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The new face of science education in Poland

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The objective of the study was to remind people that science education in lower secondary schools is a typical example of educational window dressing. An analysis of the results of the final lower secondary school examinations is presented, which indicates that nearly half of lower secondary school graduates did not attain 30% of the required competences. The basic disadvantage of the science core curriculum – the lack of the hypothetical character of natural sciences – is also pointed out. As a result, problem-based learning has been proposed as a method of repairing science education at the lower secondary school age. The possibility of using the 8 point method and its compliance with the 5E scheme is pointed out. In conclusion, the question is asked: was the elimination of the compulsory educational project for 15-year-old youth premature? Maybe the project should be implemented in the curriculum of grades 6-8 of elementary school. This question will soon be answered in 2 – 3 years while assessing the effects of school reform.

Keywords: window dressing activities, science education, education crisis in lower secondary school, education reform in Poland in 2016.

Introduction

The key to wisdom is this – constant and frequent questioning
Master Abelard, 12th century AD

Most science teachers know that *student learning* has its roots e.g. in John Dewey's pragmatism: *education must be seen as a continuous reconstruction* of experience (Dewey 1897, p. 77–80) and in Piaget's challenge: *intelligence organizes the world by organizing itself.*

However, as it has always been, knowledge of even the most economically and scientifically effective teaching (and, in principle, *learning*) of concepts does not transfer so easily into the practice embedded in the culture of schools and local communities, teachers' habits, and the tradition (often unfortunate) of developing textbooks and core curricula.

Hence, many groups and institutions from the fields of economy and science support pedagogues and form a so-called *mediating layer* (Mourshed, Chijioke, Barber, 2010, p. 91) between governmental institutions and schools. The endeavour is, above all, for graduates to be better prepared for the

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challenges of a modern economy, science and administration.

Therefore, at this point two questions were formulated. The first: Is it possible to prove that there were real problems with science education in the now cancelled lower secondary schools? If so, what were the reasons for this? The second: Was it possible to overcome this problem by changing the teaching system, for example, towards the constructivist concept? Was it possible to apply solutions prepared by an organisation working as a mediating layer to help in this process?

Research methods

According to Professor Marta Dudzikowa, the current school practice, including teaching at the lower secondary school stage, very often takes the form of *window dressing* (Dudzikowa 2013, pp. 27-82). According to the author, these *illusory activities* include the lower secondary school exam with at least one year of preparation.

The lower secondary school exam in Polish is so simple that most students pass it with good or very good grades. And the assessment of such a basic language skill as writing a statement is verified only to a very limited extent (Trysińska, Piotrowski 2017, pp. 109-133). Hence, if Polish teachers try to help their students achieve a good test result but at the same time forget to teach them important language skills (which are not on the test), they may find themselves in the area of the so-called *unreflective codes* (Piotrowski, 2013, pp. 240-254).

The mathematics examination, unlike the Polish language exam, is so difficult that almost half of lower secondary school students are unable to solve even 30% of its problems (Piotrowski, 2016, pp. 95-122). In this case, the lower secondary school exam reveals the ineffectiveness of the uniform teaching of mathematics provided to all pupils on the same level, i.e. *window dressing* being a consequence of the assumption that *it is necessary to extend uniform general education to 16 years of age*.

Can such calculations show that a similar crisis is occurring in science teaching? Our research began with this premise. Currently, in lower secondary school education, the teaching of natural sciences (biology, chemistry and physics) can be described as sheer *window dressing*.

It is true, however, that the core curriculum for lower secondary schools includes so-called *experimental requirements*, (Ministry of National Education, 2010, p. 123), but the concepts of hypothesis, research questions, etc. are missing. Therefore, it is difficult to expect that such experiments will help students understand the essence of the natural sciences, the way scientific knowledge is created, etc.

In the case of physics, a manipulative statement is even included in the core curriculum, stating: *Physics is an experimental science* (Ministry of National Education, 2010, p. 175), but at the same time, the existing excess of knowledge to be taught has not been limited. *The presented basic core curriculum (lower secondary school and first grade of upper secondary school) covers a large part of the traditional scholarly material taught thus far* (Ministry of National Education, 2010, p. 173). Therefore, conducting school experiments and observations was rendered difficult if not altogether impossible.

