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Students' Views on Usefulness of Chosen Physics Formulas

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Abstract

The study examines students' opinions on the usefulness of selected physics formulas from the school curriculum. Students have assessed 16 of the most important physics formulas, chosen by physics teachers. Additionally, eye-tracking examinations were performed. For 52 students divided on two groups: not participating in school competitions in physics and other natural sciences and participating in these competitions. Physics contest winners found over 60% of these formulas useful, whereas the average students' result was less than 30%. The paper also presents the declarations of students, graduating from middle school, concerning their interests in school mathematics, physics, biology and computer science. Students that showed more interest in the selected subjects also perceived the areas of study presented by them to be much more useful to the society. It has also been concluded that the intention of choosing one's profession within the area of a given subject depends on one's interest in the subject.

Keywords: physics formulas; science education; natural and computer science

Introduction

For several dozens of years, we have been conducting studies on enhancing students' interest in the natural sciences, particularly in physics (Błasiak, Godlewska, Rosiek, Wcisło, 2012, p. 565). Similar work has been performed in many countries around the world (Sjoberg, Schreiner, 2007, p. 3; Romine, Sadler, Presley, Klosterman, 2014, p. 261). Reluctance to learning physics appears at odds with the natural interest of students around the world and the desire to know and understand natural phenomena (Williams, Stanisstreet, Spall, Boyes, Dickson, 2003, p. 324). Osborn (2013, p. 1049) states that the study of students' attitudes to learning natural science has been one of the main areas of focus in the global community of educators over the past 30–40 years. Recent years have seen some positive changes in our country. In the assessment of science reasoning skills PISA (Programme for International Student Assessment) 2012, Polish students moved into the position of front runners among countries participating in the study, not only due to their high-ranking results, but also the dynamics of its growth in relation to the results of previous studies PISA (Gurria, 2014).

However, among all the school subjects, physics is the least popular one with Polish students. In the initial phase of learning, students' interest in the matter of physics is relatively high (Błasiak *et al.*, 2012, p. 565; Pęczkowski, 2009; Pęczkowski, Błasiak, Rosiek, 2014, p. 108). However, in the further stages of education (the middle school), interest in physics declines rapidly. One of the reasons for this state of matters is the difficulty students encounter in freely using the universal language of mathematics (Bing, Redish, 2009, p. 020108-1; Quale, 2011, p. 359; Redish, Saul, Steinberg, 1998, p. 212). The language of mathematics allows for the quantitative description and prediction of various phenomena. In the physics curricula, not only in Poland but also in most countries of the world, there are recommendations as to introducing the quantitative mathematical relationship between physical quantities, called physics formulas. Unfortunately, for many students the mathematical approach to physics is an obstacle and a source of problems in understanding the subject (Sadaghiani, 2005).

In the physics curricula there are many physics formulas, which, according to educators, students should find useful. Nevertheless, students will often memorize these formulas, but perceive actually understanding them to be irrelevant. Without an in-depth analysis and interpretation of mathematical equation symbols for physical quantities, the formulas are incomprehensible, and are thus recognized as useless by the pupils (Rożek *et al.*, 2014, p. 43). Research on knowledge in areas such as computer science, mathematics and chess show that expert skills to think and solve problems to a large extent depend on the rich resource of knowledge on a particular subject (Chase, Simon, 1973, p. 55; Chi, Feltovich, Glaser, 1981, p. 121; DeGroot, 1965). Such recognition of knowledge as an insignificant element is a destructive factor, discouraging them from learning. It leads to a loss of interest in physics and consolidates the prevailing opinion that the physics taught in school is useless in life (Pintrich, Schunk, 1996). Later on, that view influences the society's perception of physics' usefulness, as well as influencing young people's choice of educational and professional courses, driving / leading them to those unrelated to physics. Fewer and fewer high school students choose mathematics and natural science as their class profile, and the number of those eager to study physics is dropping rapidly. The profound social changes in the world cause students to pay more and more attention to the practical usefulness of acquired knowledge (Kahneman, 2011).

The purpose of the paper

The main aim of this study was to assess the opinion of students on the suitability of the selected physics formulas presented in the school curriculum. The goal was to find out the extent to which opinions on the usefulness of physics formulas are dependent on students' sex, their interest in physics, as well as their active participation in physics contests. For a deeper understanding of the mental choice-making mechanisms in our students, an eye-tracking analysis has been conducted, where the activity of their eyes, when assessing the usefulness of particular formulas, was being observed. Eyetracking study will be analysed in another paper.

