

ANALYSIS OF EXPERIENCE IN ENVIRONMENTAL PROJECT TEACHING USING ESSAY AS A FEEDBACK

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Abstract

Models of hydrogen-cars and current fuel cell topic are getting just very slowly into Slovak secondary school teaching of chemistry. The research therefore focus on different ways of suitable utilising of the model in chemistry teaching. The concept of the project teaching namely School Eko-bus with environmental issues and particular goals within which students make experiments on the hydrogen-car models was established. A part of the research is directed at finding answers on the following question: What means of feedback are the most suitable for verifying the results of making effort to develop specific competencies? In terms of research students' and teachers' questionnaires besides observation of students at practical activities, students' taking research notes, their presentations and essays are being evaluated. The study refers to advantages and disadvantages of essay as unconventional feedback device in natural science project teaching at Slovak secondary schools. Writing thus forces students to be more active, to think autonomously as well as independently, and written formulation of their thoughts proves the quality of their thinking; moreover, it also reveals content and formal deficiencies of their thinking. For teachers these deficiencies therefore become more vivid and noticeable. In their little literary works – essays, students demonstrate critical thinking; use knowledge of general and inorganic chemistry as well as knowledge of fuel cells, and in their written ideas students defend their pro-environmental attitudes.

Key words: *environmental education, essay, feedback, hydrogen car model, project teaching, textual analysis.*

Introduction

Teaching in the laboratory, science teachers are offered a great amount of opportunities to create various situations in which practical skills such as observation, experimentation as well as finding solutions to practical problems, discussing the problems and finally summarising and presenting results can be applied. Moreover, with proper teaching tools, teachers are able to lead their students into complex learning situations that provide development of learning skills, better understanding and creativity. They also are a great source of emotional experiences for students. Today, the problem of key competences is being discussed along with the proceeding reform of the school system in Slovakia. Therefore, the current demands for output and realisation of the process of education involve the development of key competencies the essential part of which are critical thinking and positive approach to the environment. Project teaching seems to be one of the most convenient ways to achieve these goals.

A part of the research examines proper implementation of didactic toy HyRunner – hydrogen car model (www.minihydrogen.com) into chemistry teaching process. Application of the car as a teaching tool is not new in school routine, but the efficiency of the model application into teaching process still has not been scrutinized. That is because the attention is nowadays focused more on proposals to introduce this model into chemistry teaching in

elementary and secondary schools. P. Opatrný reveals a complete absence of the current topic Fuel cells on curriculum in both elementary and secondary school evidence of what we can find in his knowledge and attitude analysis of grammar school students in the Czech Republic (Opatrný, Bílek, 2005). In Slovakia, there is a similar situation; therefore, the implementation of experiments with the hydrogen car models as a practical part of eko-project namely School Eco-bus on hydrogen fuel cells utilization in traffic is suggested here (Dzurišínová, 2008). Whether the above mentioned model is a proper teaching tool for chemistry lessons, the research reveals in the outcomes of our project teaching such as answer sheets, students' presentations, observation of practical classes, regular students reports, knowledge tests and essays. The results of the research provided us an opportunity to make a complex overview of project teaching advantages in which hydrogen cars are central theme.

Problem of Research

In the presented part of the research a text analysis of students' essays is portrayed. Essay is a means of feedback which provided an opportunity to gain respondents' utterances containing their interest in improvement of city environment, willingness to help financially or to prove citizen involvement. Listing particular examples, they had an opportunity to show their understanding of bonds between their argumentation and wider social, economical and environmental impact. The expectations suggested in the hypothesis are that students can use their chemistry knowledge and information received during the project teaching. It is assumed that these essays can show us how the first graders of grammar schools are capable of reasoning and can reveal us errors and imperfections in their knowledge. Furthermore, taking into consideration the experience of Turek (2003) who recommend essay as the most effective way of development of the competencies, we focused our attention on this matter.

The post, hence, briefly defines theoretical background of our study at first. The second part brings the details of the research realisation and the final part consists of the results and analyses regarding the applicability of essay as the means of background in project teaching in above mentioned context.

