Profits and Limitations of Inquiry Based Science Education

the monograph edited by:
Małgorzata Nodzyńska, Wioleta Kopek-Putała

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The monograph is edited by:
Małgorzata Nodzyńska, Wioleta Kopek-Putała

Rewievers
Jarmila Kmeťová, Martin Bílek, Paweł Cieśla,

Cover:
Małgorzata Nodzyńska

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Introduction

Sources of inquiry based or research based learning come from the early 60-ties of XX century. The concept of teaching based on constructivist theories appeared as a response and contrast to the traditional teaching. As fathers of philosophy of constructivism Piaget, Dewey, Vygotsky and Freire can be mentioned. Joseph Schwab divided the teaching based on IBSE strategies onto 4 levels, and the improvement of this division is done thank to Marshall Herron (1971) (cf. Herron Scale).

The monograph presents the results of research and reflections on the use of IBSE strategies at different levels of education. Moreover the book presents both: examples of activities conducted using IBSE strategies (from the full application of this strategy to a truncated version) as well as research on teachers' skills of creating of synopses of lessons based on IBSE. We hope that the presentation of such diverse perspectives on this strategy will enable the reader to form his own opinion on this subject.

Editors

Case studies on assessment of students´ learning through inquiry-based science education methods

Mária Ganajová, Milena Kristofová, Zuzana Ješková, Marián Kireš, Katarína Kimáková

Introduction

Understanding of a case study and its definition is not unified among authors. General definition of the case study states, that it is an intensive research of one case or of a few cases [Hendl, 2005]. Detailed research of one case contributes to the better understanding of similar cases. Researcher examines bounded case over a period of time, using detailed and in-depth data collection from several sources, such as observation, dialogues, audio-visual materials, documents, reports [Creswell, 2007].

Hartl [2000] characterizes it as a didactic technique, which is used mostly during professional teaching of adults, which can supplement or even replace systematic study of theory. Individual participants or small groups study these cases, they try to diagnose the situation and suggest a solution to the problem. If these studies are well-prepared, they help to develop analytical thinking, the ability to diagnose the essence of the problem, the ability to make strategic decisions, as well as the ability to find solutions to problems and formulate recommendations for the practise [Koubek, 1995, Kita, 1997].

Case studies abroad start to appear also in connection with Inquiry-based science education. They are designed to provide informational and inspiring sources, which illustrate ways how IBSE was designed and realized for various topics. Part of these studies are also experience and remarks from teachers and students, who participated in inquiry-based activities.

Methods

Within the ESTABLISH project [www.establish-fp7.eu] on Faculty of Science UPJŠ we prepared teaching materials for selected topics from Physics, Chemistry and Biology, which contain inquiry-based activities with different level of inquiry. Designed activities are accessible in English and Slovak language via LMS system Moodle on the web page of the project www.establish-fp7.eu.

Sequel of the ESTABLISH project is the SAILS project [www.sails-project.eu], which is focused on issues of assessment of inquiry-based science education. The aim of this project is to teach teachers use inquiry method and assess its effectiveness in terms of understanding the subject matter and developing inquiry skills. One of the options how to evaluate effectiveness of teaching is the case study. Case studies can be used during teacher trainings as practical samples of teaching through inquiry method and using tools of formative assessment to evaluate its effectiveness [Poráčová, 2010]. Case studies will provide samples of summative and formative assessment of selected elements of inquiry, such as formulation of hypotheses, suggesting experiments, measuring and data collection, formulation of conclusions, communication with classmates.

Samples of Case studies from verification of selected elements of inquiry skills.

Case study: *Development of communicative skills by inquiry method for topic „Thermal stability and thermal conductivity of plastics“*

Topic:	Properties of Plastics – Thermal stability and thermal conductivity of plastics
Inquiry skills:	communicative skills
Student group:	14-15 year old, 22 students, Primary school, December 2013

Description of teaching process [according to the teacher´s description]:

The teacher had the access to created methodical materials for teacher and students´ worksheets. At the beginning of the lesson they discussed about properties of plastics and their use in everyday life. Then, the teacher divided students into groups. Students worked in groups and performed inquiry-based activities of topic Properties of Plastics – Thermal stability and thermal conductivity of Plastics.

