On the Role of Probabilistic Prognosis in Teaching

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Abstract. Successful learning is much dependent on memory and attention concentration processes. In this paper we introduce a method allowing to maintain high levels of learners' attention based on the concept of probabilistic prognosis. Practically, it is difficult to reach high levels of concentration. However, using the selective approach it is possible: when new material is covered, each student experiences attention climax at the most relevant moments and attention decay when irrelevant material is being explained.

This approach was called selective mobilization of attention and has been successfully used on physics lessons in two colleges is Jerusalem and in the Hebrew University junior high school. The method induces strong emotional response, elevated motivation and activity levels in students. Moreover, probabilistic prognosis has significant influence on memory processes, which has been demonstrated in our experiments.

Keywords: Science Teaching, Probabilistic Prognosis, Intuitive Knowledge, Selective Mobilization of Attention, Activity Level, Memorizing Unexpected Objects.

1 Introduction

High technologies development causes changes in requirements applied to future specialists in all areas, be it medicine, economy, transport, construction, art or education. These requirements include the lifelong need to acquire new knowledge and the ability to make non-standard decisions in unpredictable situations [1].

Traditional educational system has been developing for ages and it has undeniable achievements, however, it is unable to meet current fast-changing goals. How should professional training teaching methods change without damaging the valuable accomplishments of the traditional educational practice?

Note that improving the system and the teaching quality should not be limited to making changes in study programs, such as adding new material, eliminating some traditional questions, etc., as it is often assumed. In our opinion, it is most essential to change the role of students in the learning process: from passive learners to active creators of their own knowledge dedicated to an existing goal [2]. With this approach students not only acquire new knowledge, but also become more involved, more motivated, more self-critical, independently controlling and correcting their own learning process.

The purpose of this paper is to find ways to boost motivation and encourage the active role of the learner in the study process, based on consideration and effective utilization of the probabilistic prognosis. According to the conducted research, we have developed a teaching method, which emphasizes the important role of probabilistic prognosis in education and allows creating a specific method for boosting emotional and goal-oriented involvement of the learners into the effective study process. The current paper describes the application of the above method of selective mobilization of attention in science education on the example of physics and mathematics.

2 Probabilistic Prognosis

Selective mobilization of attention method principles lay at the crossroads between various psychological and educational approaches. The first approach is connected with the concept of probabilistic prognosis, developed by N. A. Bernstein [3,4] and I.M. Feigenberg [5,6,7]. The second approach was initially developed by Jean Piaget [8] and Lev Vygotsky [9].

They studied the process of scientific concepts formation and its interaction with everyday concepts. Throughout the last half-century there was a significant success in understanding of the learning process as a process of concept formation and change based on the ideas of constructivism [10,11]. It turns out that emotional influence on this process can enhance learning [12].

Although understanding memory as a passive information storage mechanism is outdated and people don’t usually admit having such point of view, however, they often use it implicitly. Phrases like “I explained this so many times, how come they still don’t remember it!” or “how can you forget such simple things, I explained them on the previous lesson!” are rather common.

Such understanding of memory not only pops out in everyday instruction routine, when teachers see the need to squeeze in a huge amount of information into the narrow timeframe of the lesson as their main goal, but also in study books and learning programs. Sometimes teachers presume that students' memory is like a video camera, and demand exact reproduction of their words.

According to Bernstein [3], throughout the evolution our memory has acquired the ability to create a model of a future situation, “image of the required future”.

The main source of the image of the future situation can be past experience, which probabilistic structure is stored in memory. It allows one to adjust himself to the approaching events and plan his actions, which is an essential advantage in critical life situations. This memory mechanism was named probabilistic prognosis in the works of I.M. Feigenberg and has been developed by his followers [5, 6].

3 Interaction between Everyday Intuitive and Analytical Scientific Concept

The second approach we used is connected to cognitive psychology. A student who starts learning a subject, such as sciences, already holds a developed system of intuitive understanding of the surrounding world. This conceptual system has different names in academic bibliography, such as: euristics or previous knowledge, intuitive naive knowledge, mental models, alternative conceptions, common-sense patters of reasoning [13,14,15,16].

