Students Tasks and Experiments with Pendulum

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Abstract.

Most students and pupils are still educated in classes based on frontal teaching. Analyses of effectiveness of teaching methods show clearly that learning based on frontal approach is not so effective as approach based on the combination of problem based learning and project based learning. In this paper are discussed problems connected to the pendulum, different types of experiments for both: high school students and younger pupils. These experiments are practical part of problems solved by students and allow them obtain skills to solve specific types of problems and at the same time they will learn some new information from physics. The student projects are based on idea that most effective method for teaching sciences is independent work of students, which are self-inventing natural phenomenon or laws. That in this case students will be able to acquire a deeper knowledge through active exploration of real-world challenges and problems. The problems and experiments realized by students are technically undemanding experiments financially unpretentious. Experience shows that pupils under the age of 15 are able to discover themselves and thus an abstract thing as a method of determining the moment of inertia of a complex body.

Keywords: project base learning; problem base learning; pendulum; physics; frontal education

1. Introduction

This article is devout to teaching of physics and mechanics. Most students and pupils are still educated in classes based on frontal teaching. Analyses of effectiveness of teaching methods show clearly that learning based on frontal approach is not so effective as approach based on the combination of problem based learning and project based learning. In this paper are discussed problems connected to the pendulum, different types of experiments for both: high school students and younger pupils. One of problems older approach in teaching is fact, that all subjects are taught independently without creation important cross-curricular activities, that would allow deeper understanding of problems and at the same time allow its easier adoption. In these text is explained this approach on case study devout students or pupils work devout to the pendulums. Problems are divided in two groups. In the first group are problems solved by high school students and in the second group are problems and experiments for pupils from second stage of grammar school. It can be said that different experiments can serve to explain one particular phenomenon. On the other hand, one experiment can be used for learning and understanding several problems together. For example, experiments with pendulum can be used for teaching about gravity acceleration, moment of inertia, students can also discussed problems connected to the time measurement. One important aspect of teaching physics is relation between physics and mathematics. Both subjects are often learned independently, without any effort to build connection between them. In fact, many physical problems can be used to appropriately define and motivate some methods used in mathematics. Such as a typical example of this approach, this series of tasks can be considered: (1) students determine gravity acceleration using a mathematical pendulum (individual experiments differ in the thickness or the weight of the string); (2) By comparing the results, students will find out that in the case of a "thick" string with a higher weight, the measurement error increases; (3) as an explanation of the error that increases with the weight of the string, new concept of physical pendulum can be introduced. With the introduction of the concept of physical pendulum, it is necessary to introduce the concept of moment of inertia; (4) The concept of integration can be introduced by means of a chain of mass points, for physical pendulum, i.e. moment of inertia of long bar. In same way we can introduced also the moment of inertia of hoop. The projects, experiments or problems for pupils on the lower school lever are build in same way. However, these are adapted for a younger age of pupils and they are more focused on explaining the phenomenon, than on the ability used acquired skills to solve new problems. The approach in teaching, which was described in this article has a positive impact on the development of pupils' skills and cognitive abilities.

2. Project a Problem-Based Education

In this part are defined basic concepts of project a problem based learning and their advantages in comparison to the traditional concept of frontal education. For science teaching is very convenient to use Problem or project based learning. Both methods are often confused. Very many teachers tend to regard both methods as one with two subtitle names. In this paragraph, therefore, explain the basic concepts of both approaches.

Problem-based methods used to improve the educational process have a long history of develpment. This approaches are based on pupils expirience and experience-based education. Research realised by psychologist and sequential theory suggests that by having students learn through the experience of solving problems, they can learn both content and thinking strategies (Hmelo-Silver, 2004). Problem-based learning is an instructional method in which students learn through facilitated problem solving. In the case of Problem-based learning, students learning is build on complex problem that does not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in so-called self-directed learning and then apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed. The role of teacher in educational process is to facilitate the learning process rather than to provide knowledge. The goals of Problem-based learning include helping students develop some skills and knowledge such as: so-called flexible knowledge; effective problem-solving skills; self-directed learning skills; skills connected to teamwork, and also intrinsic motivation. Whereas intrinsic motivation is considered much more effective than the motivation obtained only classification. Because students with motivation based on a deeper interest in the problems are better suited for future skills acquisition than motivation aimed at obtaining a good grade but which was not accompanied by an interest in the matter (Hmelo-Silver, 2004).

Project-based learning is a student-centred pedagogy that involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge through active exploration of real-world challenges and problems (Sawyer, 2006).

Project-based learning is a student-centred education method that implements a dynamic classroom approach in which it is believed that students acquire deeper knowledge through active exploration of real-world challenges and problems. Project-based learning can be described as a comprehensive perspective focused on teaching students in through self-managed research and by engaging students in investigation. In comparison to problem based education in the case of project based learning, students work for longer time on studied subject (Dewey, 1997), (Barrows & Tamblyn, 1980).