Research Focus

ABOUT THE PROJECT

Project with the name School Eco-bus was designed as an alternative approach to teaching Redox reactions topic (or Application of Redox Reactions) in the first year of studies at grammar schools. With the content itself, the project interferes with Hydrogen topic too. There are 6 lessons planned for the tasks; 1 preparatory lesson, 2 lessons of practical work, 2 lessons devoted to the presentations and final lesson assigned for filling in the answer sheet and writing essay.

The first preparatory lesson leads the students into the simulated situation; introduction of the project goals and its details are the teachers' main objectives. The fictional situation is that the headmaster at the J. A. Rayman Grammar school is willing to buy a hydrogen-powered school bus. To get a financial contribution, he comes with the demand to the parents' school council. The council comprises of these members: an ecologist, a mechanic, a scientist, an owner of a bus company, father of two children attending this grammar school and a lady working for an advertising agency. They all show great interest and so they come up with many questions. That is the moment when each council member is assigned to one of the advisory groups of students.

The advisory group of students was given a set of task in the form of answer sheets.

The main goal was to find answers to set questions, to summarise their findings and to present the results at the upcoming meeting of the parent's school council so that they persuade the members about the accuracy of their opinions. Spontaneously, the students formed 5-member teams and within each of them they worked on partial theoretical tasks, and afterwards on practical work. Bringing the theory to practice the teams used the hydrogen car models to prove their hypotheses. Using these teaching tools we try to fully exploit inter-relationship between school subjects such as chemistry, technology, physics, sociology as well as economics.

As mentioned above, the project teaching School Eco-bus is designed to bring into chemistry teaching elements of environmental education. More specifically, the tasks, students have to solve, overlap thematically with topics such as Using alternative sources of energy, Renewable natural resources, Human air pollution (traffic), Greenhouse effect or The Sun – the biggest source of energy on Earth. Working on the assignments and outcomes, students use IT technologies and, thus we indirectly support the development of media education competencies within the topics Critical thinking and reflection on the mass media, Making news, Interpretation of the relationship between media news and real life, Making own opinion based on received information.

ESSAY AND CRITICAL THINKING

The linguists Mistrík and Gómez-Martínez (1974, 1996) define essay as a literary piece of work, genre, and reasoning written in a witty, vivid style with professional, mostly literary artistic or philosophical theme. One of the basic attributes of essay is subjectivity. The author has the right to end it up anytime and no matter how; moreover, they can use their own words and expressions. The main objectives of essay are to cultivate autonomous thinking, autonomous work and approach to the discussed topic as well as to gather courage to express writer's own opinion and to give compelling reasons.

In natural science subjects we can apply so called argumentative or critical essay (Guide to Different Kinds of Essays, 2010). While in argumentative essay the writer tries to persuade the reader of accuracy of his or her opinion, in critical essay he or she analyses the strengths, weaknesses and methods of someone else's work.

Regarding critical thinking, according to Gavora (1995) the quality of it depends on how familiar the author is with the theme, but this knowledge has nothing to do with the ability to think critically. Critical thinking is a demanding process. If assumption of critical thinking is really important, it has to be used systematically in schools. Therefore, during the project work School Eco-bus, to get constructive feedback we tried to give our students enough time to express their thoughts, to allow them to think freely and to think deeply about serious problems, to create a positive working atmosphere in which they were able to receive a wide range of ideas and views, to ensure safe workplace, free to work without fear and disdain, and last but not least, to appreciate critical thinking according to Petrasová (2003).

Methodology of Research

General Background of Research

The research work realised in two first grade classes of the Grammar school of J. A. Rayman in June 2009 featured the main idea, and once again it was repeated in June 2011, at the same place and in two first grade classes, too. The total number of students involved in the research work is 118 (66 students in 2009 and 52 in 2011). In each class there was different

chemistry teacher, whereas we expected that if teacher's personality can influence the results of survey, then the influence will show up. As there were noticed no remarkable differences in the outcomes of all four classes, the results of the same year will be presented together.

Instrument and Procedures

The realisation of the project raised a new question: How the alternative teaching approach, using environmental problems (hydrogen car model) supports the development of key competencies. Considering this, another partial aim of the research was defined: to suggest tools for models usage accuracy assessment in relationship with the above mentioned development of core competencies. Essay that students were asked to write a week after the project teaching had been chosen as one of the most appropriate tools. It was supposed that the girls and boys participating in project should be able to summarise and present acquired knowledge, experience and skills in a written form, and therefore, to show their critical thinking and scientific reasoning ability. We also expect them to assume the pro-environmental attitudes, where they show their understanding of the relationship between local and global problems (National Education Programme, 2008).