This system is formed on the basis of the person’s participation in particular situations and his/her life experience. Sometimes the system of intuitive knowledge, basis of human common sense, conflicts with scientific concepts that constitute the logical foundation of scientific knowledge.

Let us analyze two related examples. Learners imagine the familiar concept of “shadow” of an object as a silhouette on a flat surface, which contour depends on the relative disposition of the object and the light source. However, from the point of view of physics, shadow is a part of a three-dimensional space where light penetration is difficult as the object is opaque, and therefore it either reflects or absorbs the light that falls on it. In this respect the concept of “night” is nothing but a shadow formed by the Earth when the Sun is the light source. Clearly, the naïve understanding of “night” associates with specific emotions which are very far from the scientific concept.

In this context it becomes clear that as long as students’ actual knowledge level tests are an inseparable part of the standard educational system, students can find themselves in a very complicated situation. Correct, but formal knowledge can constitute logically connected concept system, which doesn’t relate to the personal everyday experience of the students.

The students face the dilemma whether to learn the required “right concepts” for a test (and get high grades) or reply using their inner “common sense” (and sometimes get lower grades!). Common are situations when both knowledge systems coexist: one is used to answer the teacher’s questions and the other one in everyday life.

L.S. Vygotsky demonstrated the development of the above systems necessary for the learning process as movement of objects directed towards each other: abstract scientific concepts should be enriched with specific material from the new experience at the time of learning, while intuitive concepts should be analytically reconsidered, generalized and raised to the level of abstract scientific concepts [9]. Clearly, this complicated and continuous process demands active participation of both the students and the teacher.

Therefore, teaching approach, which ignores personal experience of the learners and is not capable to integrate scientific and everyday concepts into a complete system adequately describing the surrounding reality, cannot be efficient.

Therefore, the following questions arise: how can we initiate and control the above processes? What should we know in order to control the relevant cognitive processes? What learner’s memory mechanisms are supposed to be involved in this process? We believe that by considering probabilistic prognosis and the process of everyday and scientific concepts development, we can try to answer these questions.

4 Probabilistic Prognosis and Selective Mobilization of Attention Method

Is it acceptable to start a lesson with a quick test about the material which is about to be studied? It is usually considered that we cannot require a student to know anything about the material before it has been covered. We also came across an opinion that tests are to check the covered material; therefore the beginning of a lesson is a good time to give a test on the material from the previous lesson.

However, this unusual lesson hit-off is justified in the following situations:

1) lesson topic is familiar to the students from their previous experience;

2) questions are multiple-choice;

3) significant condition: suggested answers presented along with the correct answer represent common misconceptions of the students in the subject area;

From our experience, students don’t find these questions difficult, because the situations described in the questions are familiar to them. However, if the suggested topic is so unfamiliar to the students that they don’t have any prior knowledge about it, this kind of test does not make sense.

In order to create such test, teacher should collect information about intuitive knowledge of the students. Creative teachers can reach this information by independent observation of their own students or from literature [13], [15,16,17].

By conducting a quick (3-4 minute- long) test in the beginning of the lesson, we allow our students to formulate their intuitive knowledge based on probabilistic prognosis, which sometimes they are not even aware of.

Let us consider the example of an optical atmosphere phenomenon – appearance of a rainbow after rain on a sunny day. We suggest our students a test in the beginning of the lesson [18].

A

B

Here are two elements of a picture of a rainbow taken from the painting of a medieval artist. Which of the following pictures is correct?
Choose and mark:
A B

Discuss your answer with the other students and mark it down afterwards
A B

Prove your answer:
____

Which answer is right (that given by the teacher)
A B

Do you consider teacher's answer being logical or strange? _____________________
Why? _________________________
____

What feelings you experienced when the teacher gave the correct answer?
____

Fig. 1. Initial test according to the method of selective mobilization of attention.

Along with the correct picture B, the answer options contain the incorrect picture A, which represents a wrong intuitive image (Fig.1). This image contains both the rainbow and the Sun (which is the light source) within the field of view.