Additional questions concerned the quantitative relationship between students' declared interests in physics, mathematics, computer science and biology and their opinion on the usefulness of the knowledge gained and plans for a profession in which the knowledge of particular subjects would be required.

Detailed research questions

How many students surveyed perceive physics, mathematics, computer science and biology as their favourite school subjects, and how many dislike them? How strong is the interest of each pupil in physics, mathematics, computer science and biology (on a scale of 0–10)? How do students assess the usefulness of physics, mathematics, computer science and biology to society? How great is the wish to choose a profession in which the knowledge of physics, mathematics, computer science or biology will be essential? What is the correlation between the interest in the selected school subject and the assessment of the usefulness of the knowledge taught? Which of the physics formulas included in the school curriculum are considered to be the most useful ones by the students and which are considered to be useless in everyday life? What is the relationship between the time spent looking at a formula and the probability of declaring it to be useful?

Methodology

Participants

There were 52 students aged 16, close to graduating from middle school, taking part in the experiment. The group consisted of 25 girls and 27 boys, of whom 34 were average in terms of their performance, and 18 were outstanding students, with achievements in provincial physics contest.

Procedure

The experiment was conducted in the Laboratory of Neuroeducation and Cognitive Teaching at The Pedagogical University of Cracow in Faculty of Mathematics, Physics and Technical Science. In the beginning, 16 years old students, after completing a three-year school course, answered the following questions (among others):

(1) Name three school subjects that you **like most**.
(2) Name three school subjects that you **likeleast**.

(3) Mark the validity of the sentence according to the given scale (0 – uninterested, 10 – very interested):
A) I'm interested in physics;
B) I'm interested in mathematics;
C) I'm interested in computer science;
D) I'm interested in biology.

(4) Mark the validity of the sentence according to the given scale (0 – I don't intend to, 10 – I intend to):
A) I intend to work in a field where physics knowledge is required;
B) I intend to work in a field where mathematical knowledge is required;
C) I intend to work in a field where computer science knowledge is required;
D) I intend to work in a field where biological knowledge is required.

(5) Mark the validity of the sentence according to the given scale (0 – useless, 10 – very useful):
A) I find physics useful to society;
B) I find mathematics useful to society;
C) I find computer science useful to society;
D) I find biology useful to society.

In the next phase of the experiment (which will also be discussed in the field of eye-tracking research), out of 16 formulas of classical physics (see Figure 1), students were asked to choose the ones they claimed to be practically useful for them in life. The command was: "Several formulas in physics are presented below. Click the mouse and select those formulas that **YOU THINK** will be useful in your life". They could select as many formulas as they wished, and they were not limited in time.

Several formulas in physics are presented below.
Click the mouse and select those formulas
that **YOU THINK**
will be useful in your life

1 $F = m * a$	2 $a = \frac{\Delta v}{\Delta t}$	3 $R_z = R_1 + R_2 + \cdots$	4 $s = \frac{at^2}{2}$
5 $E_p = m * g * h$	6 $v = \frac{\Delta s}{\Delta t}$	7 $W = F * s$	8 $T = \frac{1}{f}$
9 $E_k = \frac{mv^2}{2}$	10 $p = \frac{F_N}{S}$	11 $v_{śr} = \frac{s_{total}}{t_{total}}$	12 $\Delta E_w = W + Q$
13 $\rho = \frac{m}{V}$	14 $U = \frac{W}{q}$	15 $I = \frac{q}{t}$	16 $W = U * I * t$

Figure 1. *16 physics formulas of classical physics in the physics curricula*

Results

Interest in particular subjects by the students was rated on a scale from 0 – least interested, to 10 – most interested. The results of interest in physics and mathematics, broken down by high school students do not participate in competitions in physics and other natural sciences ("ordinary") and the students taking part in competitions in physics and other natural sciences ("extraordinary") are presented in the form of Table 1.

There were not large differences between the two groups in terms of interest in biology and computer science. In response to a question about the choice of profession, opinions were divided. As for physics as a profession, students participating in contests of physics pointed to its great usefulness, but among the other students there were also sometimes high marks.