Since we are abandoning the ineffective paradigm of knowledge transfer and expecting that about 20-30% of the population is to obtain high-level competences, it is necessary to return to the 50-year-old concept of Wincenty Okoń, who pointed out the emotional and practical sphere as equally important in the development of students (Okoń, 1967). Similarly, half a century ago, professor Czesław Kupisiewicz encouraged students to acquire active knowledge, which is an indispensable condition for performing new activities, rather than merely acquiring passive knowledge, useful only when answering externally asked questions. He proposed working through a discovery method using the following scheme (Kupisiewicz, 1976):

a) *determine the nature of the problem;*
b) *put forward, justify and choose hypotheses aimed at solving the problem;*
c) *verify the hypotheses by solving the arising issues;*
d) *perform the final verification and evaluation of the results obtained.*

Since the problem concerned several years of graduates, a convincing example had to be found, in which the curriculum mistake was corrected and problem-based learning was implemented on a large scale (thousands of teachers and tens of thousands of students).

Research results

The destructive power of *window dressing in education* is also revealed by the results of the lower secondary school exam. Although the natural science examination consists of closed single-choice questions, most of which relate to knowledge, its analysis indicates a crisis in natural science education in lower secondary schools.

By subtracting the results of guessing through a linear relation[1] from the result of the test (*y*), we obtain four categories of results. The share of pupils who received results from the individual result ranges was determined on the basis of data from the Central Examination Board (Kwiecień, Tyralska-Wojtycza, Baldy, Wieczorek, Sapanowski, 2017, p. 88). The results of the calculations are presented in Table 1.

Table 1

Results of lower secondary school exams in the natural sciences in 2017

Level	Conditions for probability (*p*)	Conditions for exam result (*y*)	Percentage share
III	$p \geq 60\%$	$y \geq 70\%$	18%
III+	$p \geq 90\%$	$y \geq 93\%$	4%
II	$60\% > p \geq 30\%$	$70\% > y \geq 48\%$	37%
I	$p < 30\%$	$y < 48\%$	45%

Level III: Students who passed the exam (with a result greater than 70%) represent 18% of the population, meaning the test was probably not too difficult.

Level III+: Out of the students who have passed the exam, as usual, a group with very good results can be distinguished (with a result greater than 93%).

Level II: Most results should fall in range *p* from 30% to 60%, but actually only 37% do. The distribution of results is therefore not similar to the unimodal Gaussian distribution. Therefore, the basic assumption adopted in many analyses may be considered incorrect.

Level I: 45% of the students were able to solve fewer than 30% of exam problems. Therefore, 45% of pupils should repeat lower secondary school before going to

[1] Using the linear approximation, the result of the exam (*y*) and the probability (*p*) that there will be a problem in the exam that the pupil can solve without guessing is linked in the equation: $y=28p+\frac{(28\,(1-p)}{4}=21\,p+7$, where 28 is the number of test items in the exam.

general upper secondary school or vocational upper secondary school. This result definitely confirms a negative evaluation of natural science education in lower secondary school. It testifies to the considerable destructive power of *window dressing in education*.

Towards problem-oriented teaching

Looking for solutions to fix the curriculum in science education, we present the 8-point model of classes.

The concept of the 8-point model for conducting school classes is based on the scientific method. The 8-point model was developed as a result of seeking a way to introduce American teachers' (VanCleave, 2007) experiments to primary school (starting from grade zero). The goal of this undertaking was to train heuristic skills in the early years of learning, and thus to equalize educational opportunities for the children of less educated parents (Piotrowski, 2011). It was intended to be a project that forms an *elaborated cognitive code* in reference to the concept of developing an *elaborated language code* defined by Bernstein (1990).

The emergence of *50 recommended experiments*[2] in the lower secondary school curriculum in 2009 (Ministry of National Education, 2010), as well as the *lower secondary school educational project* and the promotion of *key EU competences* enabled the use of a different approach to teaching and learning in lower secondary school years. To support the new curriculum, the *Student Academy* programme developed and implemented model training for approximately 1,500 teachers of mathematics and natural science, who worked with 40,000 lower secondary school pupils (Piotrowski, Dolata, Kielech, Dobrzyńska, 2012a and 2012b).

[2] The number was equivalent to one experiment per two weeks.

In a publication about the erroneous foundations of mathematical education and the ways to fix them (Piotrowski, 2016), the concept of school classes was presented as a remedy to inefficient mathematics teaching devoid of inductive research. This paper presents only those elements of the 8-point model, which are important in teaching natural science subjects, including physics.

