PHYSICS STUDYING EFFICIENCY

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Abstract

Our objective is to search for and find solutions in order to increase the efficiency of teaching physics. Even though the terms, learning efficiency or teaching efficiency, are very popular in educational circles, there are no exact definitions for them. In this paper we define teaching efficiency and present methods for measuring this, and introduce results of measuring the efficiency of a course in physics at the upper secondary level (1200 students).
Keywords: Efficiency Increment, Efficiency in the Studying of Physics, Solving Physics Problems, Learning Outcomes.

Introduction

People engaged in educational activities have most probably read, heard or used the term learning efficiency or teaching efficiency. But what is actually meant by this terminology? Seemingly, the evidence of good learning outcomes is the meaning of the term in the Estonian language. Cedefop defines: learning outcomes are statements of what a learner knows, understands and is able to do after completion of learning (Cedefop, 2008).

Ever since 2003 we have tried to elaborate an appropriate formula or mathematical model to be able to measure learning efficiency in an easy way. Without too much elaboration regarding this goal, we present herein the definition and formula of efficiency as well as students' results during a piloting efficient study of physics (Ganina & Voolaid, 2007).

In this article we define teaching efficiency and methods of measuring this, and introduce the results of measuring the efficiency.

Studying Efficiency

There are several methods of evaluation of teaching/learning efficiency. This can be done with the help of research companies, e.g. Horizon Research (Johnson, 2007), or using the scales for measuring attitudes towards science and science teaching STAS II (Turkmen, 2007) or SAI II (Moore, 1997) already in use.

Statistical methods are also being used, e.g. Rasch analysis (Boone, 2006). Also, methods for assessment are offered by Walker & Where (1982), Powers & McKernan (1998) and Cowan (1985).

But these methods are either not suitable for assessing the efficiency of studying physics, or are too complicated to use. We are seeking a method that any teacher would find easy to use, even if he/she is not familiar with mathematical statistics.

As a rule, efficiency has been measured but not defined in these research studies. This is why we decided to commence with a definition.

We based our definition of the study of efficiency, using the one based on production efficiency employed in industry. Hence we came up with the following definition: studying efficiency means an acquired quantity of new knowledge and skills, using existing resources. By resources we mean students, teachers, learning materials and study aids, the actual environment (both material and physical), study methods, time etc.

In order to measure efficiency, it is necessary to take a pre–test on the new material for establishing the level of students' prior knowledge. This level is characterized by the ratio:

$$T_{pre} = \frac{\sum_{i=1}^{N} n_i}{N \cdot n},$$

where N is the number of respondents, n – number of questions in the test, and n_i – number of correct answers given by one student.

The same test is taken again after studying the new material, only now it is called a post–test. The result of the post–test is represented by T_2 and calculated in the same way as T_1:

$$T_{post} = \frac{\sum_{i=1}^{N} n_i}{N \cdot n}.$$

To evaluate the teaching efficiency, we use the efficiency increment E indicating the difference between these two ratios: $\boldsymbol{E} = T_{post} - T_{pre}$.

When establishing E we presume the learning period to be equal at all times.

The values, of the thus calculated efficiency increment $\boldsymbol{E}$**,** fall onto a scale between –1 and 1.

When $T_{pre} = 0$ and $T_{post} = 0$, then $E = 0$;

when $T_{pre} = 0$ and $T_{post} = 1$, then $E = 1$;

when $T_{pre} = 0{,}5$ and $T_{post} = 1$, then $E = 0{,}5$;

when $T_{pre} = 1$ and $T_{post} = 0$, then $E = -1$ etc

Teachers at schools can evaluate the efficiency of a new learning method using this formula.

U.S. scientists have adopted a formula similar to ours for measuring teaching efficiency (Hake, 2003). They likewise use the difference between pre–test and post–test as an indicator of efficiency according to which they calculate the gain in results:

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre},$$

where %post – the percentage of right answers of a post–test;

%pre – the percentage of right answers of a pre–test.

The shortcoming of such a formula is the fact that the efficiency value is not located on a proportional scale, thus it becomes difficult to interpret the results. E.g. in case of maximum results of a pre–test, or%pre = 100% then the denominator in the formula would equal zero. But in the situation if%post < 100% on g = – ∞ then that seems impossible to interpret.

Methodology of Research

Research on Efficiency of Studying Physics

About twelve hundred (1200) secondary level and vocational secondary level students participated in our research. In the main part of the research, these students took tests in various fields of physics after various periods of time (a pre-test before studying a certain topic, and post-tests: immediately after studying a certain topic, and then one week, one month, one year and two years after the actual studies). Methods used during the study were noted down at the beginning of tests (these notes were provided either by the physics teacher or on basis of a discussion among the class or group of students).

Tests were prepared by topics and the questions varied in composition: one portion of these tests checked the knowledge and understanding of physical quantities, units of measurements and concepts – the so-called knowledge portion; the rest checked problem-solving and drawing conclusions – the so-called skills portion. The tests included one question with a drawing and one problem with a chart to support visual learners. The tests were multiple choice tests. In addition, we asked the students to explain reasons for making their choices if possible. This request was added due to the fact that pinpointing the right multiple choice options does not necessarily indicate that the student has a thorough subject knowledge (Knowing what Students Know, 2001).