Results regarding choice of profession, which will be useful in physics and mathematics for high school students who do not participate in competitions in physics and other natural sciences and students participating in physics competitions are presented in the form of Table 1. The results of the selection for the usefulness of physics and mathematics to the public divided on middle school students taking and not taking part in competitions in physics and other natural sciences are presented in the form of Table 1.

Table 1. The interest in physics / mathematics the choice of profession which will be useful physics / mathematics usefulness of physics / mathematics for society for students taking part and not taking part in competition in physics

Number of students:	Group	Level					p-value
		very low	low	medium	hight	very hight	
declaration of the degree of interest in physics	Extraordinary	–	–	2	5	11	< 0.001
	Ordinary	1	6	15	9	3	
declaration of the degree of interest in mathematics	Extraordinary	–	–	5	6	7	0.001
	Ordinary	4	5	8	10	7	
declaration of choice of profession which will be useful physics	Extraordinary	14	3	8	6	3	0.001
	Ordinary	1	2	3	7	5	
declaration of choice of profession which will be useful math-ematics	Extraordinary	–	–	4	6	8	0.004
	Ordinary	5	2	12	4	11	
declaration useful-ness of physics for society	Extraordinary	–	–	1	8	9	< 0.001
	Ordinary	–	3	16	10	5	
declaration useful-ness of mathematics for society	Extraordinary	–	–	2	2	14	0.040
	Ordinary	1	–	8	9	16	

We carried out a comparison of results for the significance of differences between students not involved in the competitions in physics and other natural sciences and participants in those competitions in questions on the assessment of interests, career choice and usefulness to society of physics, mathematics, computer science and biology. For this purpose, we used the test of significance for the two independent samples (Student's t-test). Serve archived results of empirical significance (p-value).

Competition entrants showed significantly better evaluations of interest in physics ($p < 0.001$) and mathematics ($p = 0.001$). No significant differences were observed between extraordinary and ordinary interest in information technology ($p = 0.819$) and biology ($p = 0.312$).

As for the declaration of choice of occupation, we noticed significant differences between the two groups of students opting to choose a profession related to physics ($p = 0.001$) and mathematics ($p = 0.004$). The significance of differences between the two groups for the choice of profession-related computer science ($p = 0.162$) and biology ($p = 0.309$) are statistically insignificant.

Students taking part in these competitions in physics and other natural sciences rated these subjects to be of much greater value to society than did those the students who did not participate in such competitions. Statistically significant differences were observed between the two groups of students regarding their life/career choices: physics ($p < 0.001$), mathematics ($p = 0.040$) and computer science ($p = 0.006$). There were no statistically significant differences between the groups of students for the selection of the suitability of biology ($p = 0.146$).

The correlation of students' interest in selected school subjects with the assessment made by them in terms of the usefulness of selected scientific discipline for society. In the declarations of students who won the provincial physics contest, the best matched linear function is $y = 0.38x + 5.25$, and the Pearson correlation coefficient is $R = 0.39$ (where y – the usefulness of physics to the society, x the declared interest in physics). In average students $y = 0.47x + 3.66$, and $R = 0.47$.

Table 2 presents the parameters of the linear functions best matches to students' answers on the usefulness of mathematics, computer science and biology to society and their declared interest in those school subjects.

Interest in selected subjects across the curriculum and students' plans regarding their choice of profession. ***In the declarations of students who won the provincial physics contest, the best matched linear function is $y = 0.98x - 1.35$, and the Pearson correlation coefficient is $R = 0.52$. In average students $y = 0.95x - 1.45$, and $R = 0.63$.***

Table 2. Linear correlation between the assessment of the usefulness of mathematics, computer science, biology and physics to society and the declared interest in those subjects by the surveyed students

Subject	**Group**	***y* = ax + b**	**Pearson correlation coefficient - *R***
Physics	Extraordinary	$y = 0.38x + 5.25$	0.39
	Ordinary	$y = 0.47x + 3.66$	0.47
	All together	$y = 0.56x + 3.37$	0.61
Mathematics	Extraordinary	$y = 0.20x + 7.32$	0.20
	Ordinary	$y = 0.34x + 5.99$	0.30
	All together	$y = 0.34x + 6.04$	0.37
Computer science	Extraordinary	$y = 0.54x + 4.27$	0.57
	Ordinary	$y = 0.34x + 5.44$	0.28
	All together	$y = 0.43x + 5.04$	0.46
Biology	Extraordinary	$y = -0.04x + 7.81$	0.04
	Ordinary	$y = 0.25x + 6.46$	0.17
	All together	$y = 0.12x + 7.15$	0.14

Table 3 presents the parameters of the linear functions best matched to students' answers on the intention of choosing a profession, in which computer science, mathematics or biology would be useful and their declared interest in those school subjects.