Students are working on the subject of learn for an extended period of time to investigate and respond to a complex question, challenge, or problem. It can be said that one of the most important features of this method is length of time period which is devout to solve problem. Project based learning in contrasts to the paper-based, which prefers memorization of facts, is based on experience and students own discovering the answers. In the case of project base learning the role of teacher represents variation between assistant, work manager and experienced colleague, on the contrary in the case older approach, where teacher presents generally known facts or portrays a smooth path to knowledge by instead posing questions, problems or scenarios. In the case of frontal education students are working exactly as instruction by teacher (Hubalovska & Hubalovsky, 2016).

3. Basic Lessons devout to Pendulum in Old-Fashioned Classes

A pendulum is one of most important mechanism in school physics and mechanics. Pendulum is a body suspended from a fixed support so that it swings freely back and forth under the influence of gravity. When a pendulum is displaced sideways from its resting, equilibrium position, it is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position. When released, the restoring force acting on the pendulum's mass causes it to oscillate about the equilibrium position, swinging back and forth. The mathematics of pendulums are in general quite complicated. Simplifying assumptions can be made, which allows to solve problem easier. These assumptions are: (1)The rod or cord on which the bob swings is massless, inextensible and always remains taut;(2)The bob is a point mass; The rod or cord on which the bob swings is massless, inextensible and always remains taut; The pendulum is biased from the equilibrium position only by small-angle oscillations. Even in this case, however, it is not possible for most high school students (and all the more so for primary school pupils) to assume the possibility of an analytical solution, because analytical solution which requires knowledge of differential equations.

However, a lot of physical problems can be solved by searching for analogies, so it is enough for pupils, when they know the functions of *sinus* and *cosinus* and have basic knowledge about graphs of this two functions. Much more complex physical pendulum is subject of lessons only for students of high-school. Among other things, because it requires knowledge of concepts such as moment of inertia. In most cases, the effort to teach harmonics, oscillations, and pendulums is only a result of knowing two or three equations, that students only remember for a short time. The equations that are taught at school:

$$\varphi = \varphi_0 sin(\%iomega.t + \phi) \tag{1}$$

where ϕ is instantaneous angular displacement of the pendulum and ϕ_0 is its amplitude, ω is angular speed and t is time. Angular speed is defined as:

$$\omega = \sqrt{\frac{l}{g}} \tag{2}$$

where l is length of rod or cord on which the bob swings, g gravity acceleration. Frot this equation students obtained motion periode T:

$$T = 2\pi\sqrt{\frac{l}{g}} \tag{3}$$

T motion periode. Basically the same formula is for the physical pendulum:

$$T = 2\pi\sqrt{\frac{l}{m.g.d}} \tag{4}$$

where J is moment of inertia, m is mass of pendulum and d is distance between pendulum center of gravity and

The main goal for most students of high schools the goal is to remember the relationship and to be able present it to the teacher at the exam. Essentially, such “skill” is of no importance for the development of mental qualities and student skills

It is much more advantageous for students and pupils to acquire ways of "scientific" thinking, to reveal them, which can then be applied to further problem solving, which is more important than short-term memorizing several equations (Hubalovska & Hubalovsky, 2016).

4. Students Project and Experiments

In these chapter we will described projects devout to the pendulum and which laws and phenomena are students able to discover by their own work. It should be added that for this type of work, it is appropriate for students and pupils to work for longer periods of time than traditional 45-minute lessons. On such projects students works several lessons, which are longer than traditional 45-minutes (Jarkovsky et al., 2018). First we will describe the work of high school students (age 15-16) and subsequently the work of pupils on second stage of primary school (age 13-15), because the latter can be considered a simpler less extensive variation of the previous one. It is also possible to say, that many younger pupils were able to achieve the same advanced results as older pupils (Hubalovska & Hubalovsky, 2016).

The students projects may have a lot of goals. Some of this goals are: (1) students study the possibility of using a pendulum to measure time.; (2) students will try to describe the movement of the pendulum and find certain quantitative patterns. Alternatively, establish a relationship describing the phenomenon.; (3) students analyze the effect of string weight on the pendulum behaviour.; (4) Students will try to use the pendulum to measure gravity acceleration or other physical quantities.; (5) Students try to study concept of physical pendulum (physical pendulum is a rod characterized by length *l* and weight m).; (6)Students try to quantify the effect of string weight and the goal here is to help students discover the moment of inertia; (7) Students try to quantify moment of inertia, students discover “integration”, i.e., dividing a body into many points, each having its moment of inertia relative to the axis of rotation, and the entire pendulum formed by the rod is the sum of many mass points on a single line.