The instructions for the final written work were: "Your task is to write an open letter to the mayor of Prešov, in which you propose the purchase of hydrogen buses for MHD (city public transport). Give the pros and cons and at the same time explain why you are persuaded about the rightness of your point of view." Students were given the limit of 45 minutes (the length of one lesson) and size of the letter should not be more than A4. The final assessment was divided into four sections: critical thinking, knowledge, expression of thoughts and environmental attitudes. In 2011, led by the results of the previous project, we slightly changed the text by adding: "Use the information you gained at the project work School Eco-bus. Keep in mind that the mayor and the city council do not necessarily need to be engineers."

Data Analysis

The following list contains expected outcomes. The core environmental competencies are written in italics. Taking into consideration acquired knowledge, students should be able to:

- explain the principle of electrolysis; to explain changes that appear at anode and cathode in proton exchange membrane electrolyser,
- explain what is a fuel cell; what is the difference between a fuel cell and galvanic cell and to name the elements of it
- explain on what principle hydrogen PEM fuel cell works; process of redox reactions in PEM fuel cell; describe partial processes in anodes as well as summary reaction
- describe the position of hydrogen in periodic system of chemical elements,
- explain the atomic structure of hydrogen,
- name the most important hydrogen properties: colour, state, consistence,
- name the ways of hydrogen production,
- explain why hydrogen was used to lift balloons
- name three ways of hydrogen storage and transportation,
- name at least three ways to use hydrogen,
- name three primary sources of energy,
- describe solar-hydrogen energy system,
- explain the difference between renewable and non-renewable resources of energy,
- state an example of possible future sources of energy,
- name some car producers testing hydrogen cars,

- name a country or a town, in which they use hydrogen powered public transport,
- explain what The Kyoto protocol is; describe it; say what changes the UN Conference in Denmark in 2009 brought,
- describe the mechanism of greenhouse effect,
- state at least three reasons of global warming.

One part of the study was focused on verifying the ability of students to express their pro-environmental attitudes. Students should be able to show that they can see the inter-relationship between their behaviour and the impact it has on our society and on the environment. The complexity of environmental problems is the first of the goals of environmental education “to foster clear awareness of, and concern about, economic, social, political, and ecological interdependence in urban and rural areas” (Tbilisi Declaration, 1977).

It is obvious that purchasing a single hydrogen-powered bus for city transportation has just a little effect on the environment. On the other hand, the principle of the complexity of the environment understanding is the understanding of our responsibility for its protection. That was the central theme of our debates with students.

There was used categorization to analyse the results; the statements students made are divided into three groups: the opinions expressing critical thinking, pro-environmental attitudes and knowledge. All ideas stated in essays are further arranged into three different categories: remarkable, considerable and acceptable achievement. The categories and criteria were elaborated on the basis of the studies concerning essay evaluation in natural sciences education area in other countries, e.g.: criteria layout by R. W. Watson (2010) or anthology of essay assessment samples by H. Košťálová and J. Straková (2008) or Atherton (2011).

Results of Research

The findings of the research are classified as follows. The scale of students’ ability to reason systematically and to support these arguments by relevant facts was the main key to the assessment of essays.

1st category – critical thinking and ideas expression

Remarkable achievement	Considerable achievement	Acceptable achievement
CRITICAL THINKING		
<p>Student proves clear understanding of a problem (at least, in two aspects of the problem). To express his or her attitude, he or she uses the most relevant information from the provided material. His or her opinion is based on facts and careful consideration of consequences; he or she is able to name pros and cons of the discussed problem; moreover, he or she bears in mind the consequences of the suggested solutions.</p>	<p>Student proves his or her understanding of a problem (at least, in one aspect of the problem). To express his or her attitude, he or she is able to use the most relevant information from the provided material. His or her opinion is based on partial deliberation of facts with just a small consideration of consequences.</p>	<p>Student proves just a little understanding of a problem or its aspects, he or she uses just basic information provided. Expressing their own attitude, students mix up facts and opinions.</p>
IDEAS EXPRESSION		
<p>A student assumes clear attitude. His or her argumentation is systematic or with just a little mistake of fact. A student takes into consideration more than one point of view.</p>	<p>A student does not assume strict attitudes. His or her arguments are more or less systematic. He or she is not able to use facts to support their ideas. The statements are too general. He or she uses just their own point of view.</p>	<p>A student is not sure in stating arguments. Presentation is too short and includes only general ideas that do not correspond with the theme too much. His or her overview is not clearly stated.</p>

