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Developing Students' Graphic Skills In Physics Education At Secondary School

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Abstract: *The research focus isthe graphic skills of students in physics education at secondary school. They arekey skills for success in college, careers and daily life in general. The graphic skills are essential skills that students need to learn and develop by solving graphical problems and conducting physical experiments involving both construction and interpretation of graphics.The aim of the research is to develop a methodology for implementation of the graphical method in solving physical problems. Our experience for classification of graphical problems is presented. A methodology for solving the basic graphical problems in teaching physics is developed. It involves constructing a physical graphics based on experimental results and on formula, determining a physical quantity by the area below a graph, retrieving information from agraphic, verbal description and explanation of the physical process, physical phenomenon, movement, etc., determining the formula corresponding to a graphically represented relation, transformation of graphics from one coordinate system to another. The proposed methodology for solving graphical problems can be applied in the study of all physical sections in secondary school. It is extremely useful for both the teacher and the students.*

Keywords: *graphical method, graphic skills, methodology, physical problems, physics education*

I. Introduction

The problem for graphic literacy of students is current. Graphs are very important types of representations in mathematics and science and they are seen as different kind of communication tools and a source for student learning of science. The graphical knowledge and skills are needed in the perception of information and in its presentation. Developing of graphical skills is essential for the success in school education, higher education, and also in further professional activity.

The graphical skills are universal educational skills. They are a part of the key competencies because they are applied in extracurricular life.

Graphic skills are formed especially effectively in teaching mathematics and physics. Graphs are initially introduced in mathematics and later on in physics. The students' graphic skills develop and improve through training in physics. They learn about and work with new graphical models – physical graphics, thermodynamic diagrams, diagrams of circuits, field lines, vector diagrams, energy diagrams and others.

Christopher Deacon notes the importance of graphs in undergraduate physics [1]. He emphasizes that the ability to plot and meaningfully interpret a graph is an essential skill that physics students should learn first using pencil and paper, and then develop through many experiments that involve plotting a graph of one form or another.

The fact that many students at secondary school, or even university level, miss the ability to understand and interpret graphs in physics is not new. It has been investigated in several physics education studies[2],[3]. [4],[5],[6],[7],[8].

The graphic skills of high school students were investigated in a studyBrassel&Rowe[6], which found that at least one fifth of the students did not have adequate graphical skills. Students had difficulties with linking the graph and the verbal descriptions of a given event and they did not understand graphs as means of representing relationships between variables.

Graphic skills also develop in solving graphical problems. They realize the greatest visibility of various processes, phenomena and movements. The graph shows the specificity of the process. It makes thephysical phenomenon understandable and makes it possible to obtain or explain a response of the problem[9],[10].

The graphical method and its possibilities are not used enough in secondary school. A common methodology for solving graphical problems is not developed. It is not explained to students by concrete examples how to plot and analyze graphics.

According to us graphic skills are essential skills that students need to learn and develop by solving graphic problems and conducting physical experiments involving both construction and interpretation of graphs.The research focus is students' graphic skills in physics education at secondary school- high school level. The skills to plot and analysis of graphics are accented.

The aim of the research is to develop a methodology for the implementation of the graphical method in solving physical problems.

II. Methodology for implementation of the graphical method in solving physical problems

2.1 Methodology for solving problems to plot a physical graphics based on experimental results

1. Drawing a rectangular coordinate system.
2. Labeling of physical quantities at the end of the coordinate axes: the independent variable on the x-axis,the dependent variable on the y-axis.
3. Marking of the interval of change of the physical quantities on each of the axes. It is not necessary to start the scale at zero. For example, if the interval of change of the volume is 40 liters to 50 liters, the volume scale should begin at 40 liters.
4. The graph represents only the experimentally studied region and it should take about 75 percent of the drawing area.
5. Choosing of an appropriate scale for the quantities on the coordinate axes. The scale is chosen in two ways: the length of the axis corresponding to a unit of physical quantity (for example 1cal = 2 mm), or the value of the physical quantity corresponding to a unit of length (for example 1 mm = 5V). The scales on the axes are chosen independently of one another.
6. Application of scales along the axes in the form of equidistant numbers, such as 2, 4, 6, 8... or 1.82; 1.84; 1.86, etc. The choice of numbers and their density should provide the greatest simplicity in application and reading out the scales. In the case of a decimal multiplier, it is indicatedwith the unit of measurement, for example instead of 1000; 2000; 3000… it should be written1; 2; 3… with a common multiplier 10^3.
7. For each two values of the independent and dependent variables perpendiculars are drawn from their respective values until they intersect. These intersections are points from the graph of the functional relation.
8. Joining of the points. The larger the number of these points, the more precise the graph is.
9. Completion of work. The graph is given a name that reflects the contents of the functional dependence. All graphical symbols used in the construction of the graph are annotated(placed beneath it).

2.2 Methodology for solving problems to plot a physical graphics based on a formula

1.Determining the independent and dependent variables in the formula.
2. Setting values of the independent variable and determining the values of the dependent variable from the formula.
3. Putting of the values of point 2 in a table.
4. Drawing a rectangular coordinate system.
5. Labeling of physical quantities at the end of the coordinate axes: the independent variable on the x-axis, the dependent variable on the y-axis.
6. Choosing of an appropriate scale for quantities on the coordinate axes.
7. For each two values of the independent and dependent variables perpendiculars are drawn from their respective values until they intersect.
8. Joining of the points.