Along with the opportunity to express their intuitive mental models, students are given some time to discuss their answers with their neighbors and prove their point of view. All students are required to write down each other's opinions before and after the discussion (the test blank contains a special section for this purpose, see Fig.1). Usually, students' opinions vary and they become curious to find out which of them is right. From our experience, the right answer given by the teacher immediately after the test causes a very strong emotional reaction (part of such lessons was videotaped) [19, 20]. It is especially strong when there is a mismatch between the probabilistic prognosis of the student and the right answer. A student might experience disappointment and annoyance: "Why? What was my mistake? This is very strange". Students whose prognosis was correct cannot help but show their excitement: "I was right! I'm proud of myself".

We believe that this part of the lesson is a very significant step in the process of attention concentration, because since this very moment the audience turns from a group of indifferent and passive listeners, preoccupied with their personal issues, into active and interested participants. Each of the participants has his/her own focus: those whose probabilistic prognosis was correct are interested to compare their explanation with the scientific one. Those who made a wrong prognosis are interested in correcting the mistake and understanding the meaning of the task. According to the studies of the Nobel Prize winner D. Kahneman and his colleagues, "loss aversion" is a very strong emotion, much stronger than "pleasure of gain" [22]. Thus, attention concentration of each participant is different: if the information is relevant to the student, he/she will demonstrate high level of attention concentration, whereas if the student is satisfied with his correct prognosis, he can relax. Therefore, we call our method "selective mobilization of attention"

Since the moment the students turn into involved listeners, the teacher starts presenting the new material. In our example a lesson about rainbow formation is considered. On the lesson students get a detailed explanation of light beam refraction in a drop of rain, consistent with multiple physics textbooks [23].

At the end of the lesson we conduct a final test based on the new material. The test gives the students a new chance to apply their probabilistic prognosis, but this time integrating their new knowledge. The test is based on the same principle as the first one, but adjusted to the new material.

In the picture there is a man who looks at the rainbow.

Which of his shadows that shown in the pictures you believe to be right? Choose and mark:

4 3 2 1

Discuss your answer with the other students and mark it down afterwards:

4 3 2 1

Prove your answer: _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Which answer is the right (that given by the teacher)?

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Do you consider teacher's answer being logical or strange? _

Why? _

What feelings you experienced when the teacher gave the correct answer? _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

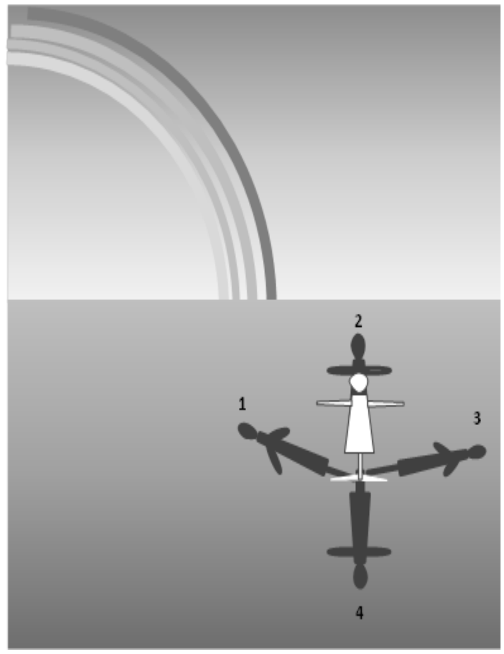

Fig. 2. Final test in the method of selective mobilization of attention

Obviously, the image used in the test allows deterring Sun location, considering the shadow direction of the object placed in front of the rainbow. Thus the teacher can check to what extent each of the students understands the geometrical basis of rainbow formation. It is interesting that this geometry aspect was first defined by Renee Descartes in 1637: the Sun must be situated behind the observer in such a way that the sunbeams reach the eye of the observer after their refraction and dispersion.

After answering the final test (which usually doesn't take more than 2-4 minutes), they announce the right answer. It causes strong emotional reaction of the students, especially those who understood their past mistake. They experience happiness, pride and self-satisfaction. When we wanted to skip the final test or postponed the announcement of the correct answers, the students demanded to give the test and were extremely interested to know the correct answers. As the feedback questionnaires showed, students' interest was due to their personal involvement in the lesson material. They found it important to check whether they understood it correctly.