Examples of the practical implementation of the 8-point model in lower secondary school science teaching have already been presented in a series of publications (including by teachers participating in the *Student Academy* project, 2014 and Dolata et al., 2014), as well as in a doctoral dissertation (Jakubowski, 2016). The analysis of these materials allows us to not only shed a different light on student *learning* about nature, but also to reflect on the need and possibilities of formulating a core curriculum for grades seven and eight; this would be in a form similar to the *Next Generation Science Standards* (National Research Council, 2012).

Comparison of the new 8-point model with the 5E schedule

In the mid-1980s, the Biological Sciences Curriculum Study (BSCS) received a grant from International Business Machines Corporation (IBM) to conduct a study that would produce design specifications for a new science and health curriculum for elementary schools (IBM – Biological Sciences Curriculum Study, International Business Machines Corporation, 1989). Among the innovations that resulted from this design study was the BSCS 5E Instructional Model (Bybee, 2015): Engage, Explore, Explain, Extend, Evaluate.

In the following years, the model evolved to 6E by adding the eNGINEER stage for technical education (Burke, 2014) or adding the *e-search* component (Chessin, Moore, 2004, pp. 47–49). The 7E cycle has also recently been discussed (Turgut, Colak, Salar, 2017, pp. 1–28): Elicit, Engage, Explore, Explain, Elaborate, Evaluate, Extend. Still, the majority of publications on teaching science subjects continue to apply the 5E model.

I. Engage

The aim of the first stage of education is to arouse students' interest so that they commit to active class participation. In this stage, pupils recognize the relationship between past experiences and present challenges.

In the 8-point programme, the *Engage* stage consists of activities meant to define the subject matter of the course:

1. Formulate a research question – the problem.
2. Create a canon of concepts and phenomena relating to the research question.
3. Students formulate hypotheses that attempt to answer the research question.

II. Explore

Using materials provided by the teacher and their own searches (most often online), students prepare an experiment to provide an answer to the research question. They verify the hypotheses formulated earlier.

In the practical 8-point scheme, the second stage consists of the following points:

4. Experiment description. Depending on the age of the students and their experimental skills, the description of the experiment may take varied forms. For children aged 8-12 (or younger), the description of the experiment prepared by the teacher may take the form of drawings and blueprints (Van Clave, 1993). In the case of lower secondary school students, the description of the experiment may include variables (Callaghan, Ross, Lakin, 2006, pp. 87-121) and literature references.

Students distinguish variables using three questions:

1) What variable/amount are we going to change? (independent variable),
2) What variable/amount are we going to measure – observe? (dependent variable),
3) What in our experiment are we not going to change, but only control? (controlled variables).

When formulating the research question and selecting the experiment, it is important to remember about the surprise effect, also referred to as the *Wow* or *Eureka* factor. Many teachers noticed that at the lower secondary school stage, having a class be spectacular is not as important – with its *Wow factor* – as is the perception and understanding of surprising causal relationships – *Eureka*. A series of classes may also be developed so that the *Eureka* effect occurs in a delayed form (Callaghan, Ross, Lakin, 2006).

5. Health and safety. This concept has two meanings. The first is associated with the usual risk of conducting experiments, often performed on the basis of information from the Internet. The second risk, as in the case of teaching mathematics, results from the possibility of infringing copyrights, in particular when the experiment descriptions are posted on the school website (which has an informative role in this situation, rather than educational).

III. Explain

In the 5E concept, students *start exchanging opinions on the results obtained – trying to combine the events into a logical whole.*

In the practical 8-point model, the explain stage consists of the following:

6. Student's memo. The students formulate and justify the answer to the research question and evaluate the validity of earlier hypotheses.

IV. Extend

The goal of the *extend* stage is to develop the competences acquired in order to solve new problems. In the 8-point concept, the *extend* stage takes the form of proposals for further student activities defined by the following three levels.

- The first level, requiring the least interest, may consist of, for example, improving a student memo.
- The second level, requiring greater involvement, may be related to finding encyclopaedic explanations of the terms from the *canon of concepts and phenomena*.
- The third and most difficult level is the definition of a new research question/problem.

V. Evaluate

In the 5E cycle, this stage is the end of teaching following self-evaluation, while in the 8-point model, self-evaluation precedes the formulation of further research plans.