It was took into consideration that the above listed categorisation might seem too subjective; therefore, we made a list of original students' answers that were given from various points of view.

Arguments for the purchase:

- *Hydrogen-powered bus*
 - *is emission free, silent, without vibrations.*
 - *produces distilled water.*
 - *is powered by hydrogen, the alternative source of energy.*
 - *is "trendy"; would make Prešov city widely known.*
- *We would lower our dependence on oil and natural gas.*
- *It would bring new job opportunities.*
- *The approval of such project would make the Mayor of Prešov more popular and bring him far more votes at mayoral elections.*

Arguments against the purchase:

- *The bus is too expensive as well as hydrogen remake of it.*
- *Hydrogen production is too expensive.*
- *The storage of hydrogen is dangerous.*
- *Building "hydrogen stations" would be necessary.*
- *Drivers would have taken special courses.*
- *We do not have enough money at this time of crisis.*
- *We need European funds as a financial contribution to run the project.*

Pro-environmental arguments:

- *Our duty is to protect the environment for future generations.*
- *Fresher air*
- *Air pollution causes serious diseases.*
- *Our region might become the synonym for the pioneer in environmental protection.*
- *Hydrogen is the solution that might renew our "Mother Earth".*
- *The ozone hole is becoming bigger and bigger.*
- *Hydrogen production is non-ecological.*

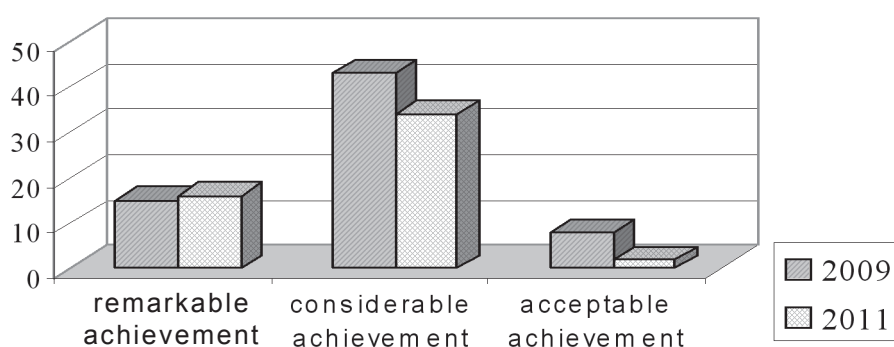


Figure 1: Results of essay evaluation in category Critical thinking.

The following diagrams clearly illustrate the results in particular classes and years in the field of critical thinking (Figure 1) and expression of ideas (Figure 2).

36 students out of 118 (30.5 %) were able to use arguments at great level, so we can put them into category of remarkable achievements. But only 31 of them (26 %) were able to express their thoughts systematically, in logical order. On the other hand, we can see that only 18 students failed at giving arguments. They quite often used personal attitudes and feelings

instead of facts. In general, we can say that even the first graders are at a relatively high level of expressing ideas.

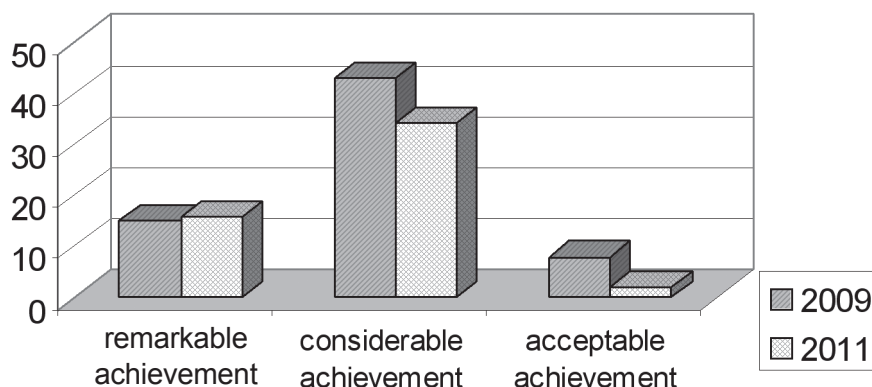


Figure 2: Results of essay evaluation in category Ideas expression.