To check the effectiveness of our method four groups of students aged 13-15 years were chosen. In two of them (N = 67) we used the method of selective mobilization (experimental groups), and in the other two (control groups) (N = 52) we conducted a regular lesson. All groups studied the same material - rainbow formation. Students in all groups were asked the same questions, namely those that appeared in the initial and final tests (Figure 1 and Figure 2). However, on the "traditional" lesson both tests were given after the explanation of the new material, and the correct answers were not revealed to the students. Thus, they were unable to juxtapose their probabilistic prognosis with the correct answers to the test questions.

In the groups that studied using the method of selective mobilization of attention, the amount of correct answers in the initial and in the final tests differed significantly: 42% versus 92%, respectively.

In the control groups that were taught using the "traditional" method, the initial test result was 47%, while the final test result was 67%. Students showed low involvement level during the lesson and didn't express strong emotional reactions at all.

To compare the effectiveness of lessons with and without the use of selective mobilization method, we can use the ratio between the difference between the successful answers in the initial and the final tests, and the amount of wrong answers to the initial test [24]

$$g = \frac{Nf - Ni}{No - Ni} \qquad (1)$$

Nf and Ni here stand for the number of correct answers in the final and the initial tests, whereas No is the total number of answers.

Thus, for the lesson with the application of the selective mobilization method (No = 67), we get the following:

$$g = \frac{Nf - Ni}{No - Ni} = \frac{92\% - 43\%}{100\% - 43\%} = 0.86 \qquad (2)$$

The same calculation for the control group (No = 52) results in the following:

$$g = \frac{Nf - Ni}{No - Ni} = \frac{67\% - 47\%}{100\% - 47\%} = 0.38, \qquad (3)$$

As it turns out, the lesson with the use of selective mobilization method is twice as effective as the "traditional" lesson.

Therefore, activation of the probabilistic prognosis in the framework of the selective mobilization method allows changing the role of the students, transforming them from passive and indifferent listeners into goal-oriented, emotionally involved participants, interested in the outcomes of their studies. As a result, the effectiveness of learning increases significantly.

We used the method of selective mobilization on the lessons of mathematics. Let us consider an example of an initial test used on a school algebra lesson dedicated to the rules of exponentiation.

A:

$$-1^{200} - (-1^{40}) - (-1)^{161} = -1 - -1 - -1 = -1 + 1 + 1 = 1$$

B:

$$-1^{200} - (-1^{40}) - (-1)^{161} = -200 + 40 + 161 = 1$$

C:

$$-1^{200} - (-1^{40}) - (-1)^{161} = -1^{200} - (+1) - (-1)^{161} = +1 - (+1) + 1 = +1 - 1 + 1 = 1$$

Three students received the following solutions one exercise in algebra. Which answer is correct? *Choose and mark***:**

A **B** **C**

Discuss your answer with the other students and *mark* it down afterwards: **A** **B** **C**

Which answer is the right (that given by the teacher)? _ _ _ _ _ _ _ _ _ _

Fig. 3. An example of an initial test given on a lesson of algebra, dedicated to the rules of exponentiation, which allows using probabilistic prognosis.

Different possible answer options in this test were formulated based on the previously revealed misconceptions of the students in the particular field of algebra.

In all the three options the answer is “1”, but the calculations are different.

The right “path” to the answer is shown in option A along with the erroneous intuitive answers B and C. Exponentiation is sometimes mistakenly interpreted by the students as multiplication of the base by the exponent as represented in option B. Answer C is the result of an incorrect use of the rules of a negative number exponentiation given an even or odd exponent value. Therefore, if a teacher ignores the way the students think, and is only interested in the final result ("right" or "wrong"), then he/she will not notice, and accordingly, won’t be able to help them correct their misconceptions B and C.

This test, used as a part of the selective mobilization method, allows a student to identify his/her own primary misconceptions that constitute a basis for probabilistic prognosis. Thanks to this, students are on the peak of their concentration specifically in the moments of the lesson which are essential for the understanding and correlation of the identified misconceptions.

5 Probabilistic Prognosis, Emotions and Memory.

So how does the discrepancy between the probabilistic prognosis and the real incoming information influence the memorizing of that particular information? To answer this question we carried out special tests.

