PROBLEM OF EMPIRICAL DISMUTATION IN TEACHING NATURAL SCIENCES

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Abstract

In 2006 on the fourth level of education new types of text tasks were introduced in Matura examination papers. Open tests relating to school experiment were supposed to increase the importance of experimenting in school labs. Test tasks such as: Suggest an experiment…, Note down the observations… should be considered easy because they have roots in empirical work of students and teachers during lessons. The analysis of passing rate of such test tasks on Matura examinations, compared with the results of research carried out on teachers who admit to do no or few lab experiments, reveals a problem existing in Polish schools. Further research proves the existence of a new problem of pedagogic, psychological and social nature that I noticed back in 2007. I called it empirical dismutation, which is a situation in which due to the lack of all elements necessary for it to arise, few people taking part in it achieve teaching success and the vast majority experience partial or complete degradation of success. The article enumerates the causes of pedagogic dismutation, suggests the methods of prevention and describes the threats arising if no prophylactic measures are taken.

Keywords: empirical pedagogic dismutation, high school, Matura exam, lab experiments, open experiment tests, chemistry education, teaching chemistry

Introduction

Tasks that teachers must face on various levels of education change very dynamically. In the light of modern core curricula for natural sciences, they make us reflect on the changes in viewing teachers' competences. It concerns mainly changes for Polish high school teachers, but also teachers and students from all countries in the former Eastern block that after 1989 entered the realities of European or American way of understanding goals of education. The changes determine on numerous planes the subject of research in pedagogy and the model of teachers who shape students' knowledge and skills in the new school reality. They also intensify the research on improving the efficiency of teaching and pedagogic process.

In 2006 a new reformed Matura exam was introduced, which was a breakthrough and it became a model for many European systems of education. Entry exams to universities were abolished. They were replaced with external exams organised in students' home schools. Such considerable changes caused a big stir among the part of society that was interested in the level of preparation of Polish schools for the new challenges. The group included parents, students and teachers but also academia who observed with disbelief and scepticism the ideas of the Ministry of Education transfering the authority to the Central Examination Board.

What constituted the main reason for concern was the new core curriculum, mainly such its implementation so as to face up to the new method of testing, new examination format and new way of grading students' exam papers.

Until 2006 the only natural sciences entry exam to universities was a *multiple choice test* in chemistry, biology or physics organised by the universities. The introduction of so-

called *new Matura exam* caused almost total rejection of multiple-choice tests, in which students chose one out of several suggested answers.

Research carried out among experienced high school teachers of natural sciences with twenty-years' work experience suggests that multiple-choice test is popular. There are several reasons for this. Firstly, a big database with exercises was created over the years. Secondly, teachers quickly learnt technical aspects of such tests and created them in a relatively short time. Thirdly, such type of test is easy and quick to assess. However, further research confirmed that modern open text tasks give students much greater freedom of doing them, formulating conclusions and proposing hypotheses. In natural sciences, comprising chemistry, biology and physics, when an exam task is well-written it is much easier to obtain unambiguous answers. Moreover, an open test eliminates random answers. Naturally, a multiple-choice task can be constructed from a number of elements to make a random answer less likely to be correct, but this causes the task to become an open one.[12]

Core curricula for Polish high schools, which were changed and modified a number of times in recent years, usually suggested that lab experiments should be done in the form of a *demonstration* or *student's individual work*. However, before 2006 the effectiveness of lab activities had little reflection in exercises or exam tasks, especially in the case of multiple-choice tests, which contained hints for students.

Polish as well as many European education systems changed in this matter in the early 21st century. The core curriculum from 2006 contained requirements for teachers to combine theoretical problems with experimenting. As early as on junior high school level general goals of chemistry education (and other natural sciences) contain the following requirements: "Students safely use laboratory equipment and reagents, design and conduct lab experiments".[13] Other fragment reads: "Chemistry is an experimental subject. That is why, the emphasis was put on *chemistry experiment* conducted by students themselves or observed by them (detailed requirements contain a fragment that reads: Student plans and carries out experiments)".