Many questions and instructions have been developed for self-evaluation in the 8-point method, including the two following sets provided as examples.

Set 1. Complete the sentence:
a) I was curious about…
b) I managed to…
c) I would like to know more about...
d) I also noticed...

Set 2 enables self-assessment based on three component competences (knowledge, skills and attitude). Complete the sentence:
e) During class, I learned that…
f) Thanks to the classes, I can make/do...
g) Thanks to the classes, I intend to...

In the 5E model, problem development and assessment can occur at all points in the process.

Discussion

To assess the qualitative change achieved by the 8-point teaching model, key competences were referred to. The methods applied at the *Student Academy* were based on the active participation of students and an assisting teacher and enabled the implementation of two fundamentally different requirements of the core curriculum, as well as *key competences for lifelong learning*.

On the one hand, each *Student Academy experiment* was linked to a detailed teaching content, and each of the projects was linked to the so-called general requirements of the core curriculum; on the other hand, the *Student Academy* was recognized by the KeyCoNet agenda of the European Parliament as a model solution for the introduction of key skills to the education system (Wisniewski, 2013).

For the vast majority of teachers, including those joining the *Student Academy*, the European Parliament's key competences document seemed to be another not-so-needed product. In time, however, they came to appreciate its form (e.g. a useful definition of competences as the sum of knowledge, skills and attitudes) and they noticed serious difficulties in introducing requirements into everyday school practice that seem simple and obvious only at first glance.

From among the eight distinguished areas of competence, pupils were learning four within the *Student Academy*:
1) mathematical competence and competence in science and technology;
2) digital competence;
3) learning to learn;
4) social and civic competences.

The effectiveness of combining the 8-point model with key competences indicates a need to change the current model of teaching science to children of middle school age. We cannot be sure if the model will turn out to be much better. However, due to the failure of existing methods, it probably needs to be used when working with lower secondary school students along with other methods of evaluating effects, not only those based on primitive one-choice tests (as is done today).

Summary

This paper presents the problems encountered in teaching natural sciences in lower secondary school. The document is meant as a background for the assessment of the new core curriculum for primary school grades seven and eight.

The effects of *window dressing in education*, including e.g. *failing the lower secondary school exam* in natural sciences by half of its graduates, was presented. Consequently, the current core curriculum was shown as preventing students not only from developing skills and attitudes, but from also being effective in its key area, namely the *application and transfer of knowledge.*

The paper focuses on two class models that may help resolve the current crisis (by transitioning from thematic to problem-focused teaching): the 5E model and the 8-point course scheme.

The 8-point model would lead to the inclusion of experiments and observations, educational games, mutual teaching and educational projects in a problem-based *learning environment*. A modification of the educational system would support the development of EU key skills.

The 8-point model contains elements of scientific dialogue that is conducted by students. By formulating questions, putting forward hypotheses and conducting research, they try to resolve doubts. The joy of knowing is enhanced by the Wow! or Eureka! factor. The summary questions allow them not only to assess their own work, but also to increase the sense of accomplishment. The last, 8th point of the model motivates them to do further research. Most teachers are familiar with traditional descriptions of experiments and the scientific method of creating knowledge, which they learned while writing their BA or MA thesis. Thanks to the 8-point model, they can enable students to discover the joy of knowing, which is rarely available in schools today. A separate question is whether they will find time for such activities. However, about 2,000 teachers at the *Student Academy* did so despite the fact that the previous core curriculum was equally unsuitable for teaching science to students of lower secondary school age as the current one is. And what is worse, lower secondary school education ended with a test consisting of primitive, closed, one-choice questions and the results of the test was the basis for assessing students and teachers. The 8-point method presented in the article, similarly to the 5E scheme, allows the use of information found in textbooks and Internet during classes. It is similar to the Oxford debate, which is changing the teaching methods of the humanities at school. Hope for the spread of new forms of teaching science is even more justified since the authors of the current core curriculum have admitted to making a serious mistake – the teaching content in primary school is two-times too large. However, such school curriculum reform is never easy. It requires such initiatives as teacher training through e-learning or blended-learning, the involvement of coaches in the training process, securing financing for extra-curricular classes, and cooperation between academics and teachers.

Similar ways to support schools were recommended by auditors from McKinsey & Company who studied successful reforms of the educational system (Mourshed, Chijioke, Barber, 2010, p. 80).

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