Description of experiments: (1) First students start with the model of mathematical pendulum which is composed from string and small bob with weight *m*. Students use other aids like stopwatch. They are monitoring the swing time, and they attempts to determine whether the swinging time increases or decreases with the string length.; (2) Students seek analogy with other periodic movements, such as a spring oscillator. An interesting analogy is the movement of a point on a rotating circle. This and other movements can be studied using a camera on a mobile phone. The video can be decomposed into individual frames and the magnitude of the swing can be plotted along with time. It then attempts to find a curve to fit the points. Students usually find a suitable function describing harmonic movement.; (3) Students try to determine relation between mass of string and the motion period. (4) Students try to determine gravity acceleration by analysis of pendulum pendulum motion. These goal was achieved with utilization Eq. 3. Students are able to recognize that the measurement accuracy or model quality is decreasing with mass of string.; (5) Students try to replace by a rod with length l and mass m. Students try to describe and modify the Eq.3. (5) Some problems which were recognized in item no. 4 or 5 can be explained by moment of inertia.; (6) Moment of inertia is defined for one very small bob on the intangible arm (arm with very small mass in comparison to the bob). In the first approximation students try to substitute the bob rod with mass m and length l with bob (with same mass) on the beam with length corresponding to the distance from the center of gravity. Students try to compare results with the measurement.; (7) Due to the major errors of the model proposed in (6) students try to improve model by splitting the rod into several parts. The discovery of how to calculate the moment of inertia will try to apply to another simple formation - the hoop.

In the case of secondary school students have mostly only first fife goals, but some pupils are also able discover moment of inertia. However, this pupils pay great interest in the motion study in the item (2) and (3).

5. Pedagogical Study

This paragraph of presented article is devout to the analysis of efficiency of this approach. From the methodological point of view it is necessary to describe how the effect of this projects on students and pupils were studied.

Some different approaches were used: (1) the teachers were observing pupils and students; (2) questionnaires were used to study pupils and students attitude to the activity (in this case the one of partial goals of research is how interesting is the work for students. Pupils are giving some marks if the work is funny or interesting, and they also describe their attitude by words. They are also asking if they would like more such hours); (3) another questionnaires and test are used for the determination of their knowledge (This type of questionnaires and test were also used for the control group of students and pupils which are participating on traditionally based lesson) (Hubalovska et al., 2019).

The differences between girls and boys when working with the construction kit during the construction activity were monitored. The ability of boys and girls to navigate the manual, the ability to work systematically, and to observe the skill of boys and girls were followed. Significant difference between the boys and girls in the monitored areas was not found. Some girls, after studying the manual, first found all the parts to build the model and only then began construction. Almost all kids were able to construct a construction model. Sometimes some of them needed some advice. One off results of analysis of questionnaires show, that younger pupils consider the work on the projects more funny than older (questionnaires used markings: 0- no fun, 5- very funny). Same approach was used to determine how interested was problem for students (0- uninteresting, 5- very interesting). The oldest students widely give worse marks, but the decreasing in interest was not so intense , than in the case of previous question. Almost all pupils and students will to prefer work on projects than attend traditional lesions with frontal education. Differences between boys and girls were relatively small and unimportant. Main difference between sexes was, that more boys than girls consider the kit to be useful. But difference was moderate. The pupils and students which attend the lessons in which these or similar tasks were solved have better knowledge and better fixed (another test were realised after 6 months and 12 under the project was solved or standard lesson devout to the same problem).

6. Conclusion

The following findings emerged from the these study. Working activities with the based on concept described in the article (as example the experiments with pendulum were selected). is attracted and entertained for boys as well as girls. There are no significant differences between the girls and boys when working on the projects, both of the monitored groups are able to orientate them selves in the instructions. More boys than girls consider the kit to be useful. These difference between boys and girls increase with the age of pupils or students. The younger pupils consider the work on the projects more interesting and funny than older. In this experiment, the kids used both manual dexterity, computer and camera technology and naturally acquired physical knowledge. The present time requires a nmultidisciplinary approach in education. The combination of science and technology curriculum at both secondary schools and high-schools seems to be the possible way to develop learners' interest in technical and scientific disciplines. The projects devout to study pendulum clearly show many aspects of one thing can be studied by simple experiments and students can improve their skills and knowledges ignificantly. They also have good motivation to study.

Acknowledgment (TNR 12pt. bold)

This paper is an output of the specific research project SV 2125/ 1440/ 1210.

References (TNR 12pt. bold)

References in text should have this form (surname, year), for example:

1 author:	(Krugman, 2012)
1 author and the same year of publication:	(Hoffman, 2012, A), (Hoffman, 2012, B)
2 authors:	(Krugman & Hoffman, 2014)
3 authors:	(Hoffman et al., 2012)

References (TNR 14pt., bold)

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