2nd category – knowledge

If students should understand the theme in its whole scale and to name pluses and minuses of it, they need some knowledge of facts as well as to get some general view of the subject. Therefore, the following categorisation is based on number and accuracy of technical words related to the topic.

KNOWLEDGE		
<p>A student is able to carry out a detailed analysis of initial information. He or she is able to discuss the subject matter in details, using the facts (at least 3 technical words related to the matter). To make a research, a student fully applies general chemistry knowledge and makes almost no mistakes.</p>	<p>A student presents only basic facts with some level of „incorrectness“. At least one topic or concept is supported by facts; he or she uses at most two technical words related to the topic. He or she is not able to fully use his or her chemistry knowledge; makes some serious mistakes.</p>	<p>A student tends to repeat one or two wrong data. He or she describes his or her thoughts just briefly, with many mistakes. Chemistry knowledge is not applied.</p>

The most frequently used facts:

About hydrogen-powered buses

- *Hydrogen buses use fuel cells in which chemical energy is transferred into electrical energy.*
- *The only emission the bus produces is water vapour.*
- *Hydrogen cars have at the same output lower fuel consumption.*
- *Fuel cells have a short lifespan.*
- *Fuel cells contain platinum electrodes.*
- *First hydrogen cars were produced in Japan in 1994.*
- *Car producers concerned with hydrogen cars are Toyota, Honda, General Motors.*
- *The Slovak Republic supported the Kyoto Protocol, and therefore committed to reduce emissions.*

About hydrogen

- *Pure hydrogen is a gas under normal conditions.*
- *Hydrogen is the most widely spread element in space (approximately 99%).*
- *Hydrogen is colourless and 14 times lighter than air.*
- *Heating may cause violent combustion or explosion the proof of what is the explosion of zeppelin Hindenburg.*
- *Storage is dangerous and needs professional manipulation.*
- *Storage methods include freezing the hydrogen to store it as a liquid, or compressing it in a tank at high pressure.*
- *Hydrogen production methods are: water electrolysis, partial separation of hydrogen from the carbon components in methane and methanol; there also exist some kind of bacteria producing hydrogen (it is also the cheapest way of production).*

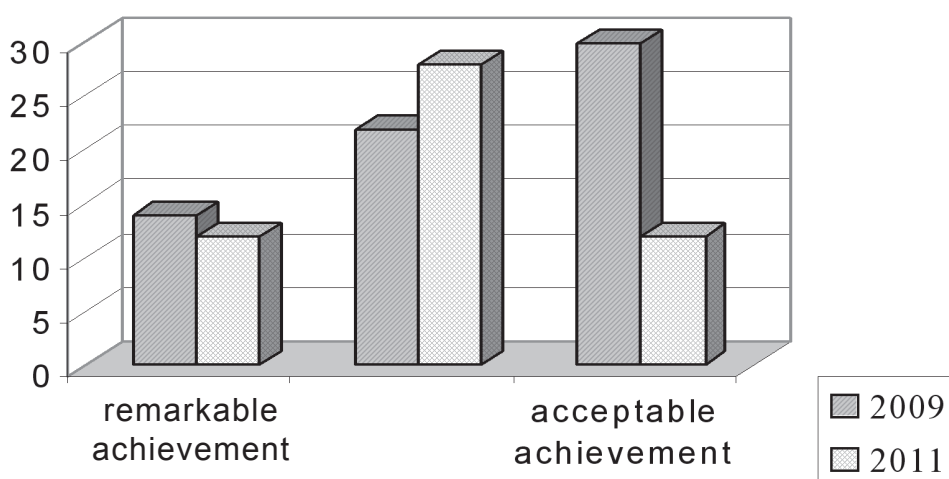


Figure 3: Results of essay evaluation in category Knowledge.

