the one hand, it enables an instructor to focus on more important actions. At the same time, computer-assistance gives an opportunity to increase a number of routinized actions. One of such actions is periodical check of students' achievements between exams and at pre-exam discussions. To this end, different test surveys are used almost universally. In Section 1.2 it was written that testing procedures were on of the first areas of computers implementing in the classrooms. Both teachers and students love them. There are several types of tests. Its classification and main behaviours were repeatedly described. The most commonly used one is a test in which a student has to find one correct answer from a set of three-five answers. All types of tests may be divided into two groups. Tests of the first group are created by a lecturer or with his or her direct participation. They are in a good agreement with the content of a theoretical part and the problems discussed at reciting classes. One can say these tests are perfectly adapted to a local situation. The students who involved in such educational programme usually get better scores than the students educated in other places. Therefore, many checking procedures use the test of the second group. These tests are the same for many institutions and different from government programmes. They do give more objective information about students' competencies. As a result, an experienced instructor has to combine the test of these two groups. He or she should study the test of local type to provide the tests with the same complexity. That is why each instructor needs reliable statistics of students' answers. This, in turn, requires constant correction of the tests' packages (Smith, 1984; Nikitina & Romanenko, 1992; Störmer, 1994).

In the routinized testing strategy a correct answer to a problem is originally introduced into the PC-programme. It means, only one answer is a correct one. All other answers are treated as mistakes. To ensure this, a test has to be strictly obvious. However, it can be a case when students' understanding is not uniform. One frequently does not understand that in some cases a computer-assisted system rejects all non-standard and unexpected students' answers as erroneous. Here one encounters the main disadvantage of computer-assisted checking. This disadvantage is that the rigid standardization of the correct answer eliminates a small number of students with original and creative points of view. After several cases with poor scores such students usually lose their creativity.

Let us describe two examples of typical tests in which one can detect some hidden alternative corrects answers. The first example was artificially created based on the widely spread traditional strategy. In this test a student has to find an object which differs from the others in the short list:

TURTLE
TRUNK
SQUIRRELL
TIGER

Each experienced instructor immediately recognises a traditional idea here: to check if a young preschool child or pupil of the first/second educational level really understands which word describes a non-animated object. So, the correct answer in PC-programme would be: *TRUNK*. Most of examined pupils usually give this answer. Yet, there are some other possible correct answers. So, *SQUIRRE*L is the only word, in which the first letter is not **T**. The word *TIGER* is the only word without letter **U.**

This is the reason for having a discussion with the students given "*non-correc*t" answers: for understanding if it is misunderstanding or original point of view.

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10.2 SOME PSYCHOLOGICAL ISSUES ASSOCIATED WITH ASSIMILATION OF NEW KNOWLEDGE

If one wants to build optimum curriculum he or she has to estimate the time, which an average student needs for the development of the new concept. As a rule, a student hears at the lectures. New concepts are sometimes taught at reciting classes, different discussion, via Internet and even during interpersonal communications. For development of each concept its idea has to be repeated several times and underpinned at practice. Only after this the new concept transforms into KSAO. Each reference to the target concept requires time. As a consequence, the question arises about the schedule capability. Based on this quantity one can evaluate the approximate number of new concepts which the student is able to master.

The capability mentioned above depends on both the number of classes scheduled within a course and the quantity of new information that can be assimilated by a student during a single class. Typically, classes run throughout a semester the duration of which varies from 12 to 18 weeks. Practical classes and lecture courses are divided into several parts if the duration of a course is more than one semester. An introductory course in one of the STEM (science, technology, engineering, mathematics) disciplines usually has two hours per lecture. The models of reciting classes, lab trainings and other practical work are various in different countries. Yet, all the time these forms of practice are hardly tied to the total number of hours of lecture course. The time for practical work per semester may vary widely from as few as 6 to as many as 15 classes per semester. This time limitation defines the total number of possible experimental and theoretical assignments that can be completed.

It appears that the existence of computer-assisted laboratory classes has the potential to positively deal with the time limit issue because students are able to perform computational experiments during their free time and/or as part of their homework. Independent work possible thanks to the usage of computers also provides students with more freedom (Krivickas and Krivickas, 2003). Since computers offer an exceptional support both for advanced and struggling students, the use of computer-assisted laboratories is in a great demand. Although a number of specific restrictions may limit students' independent use of computers, these restrictions are similar to other non-technology related educational constraints.

