PHYSICS COMMUNICATION

NATIONAL ASSESSMENT OF KNOWLEDGE OF PHYSICS AFTER FINISHING ELEMENTARY SCHOOL: IMPORTANT INFORMATION FOR PHYSICS TEACHERS

Jure Bajc[a)]

Faculty of Education, University of Ljubljana, Slovenia

1 INTRODUCTION

In the paper the results of the national assessment of knowledge of physics in Slovenia are presented. The way the data are analysed, the form in which the results are disseminated to teachers and how they can be used by teachers at their everyday work is shown as well. The knowledge of pupils who have just finished elementary school[b)] – aged 15 – was assessed. A few examples of interesting problems that show different outcomes, some expected and some not, are analysed. In particular, it is shown by examples, how teachers should interpret the national assessment's results to get the most out of the data.

In Slovenia the national final exams after finishing elementary school have been in practice for over 15 years. Up to 2005 mathematics and mother tongue were obligatory and the "third" subject was selected by pupils – each year only up to 100 pupils out of total of around 20,000 chose physics. This resulted in a non-representative sample and poor assessment of knowledge of physics. But, on the other hand, the primary task of national final exams was selection. The final exams were in fact the entering exams for secondary school, so giving poor estimate of the knowledge and understanding of physics among youngsters was of no concern for the school authorities.

In 2006 a quantitative change occurred. The selection for entering secondary school is now based solely on the marks of the pupils and the primary goal of the final exam after finishing elementary school is assessment of knowledge. Mathematics and mother tongue are still obligatory. In addition, each year there are four third subjects, selected by the Ministry of education. Each year in September the minister announces, which four, out of the list of around 12 possible subjects, will be included in the national assessment. Each pupil is tested in only one third subjects, so the Ministry divides all the schools in four groups and the schools are informed about the selection for their pupils only a month before the actual examinations in May. By doing so we tend to avoid organised preparations for the national assessment test in the third subject, because we want to measure the actual knowledge of the entire population and not of a smaller group that is

[a)] Corresponding author's e-mail: jure.bajc@pef.uni-lj.si

[b)] In Slovenia pre-university education consists of elementary school that lasts for 9 years (age 6-15) and secondary school (age 15-19).

preparing for the exam more than pupils do on average. For each third subject a representative sample is the size of around 5,000 pupils. In 2007 the knowledge of foreign language (English or German), history, chemistry, and physics was assessed, so for the first time, a representative sample of the entire generation was used in the national test of knowledge of physics.

The national assessment exam in physics is set up of 20 written problems, spanning the syllabus of physics (the last 2 years of elementary school, 8th and 9th grade, 2 hours per week) and physical topics in the subject Natural science (the 7th grade, about 18 hours in the entire year). Depending on the length and complexity 1 to 4 points are assigned to each problem, but the overall sum is fixed to 36 points. In 2007, the average score of 4,548 pupils was 16.8 points, i.e., 46.6% of maximum possible number of points. All cognitive levels after Bloom are present in the test [1], so this result is not a surprise, as we include only about 20% of low cognitive levels (knowledge and recognition, level I), about 55% of intermediate cognitive level (comprehension and application, level II), and about 25% of high cognition level (analysis and synthesis, level III). This distribution is so much in favour of higher cognitive levels, because physics is all about understanding nature. Thus knowing definitions or recognizing correct units or wording of laws of nature is not enough. What pupils should gain from physics is a scientific approach to nature, the ability to recognise key variables in particular relations and to learn how to combine theory and observations. In addition, they should develop critical thinking. For example, they should learn how to ask relevant questions related to particular phenomena. One of the major advantages of physics in comparison to other nature science subjects is that experiments are relatively simple, not to difficult to observe, and can easily be repeated. On top, theoretical models reproduce the experiments well, if the experiments are chosen correctly. All this should be used to encourage the pupil's curiosity and direct it into development of a natural scientific approach when observing nature.

When constructing the test for the assessment we had all this in mind. In the following the overall results are presented and next it is shown how groups of pupils with similar overall results solved particular selected problems and what can be inferred from these data. Although a detailed argumentation of the findings of the 2007 assessment is beyond the scope of this paper, we summarise the findings in the Conclusions and advise more interested readers to read the official yearly report on the 2007 assessment [2].

2 ANALYSIS AND OVERALL RESULTS

The distribution of the points over the representative sample of pupils is shown in Fig. 1. In order to generalise the results, four groups of pupils with distinctively different overall results have been generated. In the *G1* group (Fig. 1, line-hatched bars) there are 528 pupils around the first quartile border, i.e., the pupils with the overall score between 20 % and 30% of the entire sample. Similarly, the *G2* group (Fig. 1, grey bars) includes 926 pupils around second quartile (45 – 55 %), the *G3* group (Fig. 1, square-hashed bars) includes 756 pupils around third quartile (70 –

80 %), and the *G4* group (Fig. 1, black bars) includes 457 pupils with the best results – upper 10 % of the population.