In one series of tests with participation of school students (N=86), the memorizing of pictures was studied [20, 21], [25]. The pupils were shown a sheet of paper with 14-19 simple and clear pictures on it for a short period of time (10-15 seconds). After the sheets were taken away, the pupils had to name the pictures they remembered. There were three different versions of the pictures:

1. On the first sheet there were 18 pictures. On 17 of them animals were shown (a goat and a goose were among them) and the odd one was a motorcyclist.

2. On the second sheet there were 14 pictures; 13 represented sportsmen (among them was a motorcyclist) and on the odd one was a goat.

3. The third sheet had 19 pictures; 18 of them represented vegetables whereas one of them – a goose.

Thus, on every sheet there was one odd, “unexpected” picture, which did not match the rest of the pictures on the sheet.

The results of the test were very impressive: the “unexpected” pictures were much better memorized than the “ordinary” ones. We can see this clearly on the following diagrams (Fig. 4).

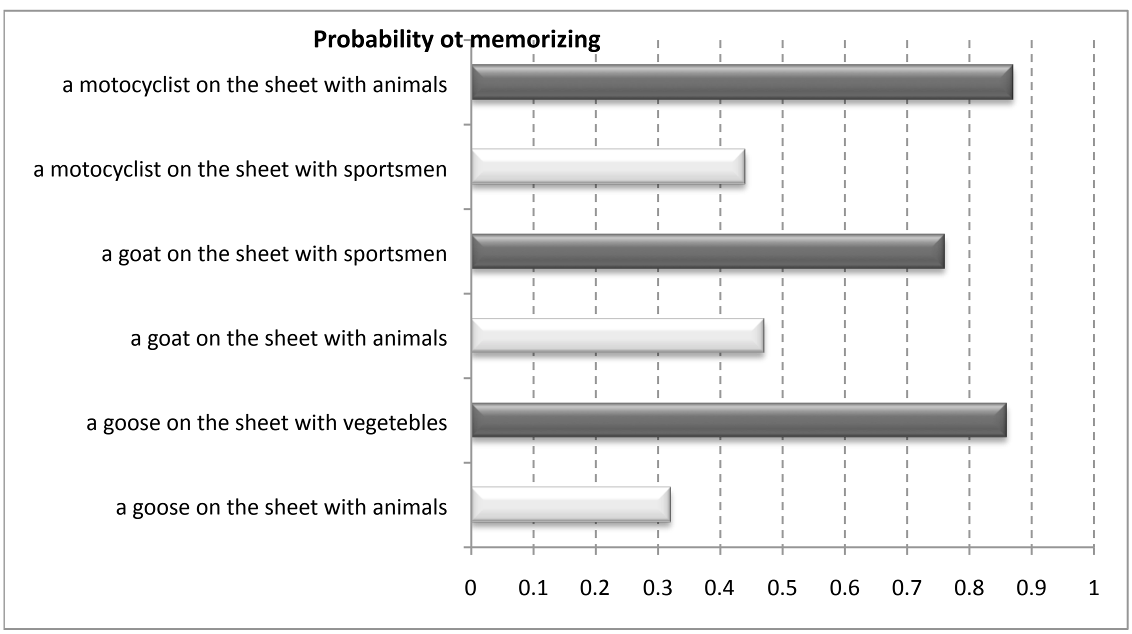

Fig.4. Memorization of unexpected objects is more efficient.

The motorcyclist on the sheet with animals was memorized almost three times as often as on the sheet with sportsmen.

The goose on the sheet with vegetables was memorized almost twice more often than the goose on the sheet with animals.

The same result was achieved in our verbal tests with memorizing words that were read to the pupils: thus, unexpected stimuli that do not match our probabilistic prognosis are memorized much better.

How can we create by the pupil the incompatibility between his probabilistic prognosis and the important information which we want him to remember?

In some cases it is useful to take some material from the history of science [26, 27].

As an example we will describe a lesson where the notion about the dual nature of light (the corpuscular and the wave theories) is given. In order to make the lesson more emotional we can structure it like a detective story [20], [25].

At the beginning the teacher tells about Newton's corpuscular theory. According to this theory, the light is a stream of particles moving with different velocity which depends from the medium in which they are moving. This theory explains very well the rectilinear propagation of light in a homogeneous medium, the reflection of light from mirrors, the refraction of light passing from one medium to another one, where the velocity of the light propagation is different (for instance, from air to water or to glass). When the pupils will have a clear conception about the geometrical optics, they will understand the following explanation without difficulties.