Table 3. Linear correlation between the intention of choosing a profession and the declared interest in those subjects by the surveyed students

Subject	**Group**	***y* = ax + b**	**Pearson correlation coefficient – *R***
Physics	Extraordinary	$y = 0.98x - 1.35$	0.52
	Ordinary	$y = 0.95x - 1.45$	0.63
	All together	$y = 0.99x - 1.61$	0.70
Mathematics	Extraordinary	$y = 0.83x + 1.14$	0.71
	Ordinary	$y = 0.72x + 2.16$	0.51
	All together	$y = 0.72x + 2.13$	0.60
Computer science	Extraordinary	$y = 0.69x + 1.27$	0.41
	Ordinary	$y = 0.99x + 1.95$	0.62
	All together	$y = 0.65x + 1.31$	0.47
Biology	Extraordinary	$y = 0.41x + 1.86$	0.24
	Ordinary	$y = -1.19x + 15.30$	0.50
	All together	$y = 0.19x + 3.29$	0.14

The choice of physics formulas recognized by students as useful. **Figure 2 shows the percentage of students who won the provincial physics contest and the percentage of average students who found the formulas displayed on the screen to be useful.**

Winners of the science competitions ("extraordinary" students) preferred the formulas 6 (83.3%), and 1 and 16 (77.8%). Only formula 8 was elected less than 50.0% (44.4%).

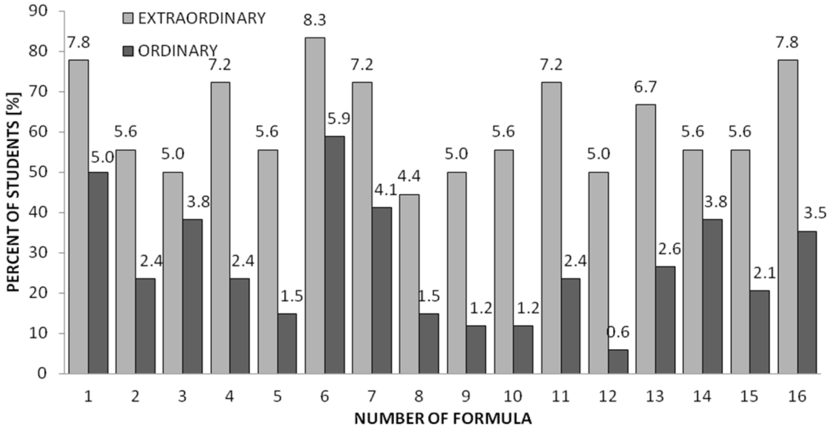

Figure 2. The percentage of students finding a given formula useful (the best = extraordinary). The figures and their assigned numbers are given in figure 1

Students, who did not take part in physics competitions ("ordinary" students), choose appropriate formulas much less than those students participating in these competitions. Just as the students taking part in physics competitions, those not taking part in these competitions ("ordinary") chose the most common formulas 6 and 1 (respectively 58.8% and 50.0%). Other formulas were chosen at the level of 20–30%, and formula 12 has chosen only by 5.9% of students.

This shows that students who are not taking part in the physics competitions considered physical formulas less useful than the students participating in this type of competitions.