Testing covered six areas of physics: mechanics, thermodynamics, electromagnetism, optics, matter and field, and astronomy.

Results of Research

The efficiency increment calculated, according to our formula, is given below as a chart (on the basis of immediate test results immediately after studying the topic):

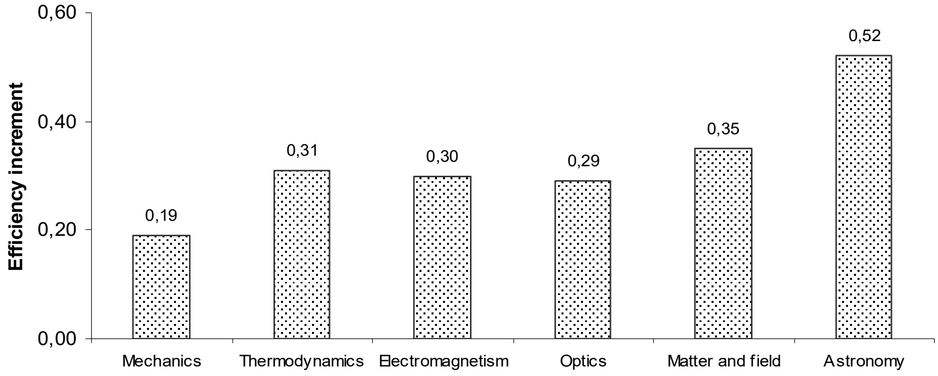

Figure 1. Efficiency increment immediately after studying (n =1200)

Our research did not reveal the reasons behind this, but to our best knowledge (based on experience and other teachers' opinion) students have better prior knowledge of mechanics and thus both teachers and students are under the illusion that there is no need to study further. The high efficiency in astronomy can be explained by a lively interest in the topic, resulting in strong motivation to study it.

As we have mentioned before, we were interested not only in checking the knowledge but also retention of the same. The results of pre-test and post-tests are shown in the table.

Table 1. Results of pre–test and post–tests (T_{max} = 1)

	Pre-test	Post-test				
	T_1	T_{20}	T_{21}	T_{22}	T_{23}	T_{24}
Mechanics	0,40	0,59	0,47	0,45	0,44	0,43
Thermodynamics	0,30	0,61	0,58	0,53	0,41	0,40
Electromagnetism	0,20	0,50	0,50	0,45	0,40	0,38
Optics	0,30	0,59	0,60	0,55	0,30	0,28
Matter and field	0,16	0,51	0,48	0,40	0,31	0,22
Astronomy	0,20	0,72	0,69	0,60	0,55	0,54

Here T_{20} – the test result immediately after studying a certain topic; T_{21} – in one week; T_{22} – in one month; T_{23} – in one year; T_{24} – in two years.

We were focused not only on checking the knowledge but also retention.

Hereinafter we present graphs of the efficiency increment timeline (so–called curves of forgetting) for two topics: astronomy and mechanics. We chose these areas as the ones of the least and the most initial efficiency.

The chart shows that efficiency increment falls mainly during the first month.

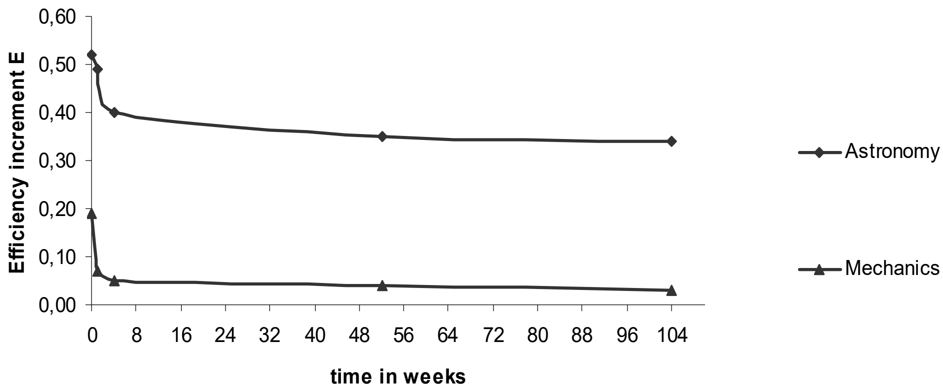

Figure 2. Forgetting curves

As a rule, relaxation processes take place according to the exponential function in nature. Ebbinghaus curves of forgetting can also be presented as an exponential function (Ebbinghaus, 1885). But the analysis of our curves of forgetting indicates that these graphs cannot be characterised by one exponent only. There should be at least two exponents: one characterizing the process in the first month, and the second thereafter. But it might be also some other function. In order to be able to predict the forgetting interval, we must specify the form of this function.

Conclusion

The objective of this research was to elaborate the term teaching efficiency in order to find the most suitable formula for calculating this, to test it in practice and find possible factors that could increase efficiency in teaching physics.

We have established an appropriate formula for calculating teaching efficiency as a result of this research. This formula can be used in teaching physics as well as teaching other subjects. Teachers at schools can evaluate efficiency of a new learning method using this formula.

Our results show that the efficiency increment falls mainly during the first month.

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