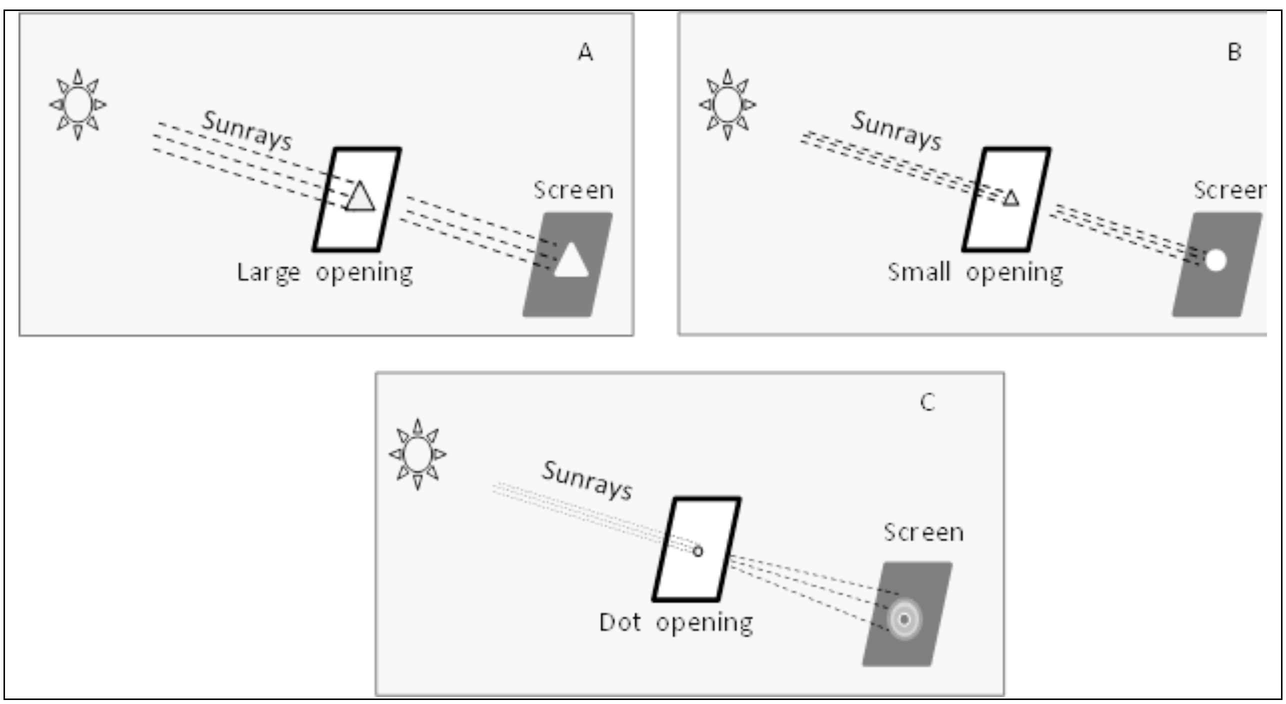

Fig. 5. Experiments with light passing through openings of variable sizes. Unexpected result in 3-d experiment raises the students' attention during explanation of the light's wave nature.

The sunlight goes through a big triangular opening in a non-transparent plate. The light spot which appears on the screen has also a triangular shape (Fig.5A).

If the sunbeam comes through a small triangular opening, the light spot on the screen will not have a triangular shape but a round one. The shape of this spot will coincide not with the shape of the opening but with the shape of the light source (Fig.5B).

If we will make the opening small enough, we will receive the camera obscura. On the screen we will see the inverted image of the light source; the shape of the hole on the plate will have no influence on the shape of the light spot.

Now, on the basis of knowledge formed by the pupils, the teacher asks: “What do you think, what will happen, if we make the hole in the plate even smaller?” The pupils will utter their suggestions and guesses.