This means that the whole students' knowledge of chemistry comes from two sources: theoretical background, including simple calculations, and lab experiments. The latter is of the greatest importance. The *core curriculum* and commentary on it clearly indicate the obligation to carry out ***lab experiments*** during lessons. Simultaneously, exam tasks in *exam papers* refer to students' ability to conduct lab experiments or their observations of demonstrations given by teachers.

Having analysed the effectiveness of the new way of examining Polish high school students in natural sciences, I observed that between 2006-2013 the passing rate of *open experiment tests* included in Matura exam papers among all Polish high school gratuates who chose chemistry as one of exam subjects came to 20-40%, sometimes as low as below 10%. What is more, since 2006 there has not been a single Matura exam paper which did not include instructions such as: *suggest an experiment, draw up a diagram of experiment, choose necessary reagents out of*… etc.

The carried out research was a comparative juxtaposition of three elements:
carrying out lab experiments, described in the commentary on core curriculum, during everyday school work,
teachers' empirical work with tests taken from exam tests,
passing rates included in fact sheets compiled by the Central Examination Board.

Empirical pedagogic dismutation

[12] TwardowskaA., Grajkowski W., Chrzanowski M., Ostrowska B., Spalik K., *Dlaczego warto zamykać zadania?*, Instytut Badań Edukacyjnych, XVII Konferencja Diagnostyki Edukacyjnej, Kraków 2011.
[13] Podstaw programowa. Edukacja przyrodnicza (…) w liceum. MEN 2013.

I first introduced the term empirical pedagogic dismutation in 2007 in the preface to my problem books in chemistry for students preparing for Matura exam.[14]

Dismutation is a term derived from chemistry. On pedagogic ground it is similar in character to the chemical process described by the term. Empirical pedagogic dismutation is a situation in which due to the lack of all elements necessary for it to arise, few people taking part in it achieve teaching success and the vast majority experience partial or complete degradation of success. I coined this term to describe the state I observed while doing research on Polish chemistry teachers when new Matura exam was introduced.

The conducted research revealed that 100% teachers admitted that they were unable to carry out all lab experiments described in the core curriculum, even though exam tasks referring to lab experiments appear every year on Matura exam. The same applies to experiments that are part of other tests in exam papers.

When we juxtapose other test tasks with data on conducting such experiments during lessons and then with the passing rate, it comes as no surprise that the rate is so low.

Let us assume there is an open test task to do in the form of an experiment. Students who are to complete it ought to have done it themselves or should have observed a teacher's demonstration during chemistry lessons. Students under teacher supervision learnt all the elements of a lab task: 1) design of experiment (choice of glassware, methods, etc.), 2) choice of reagents, 3) record of observations, 4) conclusions, 5) chemical equations.

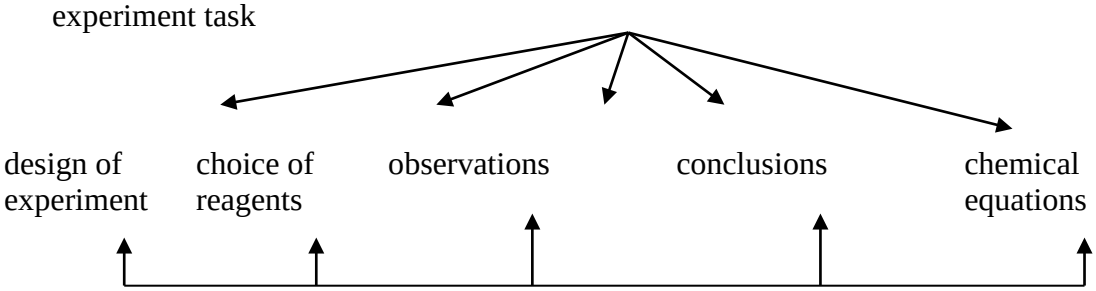

Fig. 1. Mutual relations between elements of experiment.
Source: own data

The diagram shows that all five elements of experiment are closely combined. Usually the knowledge of just one element enables to describe the others. This is the sense of all exam experiment tasks.

Research carried out among teachers proves that situations when they do not do lab experiments with students arise permanently. Teachers often believe that theoretical knowledge (two out of five elements of experiment) is sufficient. When students during examination encounter a task such as: design an experiment… and they have never done or seen it before, a situation arises that is called *empirical dismutation*.