Diagram (Figure 3) shows that one fifth of students proved remarkable knowledge of the matter. More interesting fact is that 45% of them (30 students) in 2009 did not use in their written works relevant information gained during the project work or knowledge gained at chemistry lessons in general. In 2011, the number was just 12. The reason might be, as stated earlier, that in 2011, the instructions to the task had been slightly changed to attract students' attention more to argumentation. As we can see, students thus focused their attention more on explanation, but doing so they did not concentrate on expressing pro-environmental attitudes.

3rd category – pro-environmental attitudes

The task was created to foster students to think more of the environmental protection and to express their commitment.

In categorisation we concentrated principally on environmental protection viewpoints declared by students.

PRO-ENVIRONMENTAL ATTITUDES		
A student is able to name advantages as well as disadvantages of hydrogen bus purchase. He or she clearly assumes the attitudes towards environmental protection and its allied problems.	A student is able to name the pros and cons of hydrogen bus purchase as well as to assume his or her attitudes towards the environmental protection, but is not able to support his or her viewpoint anyhow.	A student is not interested in the environmental issue at all; therefore, he or she is not persuasive at all.

Arguments and facts formulated by students:

- *Hydrogen-powered bus is emission-less.*
- *The Earth is freed from CO₂ emissions.*
- *Ice caps melting, ocean level rising, climate changes – thus are the consequences of enormous CO₂ production.*
- *The supplies of fossil fuels are limited.*
- *Hydrogen-powered bus does not produce any greenhouse gases by what it prevents the Earth from global warming.*

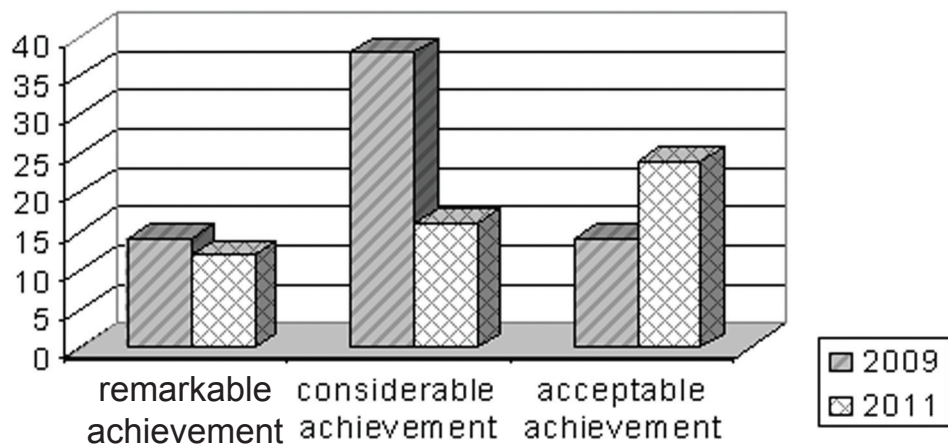


Figure 4: Results of essay evaluation in category Pro-environmental attitudes.

In the field of pro-environmental approaches, it is vital to refer to the fact that while in 2009 only 21 % of students, or 14 altogether, were not capable of showing a clear attitude (Figure 4), in 2011 the number increased. Once again, we might suppose that it was caused by the text change. And, consequently, the students turned out to be confused and then they presented personal accounts and feelings rather than arguments. The majority of students (80 students) found it quite easy to be pro-environmental, but more or less they were not able to support their ideas by persuasive arguments.

Discussion

Pros and Cons of Essay Writing

The conception of essay as of a method for getting feedback is not purpose-built. The number of reasons is just a few. This method supports the improvement of ideas expressing, reduces stress of testing, brings personal analyses of subject matter and allows students to

present their views and attitudes. At the same time, it brings some shortcomings to assessment system and interpretation of results. The system entails a lot of experience.

But the experience provided evidence that the written task attracted students' attention, and thus highly motivated them. The untraditional instructions of the task were created to make students feel free in their interpretations and application of knowledge. Students were even happy to use their fantasy what was caused chiefly because they were announced that these written works would not be graded. Their utterances supplied us with a preview of their knowledge and gave us an idea in what context they are able to use it. As it can be seen in the following list of answers, the essays also helped us to detect errors in the students' understanding of the theme.