The teacher shows them the results of the experiment when the sunbeam passes through a very small hole (Fig.5C). The shape of the light spot on the screen coincides neither with the shape of the opening, nor with the shape of the light source. The result does not coincide with the expectations of the pupils too. On the screen are appearing concentric circles – a fact which is completely unexpected by the pupils and does not fit into their former knowledge about the nature of light. What is the reason for that?

The discrepancy between the real results of the experiment and the prognosis of the pupils receives emotional significance, it heightens their attention and interest to the further explanations by the teacher. Against the background of the question which arises in this situation and the heightened attention and motivation of the pupils, the teacher begins his explanation about the wave hypothesis of light. And the rectilinear propagation of light, the reflection of light from mirrors and refraction of light receive another interpretation; the phenomena which could not be explained by the corpuscular theory of light (for instance, the interference of light) become clear.

As you see, we applied here the same psychological method which is used in detective stories – the discrepancy between the most probable prognosis of the reader (or listener) and the information received by him. And it is done not by distraction from the scientific content of the lesson but, on the contrary, on the basis of the material of this lesson.

The comparison with a detective story does not at all belittle the pedagogical principles. The Latin “detego” means “to open”, “to expose”, “to discover”. And just the same must happen before the audience of pupils. We have to discover, to open, to expose to them the nature of certain phenomena, of a certain process, the nature, which is concealed in the every-day life from a superficial view and is revealed only through scientific research or experiment. And it will be the best when the teacher will conduct the lesson in such a way that the pupil will have the impression that he himself has “discovered” the truth before the teacher explained it to him. The pupil must make discoveries by himself! And the history of science – used properly – is a powerful tool in the hands of the teacher in achieving this goal.

If we, on the contrary, will give to the pupil an answer before the question will arise in his mind – that will be not effective from the pedagogical point of view.

6 Conclusion

In literature dedicated to effective methods of physics teaching there are sometimes examples of lesson plans requiring that students give a prognosis, for instance, before a demonstrational experiment [28]. In the article [28] it was proved that it causes interest level increase in the students. We are convinced that this increase can be explained by the involvement of the probabilistic prognosis mechanism. In case of a dissonance (the demonstration itself provides the right answer), the motivation of the students sharply increased, and consequently the lesson was more effective.

Misconceptions, sometimes unconscious, based on personal experience allow the students to make fast decisions in cases of uncertainty [15, 27, 29].

A teacher that knows what intuitive and sometimes erroneous perceptions are behind students' decisions can transform passive students into active and co-involved participants. In some cases it is useful to take some material from the history of science.

The method of selective mobilization based on probabilistic prognosis was created exactly for that purpose. Probabilistic prognosis helps students identify their intuitive perceptions in the beginning of the lesson, even before the new material is explained. It changes the role of the student during the lesson. In case of dissonance between the prognosis and the right answer, students experience a strong emotional reaction and selectively mobilize their attention when the important material, specifically relevant to them, is explained. Behavior of the students becomes goal-oriented and their desire to adjust their perceptions makes them active creators of their own knowledge. At the same time, the strong emotional reaction contributes significantly to the memorization level.

Thus, probabilistic prognosis has been proved to play a significant role both in developing the selective mobilization method, improving the memorization level, and, consequently, in raising the learning effectiveness on our lessons of physics and mathematics.