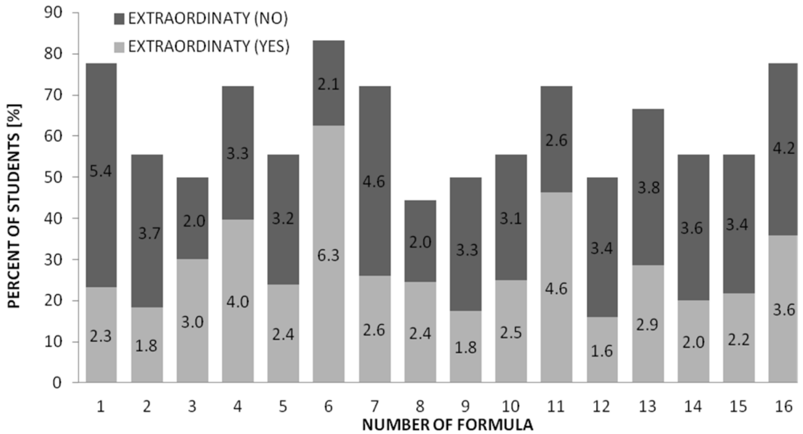

Figure 3a. The percentage of extraordinary students finding a given formula useful and who know the meaning the formula (YES) and who don't know the meaning the formula (NO)

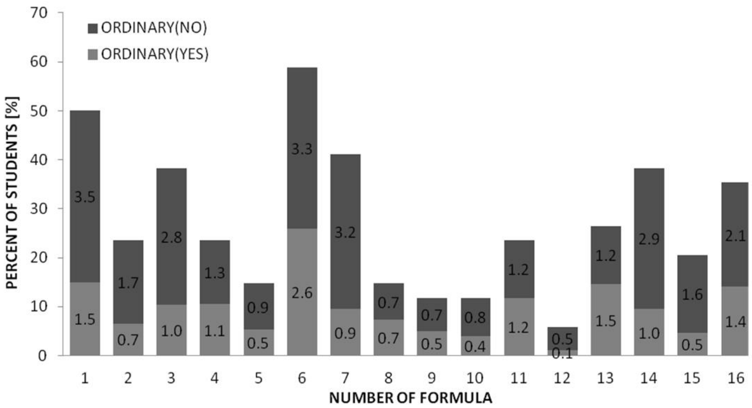

Figure 3b. The percentage of ordinary students finding a given formula useful and who know the meaning the formula (YES) and who don't know the meaning the formula (NO)

Figure 3a and Figure 3b show the percentage of students who won the provincial physics contest ("extraordinary") and the percentage of average students ("ordinary") who found the formulas displayed on the screen to be useful in two groups. First group (YES) consists of the students who know what given formula means. Second group (NO) consists of the students who don't know what given formula means.

T-Student test show that the difference in understanding formulas between ordinary and extraordinary students in statistically significant (p-value < 0.001). Pearson correlation in understanding formulas for ordinary and extraordinary students is 0.812.

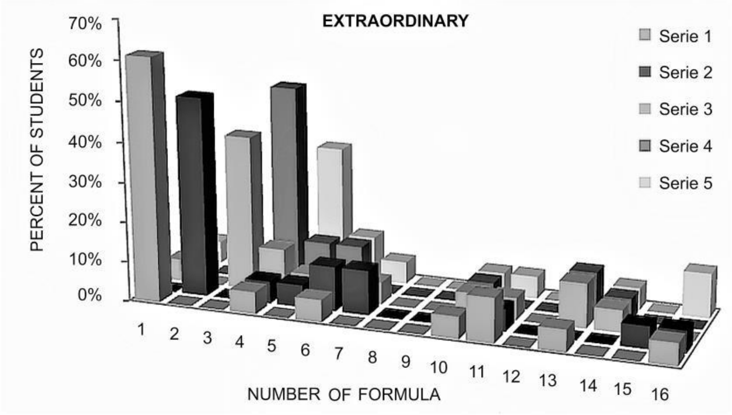

Figure 4a. The percentage of students choosing a formula in the order of selection for the first five places to choose in a group of students taking part in the physics competitions ("extraordinary"). Number of sequences (from Series 1 to Series 5) denote the order of the selection formula. The figures and their assigned numbers are given in figure 1

In Figure 4 we show the percentage of students choosing a formula in the order of selection for the first five places to choose: a) in a group of students taking part in the physics competitions (“extraordinary”) and b) students do not participate in these competitions (“ordinary”). The number of sequences (from Series 1 to Series 5) denote the order of the selection formula. The figures and their assigned numbers are given in figure1.