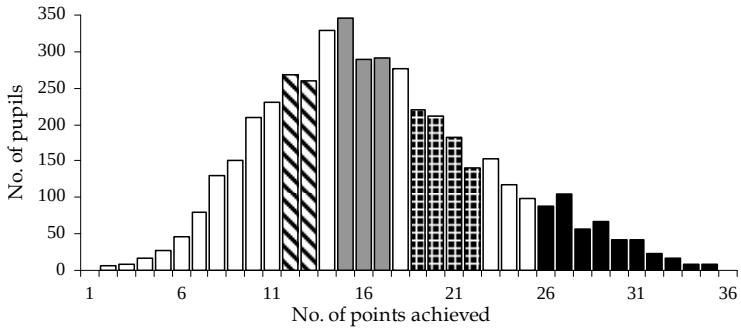


Figure 1 Distribution of the pupils with respect to the overall score.

Although the 46.6 % average overall score does not seem very high – in particular the politicians might not like it, which is always an important issue – one should not think that this necessarily means half of the population should not pass physics at the end of elementary school. Since we are assessing the *knowledge* of physics and we are not making a *selection* test, the test should be set up in such a way to differentiate between the knowledge of the entire population, even between the pupils with very little knowledge and those with little knowledge as well as between the pupils with excellent knowledge and very good knowledge. One gets the most valuable information out of the test when there are not many problems that everybody solves or nobody solves. Having this in mind the national physics test in 2007 was very good and informative.

The questions are organised in groups according to the success of the pupils at a particular question in each group of pupils. So the problems are also named *G1*, *G2*, *G3*, and *G4*. A question is named by the name of the group of pupils with the lowest overall knowledge, who have successfully answered the question. We decided that a question is successfully answered in a particular group of pupils, if more than 2/3 of the group answered it correctly. If, for example, a question is answered correctly by 50 % of the G1 pupils, by 70 % of the G2, 80 % of the G3, and 90 % of the G4 pupils, we put it into a group of G2 questions. An additional group of questions is formed of the questions that have statistically not been successfully answered even by the best 10 % of the population. These questions fall into the "*above the G4*" group. General conclusions are drawn from the common characteristics of each group of questions. We illustrate the analysis by a few examples.

3 EXAMPLES OF THE PROBLEMS

3.1 Problem example 1

The problem has three questions, all related to the electric circuit drawn (Fig. 2) with a voltage source, bulbs (B_1, B_2, B_3) and switches (S_1, S_2). The original wording of the problem is:

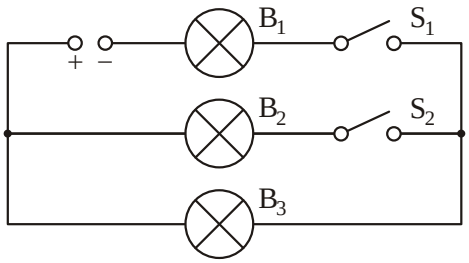


Figure 2 The electric circuit is shown.

a) Through which bulbs is the current flowing, if only the switch S_1 is switched on?
b) Through which bulbs is the current flowing, if only the switch S_2 is switched on?
c) Through which bulbs is the current flowing, if the switch S_1 and the switch S_2 are switched on?

Answers: *a)* B_1, B_3; *b)* none; *c)* B_1, B_2, B_3 .

The three questions seem very similar and we expected similar success of pupils for all three, but the results are quite different (Table 1). The *c)* question was the best answered question in the entire test, with the average success of nearly 90 %. The *a)* question has the overall success of 60 % and the *b)* question has the overall success of 30 %, which puts it among the 12 most difficult questions in the test. The differences illuminate the way the kids think. The *c)* question is trivial for majority – when all the switches are on, all the bulbs glow. In the *a)* question it is necessary to realise that bulb B_2 is not in a closed circuit. One third of the pupils are not aware of that. Finally, for the pupils, the question *b)* is twice less correctly answered than question *a)*, because many overlook that in question *b)* there is no source in the closed circuit with bulbs B_2, B_3. According to the grouping of questions (Section 2), question *a)* falls into group G3, *b)* into G4, and *c)* into G1.

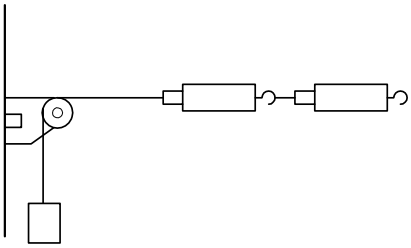
Table 1 The statistics for the first problem example.

	portion of pupils solving the question [%]				
question	G1	G2	G3	G4	Overall
a)	47.7	60.5	75.1	92.6	60
b)	11.4	24.2	45.5	75.1	30
c)	87.3	93.7	95.1	98.0	89

3.2 Problem example 2

The problem is a multiple choice question related to equilibrium of forces and third Newton's law (Fig. 3). The original wording of the problem is:

The one kilogram weight in the figure is at rest. What are the forces shown by the two dynamometers? *Encircle the letter in front of the correct answer.*



A The first 5 N, the second 5 N.
B The first 5 N, the second 10 N.
C The first 10 N, the second 5 N.
D The first 10 N, the second 10 N.