References

1. Feigenberg, J. M., Lavrik L. V.: Immediate and Long-term Goals of the Teacher's Work. Educational Policies, Moscow, 2(52), 106-110 (2011) [In Russian]
2. Feigenberg, J.M., Lavrik, L.V.: School Teacher and Society, http://elektron2000.com/feigen_lavrik_0252.html
3. Bernstein, N. A.: The co-ordination and regulation of movements. Pergamon Press, Oxford (1967).
4. Bernstein, N. A.: From reflexes to the model of the future. Motor Control, 3,3, 228-236 (1999).
5. Feigenberg J.M.: The Model of the Future in Motor Control. In: Progress in Motor Control, vol.1. Bernsteins Traditions in Movement Studies. M. Latash (ed.), pp. 89-103. Human Kinetics (1998).
6. Feigenberg, J. M.: Wahrscheinlichkeitsprognostizierungim sian].
   System der zielgerichteten Aktivität.: AFRA Verlag, Butzbach-Griedel (2000).
7. Feigenberg, J. M.: Probabilistic prognosis and its significance in normal and pathological subjects. In: A handbook of contemporary soviet psychology. Cole M., Maltzman, J. (eds.), pp.354-369. Basic Books Inc., New York - London (1969).
8. Inhelder, B., Piaget J.: The Growth of Logical Thinking from Childhood to adolescence. Routledge and Kegan Paul, London (1958).
9. Vygotsky, L.S.: Thought and Language. MA, MIT Press, Cambridge (1934/1986).Posner, G. J., Strike, K. A.,
10. Posner, G. J., Strike, K. A., Hewson, P. W., Gertzog, W. A. Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. Science Education, 66(2), 211-227 (1982).
11. Duit, R., Treagust, D. F.: Students' Conceptions and Constructivist Teaching Approaches. In : Improving science education. Fraser, B. J., Walberg, H.J. (eds.). The National Society for the Study of Education, Chicago (1995).
12. Pintrich, P. R., Marx, R.W., Boyle, R. A.: Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change. Review of Educational Research, Summer; vol. 63, 2: pp. 167-199 (1993).
13. Driver, R., Guesne, E., Tiberghien, A. (eds.): Children's Ideas in Science, Milton Keynes, UK, Open University Press. Fellows, N. J. (1994).
14. diSessa, A. A.: Phenomenology and the Evolution of Intuition. In: Mental Models. Gentner, D., Stevens, A. L. (eds.) pp. 15-33. Hillsdale, Lawrence Erlbaum, NJ (1983).
15. Fishbein, E.: Intuition in Science and Mathematics: an Educational Approach. Reidel, Dordrecht, (1987).
16. Arons A.: A Guide to Introductory Physics Teaching. Willey, New York (1990).
17. Feigenberg, J. M., Lavrik, L. V., Shunyakov, V.: Space Scale: Models in the History of Science and Students' Mental Models. Science and Education, 11(4), 377-392 (2002).

18. Lavrik, L. V., Feigenberg, J. M., Shunyakov, V. M.: The Method of Selective Mobilization of Attention and Motivation in Science Teaching. In: Modelling in Physics and Physics Education Preceeding GIREP conference, pp. 986 -1004. Amsterdam (2006).
19. Lavrik, V. L., Feigenberg, J.: Teaching Physics Using Selective Mobilization. In: 9th European Conference of European Association for Research on Learning and Instruction, Biennial Meeting, Switzerland, Freiburg (2001).
20. Lavrik, V., Feigenberg, J.: Increasing Motivation in Learning Physics. In: 7th Workshop in Achievement and Task Motivation, International Conference on Motivation, Leuven (2000).
21. Lavrik, V. L., Feigenberg, J.: Learning and Teaching Environments: Stimulating Students Emotional Level Using Selective Attention' Mobilization. In: Proceeding of the Fourth International Conference on Teacher Education, pp.357-367, Tel Aviv (2002).
22. Kahneman, D., Tversky, A.: Prospect Theory: An Analysis of Decisions under Risk. Econometrica, 47, 263–291 (1979).
23. Hewitt, P. J.: Conceptual Physics (9th Edition) Pearson Education, Inc., Addison Wesley (2004).
24. Hake R.R., Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. American Journal of Physics, 66(1), 64-67(1998).
25. Feigenberg, J. M., Lavrik, V. L.: Probabilistic Prognosis and Memory in Learning Activity. Psychology World, 1(25), 174-181 (2001) [In Russian].
26. Matthews, M. R.: Science Teaching. The Role of History and Philosophy of Science. Rouledge, New York (1994).
27. Monk, M., Osborn, J.: Placing the History and Philosophy of Science on the Curriculum: a Model for the Development of Pedagogy. Science Education, 81, 405-424 (1997).
28. Sokolov D.R., Thornton R.K.: Using Interactive Lecture Demonstrations to Create an Active learning Environment. The Physics Teacher, 35, 108-119 (1987).
29. Tversky, A., Kahneman, D.: On the Study of Statistical Intuitions. In: Judgment under Uncertainty: Heuristics and Biases. Kahneman, D., Slovic, P., Tversky, A. (eds.). pp. 493-508, Cambridge University Press, Cambridge, New York (1982).