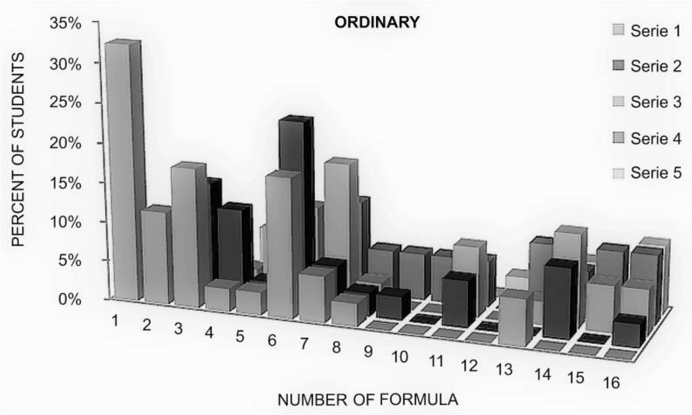

Figure 4b. The percentage of students choosing a formula in the order of selection for the first five places to choose in a group of students do not participate in these competitions (“ordinary”). Number of sequences (from Series 1 to Series 5) denote the order of the selection formula. The figures and their assigned numbers are given in figure 1

Formula 1 was chosen by the majority of students in the first place (61% of “extraordinary” students and 32% of “ordinary” students). “Extraordinary” students choose Formula 2 in second place of (50%) and “ordinary” students Formulas 6 (24%) and 3 (15%), 4 (12%). Formulas 8, 9, 12 were not selected by the “extraordinary” students for the first five places, whereas among “ordinary” students Formula 8 was occasionally selected for places 1–3 (3%) and 4th (6%).

Discussion and conclusions

Our questions concerning students’ interest in the school subject and the assessment of the usefulness of the knowledge acquired at school, along with their intentions as to the choice of future profession, have corresponded with the questions posed in the studies of Sjoberg and Schreiner (2007, p. 3). Nevertheless, we have expanded the scale of students’ possible answers, which allowed for examining the numeric correlation between their views and their interest in school subjects. Students’ interest in the subjects taught has a huge impact on their subsequent life choices (Osborne, Simon, Collins, 2003, p. 1049; Romine *et al.*, 2014, p. 261; Trumper, 2006, p. 47).

In the whole group of respondents, mathematics enjoyed the greatest interest; next in order were physics, biology and computer science. The average students were most interested in biology, whereas physics finalists in physics. The aim of the educators is not only to work with students who are already interested in the subject, but also to reduce the number of students who dislike the course and even inspire interest in a subject. In this work, we have introduced the rate of the difference between the percentage of students who like and dislike a particular school subject. For the so-defined difference, the best result recorded is for physics and mathematics, among the finalists of the Cracow physics contest. It was, of course, quite natural and easy to predict. In average students the situation of the same subject is far less favourable, with the number of people who dislike physics and mathematics being greater than the number of people who like them.

Using the method of least squares, we have matched the linear correlations for the declarations obtained from the students. The relation between a declared interest in physics and the assessment of its usefulness is an increasing function. Mathematics presents itself in a similar way. A rather weaker, but still increasing, dependency has been noticed in computer science and biology. There is hope that in the future young people will be spontaneously drawn to the same areas of study which attracted their attention when they were at school.

An interest in a school subject seems to have a huge influence on the choice of one's future profession. The students surveyed by us will be deciding on their profession within three years. However, it is now that they have to decide on the profile of their class in high school, which later on will have an impact on the choice of their occupation or field of studies. The greatest correlations between the interests and the willingness of choosing a related profession have been observed in physics and mathematics. The Pearson correlation coefficients for the fitted lines were always greater than 0.5.

Students have assessed 16 of the most important physics formulas, chosen by physics teachers. From the 16 physics formulas the students have recognized as the most useful the formula for velocity and Newton's second Law. As the least useful the second law of thermodynamics and the relationship between period and frequency. Physics contest winners have found over 60% of these formulas useful, where as the average students' result was less than 30%.

We have performed additional analyses using the results from our students in the state exam. Those who gained high scores in the state exam in the mathematics and natural science at the end of the middle school have found more physics formulas to be useful. The defined relationship between the percentage of formulas selected by average students (y), and their results in the state middle school exam (x) is as follows: $y = 0.2x + 15.6$, and $R = 0.84$. There were no significant differences in the declarations of boys and girls.

The declarations of pupils on the suitability of the selected physics formulas were compared to the declarations of 10 experts in professional training of future physics teachers. No significant preferences have been noticed in comparison to the group of students who were the winners of the provincial physics contest. In average students, the differences between their preferences and the priorities indicated by the experts were significant.

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