Time allocated for practical and lab classes affects the acquisition of instructional content. There are some laws that define the pace of learning and amount of information acquired by an individual. Apparently, in any practical class task it is possible to offer no more than five to seven new strategies conducive to the development of different concepts. In addition, the well-known psychological law called "*Miller's Law*" or "*7±2*" sets limitations for rapid understanding (Miller, 1956). The law states that, at most, seven simple facts can be acquired by an individual at a time. In order to store any new concept in memory, each individual must run across this concept several times.

During each encounter with a new concept, the quantity of information imprinted in one's memory can be represented by the value of I so that when $I = 0$, the initial information about the concept is absent. Let us assume, for the sake of argument, that when a concept is fully acquired by an individual, then $I = 1$. Let Q represent the amount of information that can be acquired. The larger the number of one's encounters with a concept to be acquired, the smaller is the contribution of each new encounter to the value of Q. In other words, any new idea, investigation, or data analysis are reduced in value in terms of their contribution to the novelty of information. First this problem was discussed in 1977 by two Russian scientists: N.M. Solomatin and V.A. Belyaev. Unfortunately, the book in which their results were published is a bibliographic rarity even in Russian. After this the same problem was studied in more detail in (Nikitina & Romanenko, 1992). In the English language it was repeated in (Abramovich, 2012 vol.2, part 6). Similar to these results one can write:

$$I = 1 - bQ \qquad (10.1)$$

where b represents the so-called threshold of semantic sensitivity. Formula (10.1) shows that I = 1 when b = 0 and I = 0 when b = 1/Q.

Another law related to recording of information by memory describes the rules of convolution of information and is commonly referred to as the Weber-Fechner law (Weber’s law, 2011). Consider the relation:

$$x = \ln Q \qquad (10.2)$$

where x denotes the level of information recorded by memory of an individual.

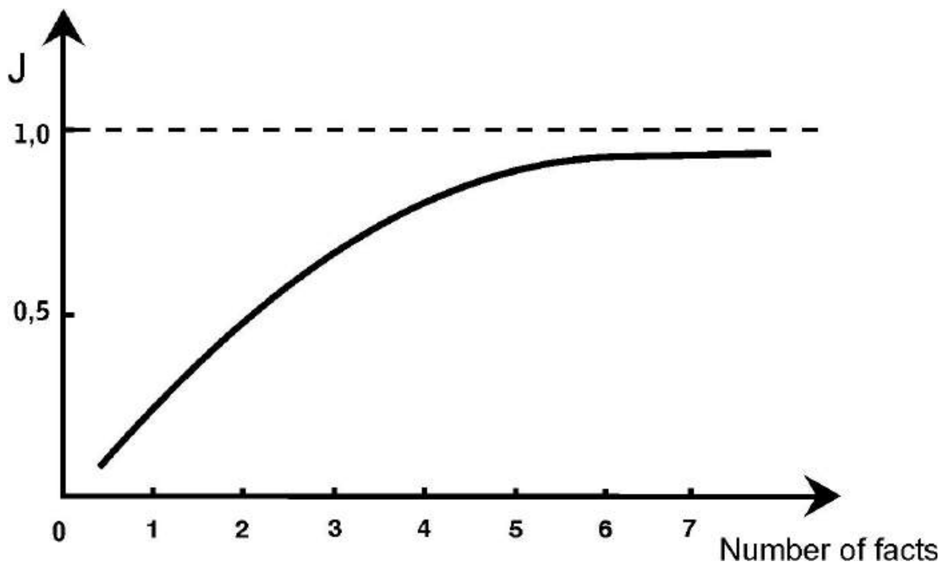

Fig. 19. How the amount of acquired information depends on the number of facts.

Applying graphical methods to relations (10.1) and (10.2) under the assumption $b = 1$, one can find that in order to achieve full comprehension of a new concept, the number of new facts related to this concept and recorded by memory should not be smaller than six. This means that an individual has to encounter a new concept in the practical settings not fewer than six times in a relatively short time span. In addition, one has to take into account that through a single assignment it is possible to introduce at most eight new concepts. Therefore, given time schedule for classes, this calculation yields the total number of teacher-guided assignments that can be introduced in the course of a semester. Also, it is necessary to take into account that some time must be reserved for students to do missed assignments and to fill other gaps in their course work.

Numerical evaluations given above are only fundamental laws for counting necessary time span for practical study of any subject. To create an effective schedule one needs to recollect that some time during the classes must be devoted to creating hidden KSAO's (Chapter 5). For estimation of the time to be spent one can assume that creation of hidden KSAO's takes one half of the class time. More difficult estimations are connected with the fact that several KSAO's are independently developed in various subjects. This cross-subjects studies are probably the most problematic part in the area of numerical estimations which are desirable for building a good schedule.

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