LEARNING THROUGH PROBLEM SET DEVELOPMENT BY FUTURE TEACHERS

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Abstract

The paper presents the method for the development of educational physical problem sets on an analysis of the physical situation. It cites the development of educational physical problem sets for the stretching of ponderable and imponderable springs as an example. It cites examples of the development of educational biological problem sets too.

Keywords: problem-based training, problem sets, problem design, problem set design, teacher training.

1. INTRODUCTION

The system of science teachers training adapted in Russian universities consists of theoretical education during lectures, problem solving and hands-on training during the practical training classes (seminars), and experimental training in laboratory settings. This system provides the students with the opportunity to study their future subject from three different angles during a single semester, resulting in a solid subject training for the future teachers. The problem solving allot a significant portion of time: at least two hours of classes per week, and up to 4-6 hours including the students' at-home studying. Standard problem books are employed and supplemented with problem solving guidebooks, the latter including both sample problem solutions and exercises. The problems solve by the students both individually during the classes and at home, with an occasional e-mail assistance from the teacher as needed.

Our multiyear experience of Physics and Biology teachers training suggests that the students benefit the most from problem solving if the problems offer for the solution not in an arbitrary order, but in a carefully designed sequence within a pre-developed problem set (Belyanin, 2014, 2011). A good problem set includes a variety of problems of different types unified by a common theme. The design of a problem set takes advantage of modern teaching methods and educational process management.
Our recent survey study indicated a clear interest of the teachers and the students alike to adapting pre-designed problem sets in the study process (Belyanin, 2013). Solving problems that are related to each other keeps the students interest and more involved, while at the same time lowering the overall difficulty level of the solution process. However, no textbooks based on pre-designed problem sets suitable for the future teachers training have not been published to date, and neither have the corresponding study guides been developed.

2. MATERIALS AND METHODS

We further propose to expand the subject training of future science teachers from solving pre-designed problems and problem sets offered by the teacher to designing of both individual problems and problem sets by the students themselves. We have developed the theory of the students' learning through problem set design and implemented the theory in practical educational process. We propose to base the educational problem design for each specific subject on a putative situation pre-determined for each subject. A variety of possible problem-generating situations can be identified for pretty much any subject: Mathematics, Chemistry, Physics, Biology, etc. For example, a problem set-generating situation in Physics could be defined as a pre-determined space-time interval for the existence of a physical body or a physical phenomenon.

Understanding the physical situation as an element of objective reality provides us with a baseline for defining such notions as the "Physical Problem", "Solution of a Physical Problem", "Development of Physical Problems", and developing the method for the design and solution of educational problem sets. A typical design of a physical problem understood as a design of a solvable problem that cannot be found in existing textbooks or the modification of the known problem based on modifying the underlying physical situation. In the latter case, the new problem design might result in certain modifications of the problem solution procedure.

3. RESULTS

Our manuscript showcases specific examples of problem set designs for Physics and Biology, accomplished by students under their teachers' guidance. The unifying theme of the problem set was the calculation of the elastic forces resulting from a spring deformation. The spring represents a physical body whereas the elastic forces represent a physical phenomenon. The physical law guiding such a situation is the law of proportionality between the stretching force and the spring extension. Every new problem in the set is formulated through introducing a new factor affecting the principal object of the problem: the spring. Two problem sets were developed for massless springs and springs of a nonzero finite mass.

Series and parallel connection of imponderable springs
Problem 1. Imponderable spring of length l, hanging vertically at one end, stretched under load m kg x m. Evaluate the rigidity of the spring.
Problem 2. Two identical imponderable springs length l each with coefficient of rigidity kconnected in parallel. Evaluate the rigidity of the resulting system of springs.
Problem 3. Two identical imponderable springs length l each with coefficient of rigidity kconnected in series. Evaluate the rigidity of the resulting system of springs.
Problem 4. Two imponderable springs the same length l each with rigidity k1 and k2 connected to each other in parallel. Evaluate the rigidity of the resulting system of springs.
Problem 5. Two imponderable springs the same length l each with rigidity k1 and k2 connected to each other in series. Evaluate the rigidity of the resulting system of springs.
Problem 6. An imponderable spring of length lis cut into two equal pieces. Evaluate the rigidity of each of the springs.
Problem 7. An imponderable spring of length lis cut into two parts in the ratio 1:4. Evaluate the rigidity of each of the springs.
Problem 8. An imponderable spring of length lis cut into n equal parts. Evaluate the resulting rigidity ofthe nth part of the spring.

Problem 9. An imponderable spring of length l arranged horizontally and fixed it ends. Evaluate the rigidity of the spring in a horizontal direction relative to its centre.
Problem 10. An imponderable spring length l arranged horizontally and fixed its ends. Evaluate the rigidity of the spring in a horizontal direction relatively to a point at a distance l/n from the end of spring. The n is an integer.