2.3 Methodology for solving problems to determine a physical quantity by the area below the graphicsfor linear dependence

1. The physical meaning of the area bounded by a line graph, the x- axis and the ordinates of the endpoints is revealed.
2. The type of the figure (rectangle, triangle, trapezoid) is determined.
3. The placement of the figure (under or over the x-axis) is determined.
4. The formula for the area of the figure is determined.
5. The area of the figure is calculated.
6. The numerical value of the quantity is equal to the area. In determining the sign of the quantity the placement of the figure is taken into account.
7. Correct presentation of the units of measurement.

2.4Methodology for solving problems to determine the physical quantity by the area below the graphics for non-linear dependence

1. The piece of the x-axis between the endpoints of the line is partitioned intoa number of equal parts. The more they are, the more accurate the result is.
2. Straight lines, parallel to the y-axis are drawn through the points of section, crossing the curve and splitting it into parts.
3. Segments parallel to the x-axis that form figures with equal areas are drawn in each part of the curve.
4. The heights of the resulting rectangles are summed up and the resulted sum is multiplied by the length of one part of the section of the x-axis.

5. The resulting product is equal to the area of the figure.

If the graph is drawn on graph paper, the algorithm is:
1. The area between the line of the graph and the coordinate axis must include several hundred cells.
2. The number of the cells is determined.
3. The area of each cell is calculated.
4. The area of the cell is multiplied by the number of cells.
5. The resulting product is equal to the area of the figure.

2.5 Methodology for solving problems for retrieving information from a graphic
1. The relationship between which physical quantities is represented graphically is determined.
2. The units used for the values of the physical quantities are determined.
3. The intervals of change for the dependent and independent physical quantity are determined.
4. Determine the scale of physical quantities on the coordinate axes.
5. The initial andfinal points of the line on the graph are determined by drawing perpendiculars to the coordinate axes.
6. The form of the line on the graph is determined. If the line is broken perpendiculars are drawn from the ends of each section to the axes.
7. Quantitative analysis is performed of the characteristics of the physical process, physicalphenomenon, movement, etc.

2.6 Methodology for solving problems for verbal description and explanation of a physical process, physical phenomenon, movement, etc.
1. The physical quantities marked on the coordinate axes and their units are determined.
2. The part of the graph which represents the corresponding physical process, movement, etc. is determined.
3. The type of process, movement, etc. is determined.
4. The way of change of physical quantities in various parts of the graph (increase, decrease, remain constant) is determined.

2.7 Methodology for solving problems to determine the formula corresponding to a graphically presentedrelation
1. The physical quantities marked on the coordinate axes and their units are determined.
2. The part of the graph which represents the corresponding physical process, movement, etc. is determined.
3. The type of process, movement, etc. is determined.
4. The type of the functional dependence is determined base on the type of graph.
5. Specific numerical values of physical quantities are determined.
6. Based on the law for the process (movement) in general form and the determined numerical values the formula of the functional dependence is written down.

2.8 Methodology for solving problems totransform graphics from one coordinate system to another
1. The parameters characterizing the initial state and their values are determined from a given graph and the values are transferred to the other axes.
2. The initial state is represented in the other coordinate system.
3. The type of the graphically represented process is determined, for example by a line 1–2.
4. The process 1–2 is analyzed (the way the quantities that characterize it change is determined).
5. The graph of this process in the other coordinates is drawn and its direction is determined.
6. Point 2 corresponding to the other state is determined.
7. The process represented graphically by line 2–3 is analyzed etc.

According to us solving graphical problems will aid the formation of skills to interpret physical graphs if it is donesystematically and follow a common approach to work by both the teacher and the students. Before teaching the section in which graphical problems will be solved the teachermust do the following: (1) Analysis of the educational content and the possibilities for solving graphical problems; (2) Determining typical graphical problems and developing algorithms to solve them; (3) Determining the minimum mathematical and physical knowledge and skills needed to successfully implement the algorithms; (4) Developing a system of graphical problems to check the initial level of the students; (5) Selecting an optimal system of graphical problems, ensuring the achievement of the purposes; (6) Developing a system of graphical tasks to check the final level of the students.

III. Conclusion

The implementation of the graphical method in solving physical problems is a complex, purposeful didactic process. The objectives of this process are:

- ✓ perception, awareness and understanding of knowledge of physical quantities, laws, processes and phenomena by students;
- ✓ formation and development of the graphical skills of students;
- ✓ formation of generalized knowledge of graphical method for solving physical problems;
- ✓ increasing the level of students' graphic literacy;
- ✓ formationof graphic culture.

The graphical method for solving physical problems is visual, accessible and informative. Graphical problems are an original didactic tool in the work of the teacher for developing students' graphical skills. Solving problems of plotting and interpretation of physics graphs implies knowledge in mathematics and physics, knowledge related to the intuition and life experience of the students. This enhances their interest in physics as a science and subject, develops their logical thinking.

The didactic importance of graphics problems necessitates their systematic use in teaching physics in secondary school. All physical sections suggest solving graphical problems. In this regard, we believe that they should become a key element in the work of the physics teacher.

The proposed methodology for solving graphical problems is extremely useful forboth the teacher and the students. There is a need in physics education for solving graphical problems based on experimental data.This way,students acquire the ability to plot a physics graph with concrete examples. The purpose of the problems to plot a physics graph is the developing of skills for plotting graphics, as well as in preparing students to analyze graphics.

To master the ability to solve physical problems with a graphical method the basic generalized image matters. The formation of such an image in students requires the varying of the drawings in solving graphical problems. In this regard, our idea is for the physics teacher to present and analyze all possible graphical representations of processes, phenomena, movements.

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