Students strive to find the elements of experiment. They are unable to do it because they have never seen this exercise – they have neither seen the necessary reagents nor have observed the processes organoleptically. Some students, especially those gifted ones, will have good theoretical background, but no empirical) knowledge. Nevertheless, in this group of students we can assume that the result of empirical dismutation will be a success.

[14] Witowski D., *Chemia. Zbiór zadań otwartych wraz z odpowiedziami*. vol. 1-2, Oficyna Wyd. Nowa Matura, Łańcut 2007.

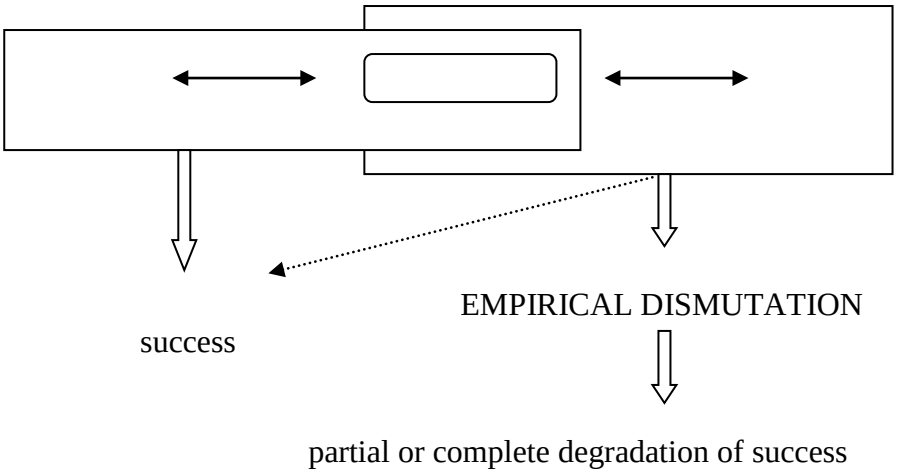

Fig. 2. Emergence of empirical dismutation.
Source: own data

Low passing rate of such text tasks is a consequence of the fact that chemistry teachers abandoned lab experiments in schools. Among the majority of students (mainly average and poor ones) a stressful exam situation together with no empirical knowledge of a task and insufficient theoretical background will lead to an instant degradation of success due to empirical dismutation. In this situation students are unable to combine the elements of experiment. When a task concerns one element, but it requires adding other elements of experiment as well, a degradation of one or all elements takes place.

Let us assume that an instruction to a task contains one element of experiment, e.g.: chemical equation, but students are asked to write two other elements: reagents necessary to produce a complex chemical reaction and observations. Empirical dismutation can degrade the whole process of reaching correct answers because students will not be able to relate ions to necessary reagents. To counteract total degradation of success, students can be given some reagents as a hint. Then, passing rate of this part of test may be slightly higher. Unfortunately, no such thing can be done in the case of the second part of instruction, i.e.: observations. Students who had not carried out a similar experiment and had not recorded all its elements will not write any observations. Here, partial dismutation takes place.

As shown on the diagram below, in a situation when an open test to be done refers to at least one element from *experiment record form*, which element was not observed during lab experiments in school, partial or total degradation of correctness of answer is about to take place.

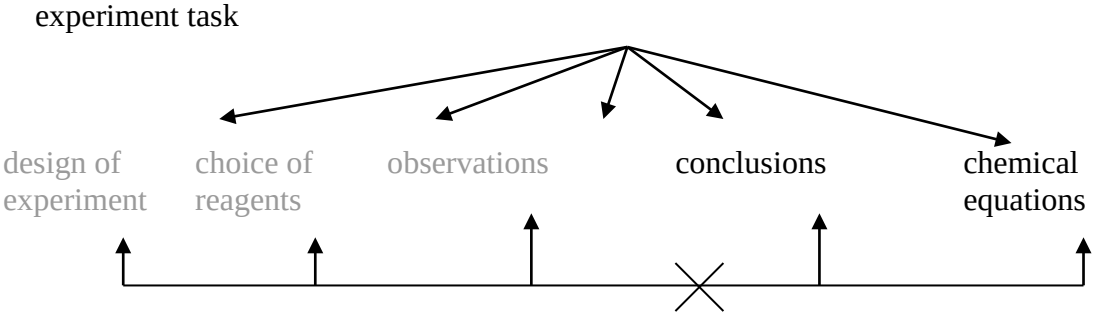

Fig. 3. Degradation of elements of experiment as a result of dismutation and absence of teacher's empirical work.
Source: own data