The tencile elongation of the ponderable springs
Problem 1. Spring mass m, the length l and rigidity k is suspended vertically at one end. Evaluate the elongation of the spring under its own weight.
Problem 2. Spring mass m, the length l and rigidity k placed vertically at the bottom end. Evaluate compression of spring length under its own weight.
Problem 3. Spring mass m, the length l and rigidity k is suspended vertically at one end. To the lower end attached a load mass M. Evaluate the elongation of the spring.
Problem 4. Two identical springs mass m, the length l and rigidity k each connected in parallel and suspended vertically at the upper ends. To the lower end of this system of springs attached a load mass M. Evaluate the elongation of the springs.
Problem 5. Two springs the same mass mand length l having rigidities k1 and k2 connected in parallel and suspended vertically at one end. To the lower end of this system is attached load mass M. Evaluate the elongation of the springs.
Problem 6. Two springs of the same length l masses m1 and m2, with rigidities k1 and k2 connected in parallel and suspended vertically at the top end. To the lower end of this system is attached load mass M. Evaluate the elongation of the springs.
Problem 7. Two identical springs the same mass m, length l and rigidity k each connected in series and suspended vertically at one end. Evaluate the total elongation of the springs.
Problem 8. Two identical springs the same mass m, length l and rigidity k each connected in series and suspended vertically at one end. To the lower end of this system of springs attached load massM. Evaluate the elongation of the resulting springs system.
Problem 9. Two springs of the same length l with the masses m1 and m2, with the rigidities k1 and k2 respectively, connected in series and are suspended vertically at one end. To the lower end of this system of springs attached load of mass M. Evaluate the elongation of the system of the springs.
Problem 10. A spring mass m, the length l and rigidity kis suspended vertically from one end. At the distance y = 0.25l from the top end to the spring attached load mass M. Evaluate the total elongation of the spring.

Systems of biology problems
As an example, consider the sequence of steps of student when evaluating of systems of biology problems. This system of problems allows you to track what happens to a protein molecule according to different genetic manipulation occurring in a molecule of DNA. Each new problem appears in the system due to additional impact to the object-DNA molecule.
Problem 1. The sequence of nucleotides in the DNA chain: GTTCGTAAGCATGGGCT. Evaluate the amino acid sequence on it in polypeptide.
Problem 2. The sequence of nucleotides in the DNA chain: GTTCGTAAGCATGGGCT. As a mutation result, at the same time fall second and sixth nucleotides. Record a new sequence of nucleotides in the DNA chain. Evaluate the amino acid sequence on it in polypeptide.
Problem 3. The sequence of nucleotides in the DNA chain: GTTCGTAAGCATGGGCT. As a mutation result, the purine bases changed into other purine bases. Record a new sequence of nucleotides in the DNA chain. Evaluate the amino acid sequence on it in polypeptide.
Problem 4. The sequence of nucleotides in the DNA chain: GTTCGTAAGCATGGGCT. As a mutation result, the pyrimidine bases changed on the other pyrimidine bases. Record a new sequence of nucleotides in the DNA chain. Evaluate the amino acid sequence on it in polypeptide.
Problem 5. The sequence of nucleotides in the DNA chain: GTTCGTAAGCATGGGCT. As a mutation result, all the pyrimidine bases changed on the purine bases. Record a new sequence of nucleotides in the DNA chain. Evaluate the amino acid sequence on it in polypeptide.

An example of a developed problems system by students on the theme "Gametogenesis".
Problem 1. Diploid cell contains three pairs of homologous chromosomes. During meiotic division two homologous chromosomes differ each other to different poles independently of the differences of other homologous chromosomes each other. How many different combinations of non-homologous each other chromosomes may form in gametes resulting meiosis of this diploid cells?

Problem 2. Diploid cell of one organism contains six chromosomes, three from those he got from his father, and three from the mother. Can his normal developing gametes contain only paternal chromosomes and why?
Problem 3. Diploid cell of one organism contains six chromosomes, three from those he got from his father, and three from the mother. Can his normal developing gametes contain two paternal and one maternal chromosomes and why?
Problem 4. . Diploid cell of one organism contains six chromosomes, three from those he got from his father, and three from the mother. Can his normal developing gametes contain two paternal and two maternal chromosomes and why?
Problem 5. Diploid cell of one organism contains six chromosomes, three from those he got from his father, and three from the mother. Can his normal developing gametes contain three paternal chromosomes, each of which will be have sections of maternal chromosomes instead of the homologous to them sections of paternal chromosomes, and why?

4. DISCUSSIONS

The general plan of an educational activity based on the development of a problem set devoted to a certain physical situation is the following.
Adoption, solution, and the solution analysis for the first problem in the set. The first problem may be invented by the student, or borrowed from a textbook.
Determination of the principal physical object described by the problem.
Formulation of a hypothesis about possible factors affecting the object, with the purpose of evolving the initial physical situation for the new problems in the set.
Introducing the first additional factor into the first (initial) problem, formulation of the second (modified) problem.
Solving the second problem, correcting the problem setting, if necessary.
Investigation of the second problem solution in general and specific cases. Determination of the dependence of the problem answer on the situational conditions specified in the problem, as well as those conditions' possible variations.
Introducing the second additional factor into the second (modified) problem, resulting in the third (further modified) problem.
Repeating steps 6-8 for problems 3-10 of the set.
Reflection: analysis of the problem design and solution process, analysis of the expanded mental picture of the physical situation compared to that existing for the initial problem. Searching for new physical situations on which the subsequent educational problem sets will be based.

5. CONCLUSION

Accomplished by authors investigations points to enough high effectivities to use the method of learning through problem set development by future teachersas an addition to solving of usual problems from a course of physics. The method of problem set development based on understanding of generalized physical situation creating by student as broadened interpreting of picking out by him physical situation.Physical situation you should understand some the element of a physical system, space-time interval of the existence of the selected by student physical object. Physical object occupies within the selected subject area of its existence the primary role, brings together in a coherent whole physical phenomenon, characterize his physical quantities, physical model of the object as well as reflecting the reporting physical phenomena physical laws. Modifying the physical situation, summarizing its teacher and student are able to develop new problems, changing the condition of the physical object existence in the physical situation.
Learning through the development and analysis of problem sets provides future teachers with a more active and engaging learning process both in class and at home, and leads to an increased creative interaction between the student and the teacher during the subject training.

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