Frequency of the answers:
A: 2214, B: 659, C: 437, D: 1123

Figure 3 The dynamometers and the weight.

Answer: D

Unexpectedly this turned out to be one of the most difficult questions (Table 2). But on the other hand the results prove that the pupils do not understand the third Newton's law and the distinction between the third Newton's law and the equilibrium of forces.

Table 2 The statistics for the second problem example.

portion of pupils solving the problem [%]				
G1	G2	G3	G4	Overall
20.3	25.1	27.9	38.3	25

3.3 Problem example 3

The problem is a multiple choice question related to transfer of heat and conservation of energy (Fig. 4). The original wording of the problem is:

In a container there is 100 ml of water at 16 °C. We add another 100 ml of water at 80 °C into the container. What is the temperature of the mixture?
Encircle the letter in front of the correct answer.

Figure 4 Hot and cold water mix.

A 80 °C
B 64 °C
C 48 °C
D 16 °C

Frequency of the answers:
A: 426, B: 2899, C: 1119, D: 26

Answer: C

This is another difficult question with the overall result of 25 %, which is similar to example 2 (Tables 2, 3). On the other hand the internal distribution of results is quite different (Fig. 5).

Table 3 The statistics for the third problem example.

portion of pupils solving the problem [%]				
G1	G2	G3	G4	Overall
11.2	17.3	33.6	64.3	25

For question 2, the wrong result A is more frequent than the correct result D in the entire population (Fig. 5, left). Even the pupils with the best overall score select A and D with equal probability. This confirms that Newton's third law is not well understood by all pupils. On the other hand, in spite the huge portion of pupils who select the wrong answer B (64 °C = 80 °C – 16 °C) for question 3 the pupils with the overall score 70 % or more do select the correct answer B over C (Fig. 5, right). Thus the averaging of the temperature of two equal masses of water when mixed is understood better than the third Newton's law regardless of the equal overall success of both questions. Both examples fall into the category "*above the G4*" problems.

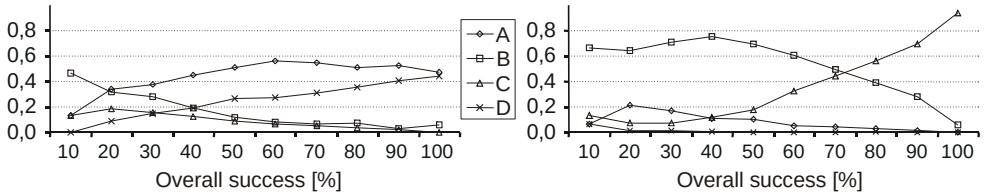


Figure 5 Comparison of examples 2 (left) and 3 (right). The *y*-axis shows the fraction of pupils that encircled A, B, C, or D as a function of the overall success in the test.

4 CONCLUSIONS

The comparison of statistically well analysed questions shows many details that are beyond the scope of this paper, but we present them in another publication [2]. None the less, we demonstrated the power of the national assessment of knowledge of physics and in particular the possibility of deducing more valuable information from well posed multiple choice questions. By reasoning in a similar as above and using the 2007 assessment of knowledge of physics data [2] we have come to the following general results, relevant for the future work of teachers:

- Pupils generally answer correctly to the reproduction questions, where they are required to recognise or select the right answer or where knowledge of facts is required.
- The questions that require more than one step in thinking, the so-called *structured questions*, are very poorly answered.

- Only the top 10% of the population show conceptual understanding of physical phenomena.
- In spite of general common opinion among physics teachers that open-ended questions show understanding of pupils much better than multiple choice questions, we show that one can pose multiple choice questions that give useful conceptual information. It is just that the question and given answers should be carefully prepared.

ACKNOWLEDGEMENTS

All the data used in the paper have been collected and statistically analysed by the National examination centre (RIC – Državni izpitni center, (http://www.ric.si)). The assessment test was prepared by Branko Beznec, Uroš V. Brdar, Vinko Udir, Ivo Verovnik, and Jure Bajc.

REFERENCES

[1] Bloom B. S. 1956 *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. (New York: David McKay)

[2] Rigler Šilc, K. and Štraus, M. (editors) 2007 *Letno poročilo o izvedbi "Nacionalnega preverjanja znanja" v šolskem letu 2006/2007*. (Ljubljana: Državni izpitni center) (*Yearly report on the "National assessment of knowledge" in the school year 2006/2007*. (Ljubljana: National exam centre))