The Central Examination Board in 2010, i.e. four years after so-called new Matura exam had been introduced, made a probably random diagnosis telling what to do in order to prevent empirical pedagogic dismutation: "(…) those few students who attempted to complete the exam task and planned further steps of experiment, frequently described actions impossible to perform (…). Such answers are the consequence of verbal teaching of chemistry with students learning about experiments mainly from coursebooks. We must bear in mind that full understanding of chemical processes can only be achieved through unassisted carrying out experiments by students. Unless the teaching process of chemistry changes, all tasks referring to experiments (designing, recording actions and observed changes) will always be considered difficult or very difficult."[15]

The research I have carried out over the last few years indicates that as many as 20% teachers of natural sciences have not carried out any lab experiments in schools since 2006, i.e.: since the introduction of so-called new Matura exam. Only 38% conduct more than a half of experiments required by the core curriculum and contained in experiment tests in Matura exam papers. And this number represents the approximate passing rate of more difficult exam tasks. Thus, a direct relation can be observed between underestimation of the importance of empirical approach to school experiments and the results of Matura exam.

The teachers subjected to research gave the following reasons for not conducting lab experiments: lack of time due to insufficient number of lessons allocated for the subject (100% answers), unavailability of reagents (45%), low school funding which does not allow to buy reagents and lab glassware (38%) and others.

What is worth emphasising, also 12% students indicate that lab experiments are very time-consuming. Not understanding the growing problem of empirical dismutation, they suggest multimedia presentations as an alternative to real-life lab experiments.

The problem of empirical dismutation will increase in the following years. It is now of not only pedagogic but also social nature. We should also pay attention to parents' dilemmas who observe with surprise students' low results in experiment tasks, which were supposed to be easy to complete. When parents blame teachers, they explain that experiment tasks were discussed in the lessons. They may have been discussed, but not carried out and when an exam task requires students to design an experiment, choose reagents and record observations they are unable to do it. During examination lack of practical knowledge triggers empirical dismutation, which manifests itself in partial or total degradation of synthesis of data needed to provide correct answers.

Conclusion

On the basis of research on low passing rate for experiment tests and analysing commentaries on the reports produced by the Central Examination Board, one might get an impression that such type of test is difficult for examinees.

But the real cause for low exam results is the problem of psychological, methodological, and social nature, which I called empirical dismutation and which has not been discussed or researched yet. The underlying cause is the nationwide wrong approach to lab experiments in teaching natural sciences. It demonstrates in the legal and mental spheres as well as in the growing concern in schools.

The described dilemmas, being the result of laborious research on teachers' work, ought to undergo further study in order to make a correct diagnosis and counteract the growing problem of empirical dismutation. Proper pedagogic prophylaxis supported by nationwide measures such as intense control of following the core curriculum could overcome the effect of dismutation and teaching failure, the latter showing in poor exam results.

[15] *Osiągnięcia Maturzystów*, Sprawozdanie z egzaminu maturalnego, CKE, Warszawa 2010, p. 129

References:

Osiągnięcia Maturzystów, Sprawozdanie z egzaminu maturalnego, CKE, Poland, Warszawa 2009, p. 164, 2011 p. 104, 2008, p. 102, 2010, p. 129.

Podstaw programowa. Edukacja przyrodnicza (…) w liceum. MEN 2013.

Grajkowski W., Chrzanowski M., Ostrowska B., Spalik K., Twardowska A., *Dlaczego warto zamykać zadania?* Instytut Badań Edukacyjnych, XVII Konferencja Diagnostyki Edukacyjnej, Kraków 2011.

Witowski D., *Chemia. Zbiór zadań otwartych wraz z odpowiedziami*. vol. 1-2, Oficyna Wyd. Nowa Matura, Łańcut 2007.