Many statements express the creativity and level of fantasy of our students, while others set examples of inexact expressions of ideas:

- *Hydrogen-powered buses will not get out of order too often because they contain stagnant elements.*
- *Hydrogen production is very easy. or Hydrogen as a pure substance does not exist under normal conditions, and therefore its production is too complicated.*
- *Despite the fact that hydrogen is explosive and at its leakage can cause greenhouse effect, it is a kind of ecological type of fuel.*
- *Hydrogen is explosive only under high pressure or with considerable amount of O₂, or Hydrogen is explosive only when it is pressed within a small space.*
- *We breathe in harmful fumes from old buses.*
- *Producing energy, the hydrogen buses do not produce any fumes, neither the harmful ones, their only side product is pure water.*
- *Hydrogen buses do not produce any exhausts.*
- *...clear air without any smog that the old buses produce...*
- *Disadvantage of hydrogen-powered bus is the danger of fuel leakage.*
- *Hydrogen is made of some kind of algae; the technology does not need any light – it means that hydrogen is inexhaustible source of energy.*
- *There exists more than one natural way of hydrogen production.*
- *There exists more than one way of hydrogen production, but its exploitation is too complicated.*
- *Hydrogen is not just a product of chemical substances, but also of life nature (microorganisms produce H₂).*
- *Using hydrogen as fuel we reduce assumptions that the broken parts of old buses will have to be repaired.*
- *Materials for buses repairs are expensive and in short supply.*
- *Electrolysis uses PEM membrane that has two electrodes.*
- *One of the serious problems is explosiveness of hydrogen in contact with air (oxygen) that is a part of galvanic cell.*
- *One of the crucial minuses of hydrogen fuel is that it is not perfectly scrutinized what can cause people's confusion that, without careful manipulation, might lead to frequent and various accidents as well as explosions.*

The results of pro-environmental attitudes clearly correspond with the findings of J. Činčera in his research of ecological literacy of secondary school students. The students of the J. A. Rayman Grammar school, in their essays, besides showing their interest in environmental protection, claim that they will follow any pro-environmental rules if it is not financially demanding. Thus, it can be stated that the declared attitudes of students do not correspond with their maintained life attitudes.

The essays revealed the problems that could not be detected in a different form of feedback. Many mistakes were discovered in understanding and realising the subject matter

as well as errors in using proper terms. The writings also contained many misconceptions. It is vital to say that many of the mistakes could have been caused by the time limit set for writing the essay, evidence of what are unfinished sentences or ideas, or chaotic word order in sentences. Limited scale of the writing (one page of A4) did not allow students to write detailed arguments what might have distorted the level of knowledge, too.

Despite the demanding data evaluation, this form of feedback can be only highly recommended. With regard to such small sample, we cannot generalise the results of the research. In the new study it is necessary to perform a critical analysis of this methodology of research.

Conclusions

The most suitable means of feedback that would develop the above mentioned competencies seemed to be writing of an essay.

The study proved that the ability of critical thinking, argumentation and ideas expression is at the majority of students of the grammar school characterised by remarkable or considerable achievement. 15 % of students failed in argumentation and the same group of students also had problems with thoughts expression. Unexpected results were obtained in 2009 regarding usage of general knowledge of chemistry or of facts gained during the project teaching. These were used rarely, 45 % of students reached basic or acceptable achievement. They only used one or two incorrect data; moreover, they did not use chemistry knowledge at all, and hence in 2011, we emphasised the need of professional argumentation at stating their cases. Better results in the field of knowledge became evident. On the other hand, the students did not pay so much attention to vindication of their pro-environmental approaches. In the area of pro-environmental attitudes we learnt that students are aware of environmental protection issues, but economical aspects prevailed. The fact that the simulated problem was put into reality (firstly, we put it into school in the project teaching itself and secondly into the town) affected students so much that in their arguments they appealed to the affiliation of the city mayor or expressed personal experience with the pollution in their city. In the written works we could feel emotional involvement in environmental protection in their city. They named particular problems that are obvious in Prešov city.

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