Assessment of communication skills:

Students assessed the group work with a scale questionnaire of own construct. The questionnaire was focused on self-assessment of own work in the group, on cooperation with other members and on mutual cooperation of the members.

Questionnaire on group work assessment			
Describe your work in the group with smileys:	very good	good	I have to improve
1. How did I help during group work?			
2. How did other members of the group help me?			
3. Did I make group work harder with obstacles?			
4. How did I manage to fulfil the goal of the lesson?			
5. How did other members of the group manage to fulfil the goal of the lesson?			

Data collection:

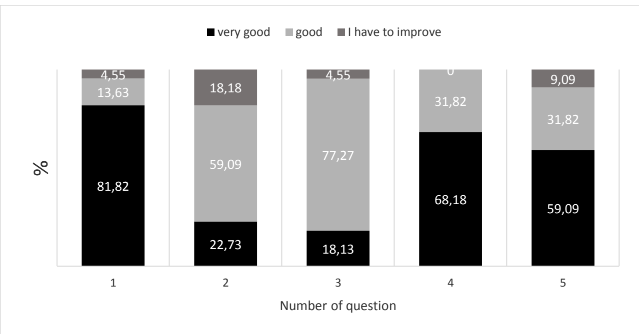

Fig. 01. Percentual results of the questionnaire

Teacher´s notes:

Students helped each other during group work. At the end, they were supposed to evaluate the role of classmates and themselves in the group. This assessment does not necessarily have to be objective. Students should understand that it is not the point to assess their friendship, but their real performance. I will carry on using this way of assessment, because it provides both the student and the teacher with information what the student has already mastered and on the contrary what the student needs to improve.

Observer´s notes:

Students are not used to this kind of assessment. They need to learn how to assess. High percentage of students [81,82%] stated that they had certainly helped during the group work and that they certainly had fulfilled the goal of the lesson [68,18%]. Students´ answers showed that some problems occurred during the group work. To improve the quality of students´ group work, it is necessary to expand the questionnaire with questions focused on the specification of the problems which occurred during the group work and try to eliminate them in the future.

Case study: *Development of understanding, argumentation and formulation of conclusions after inquiry method teaching of topic "Natural substances in food"*.

Topic:	Natural substances – Natural substances in food
Inquiry skills:	ability to work with information, formulation of logical arguments, deduction of conclusions
Student group:	17-18 year old, 23 students in experimental class and 22 students in control class, grammar school, December 2013

Description of process:

Students were supposed to study composition of breakfast cereals [Tab.01.] and decide if they would buy them. They dealt with this task before and after instruction with inquiry activities of topic Natural substances.

Tab. 01. Table with nutrition information on breakfast cereals

NUTRITION INFORMATION					
	100 g cereals	40 g cereals serving with 60 ml milk		100 g cereals	40 g cereals serving with 60 ml milk
Energy	1800 kJ 430 kcal	880 kJ 210 kcal	Fibre	6 g	2,5 g
Protein	8,6 g	5,4 g	Sodium	0,4 g	0,2 g
Carbohydrate sugar	65 g 25 g	29 g 16 g	Vitamin B1	0,3 mg (20% *)	0,1 mg (7% *)
Fat saturated fat	15 g 5 g	8 g 3 g	Iron	3 mg (20% *)	1 mg (7% *)
			Magnesium	94 mg (30% *)	45 mg (15% *)
*) Percent Daily Values					

Skills assessment:

Expected answers: No, they contain too much sugar and fat, little proteins, fibre and vitamins, the content of energy is high. We divided students´ answers into 3 groups: correct, partly correct and wrong.

Data collection:

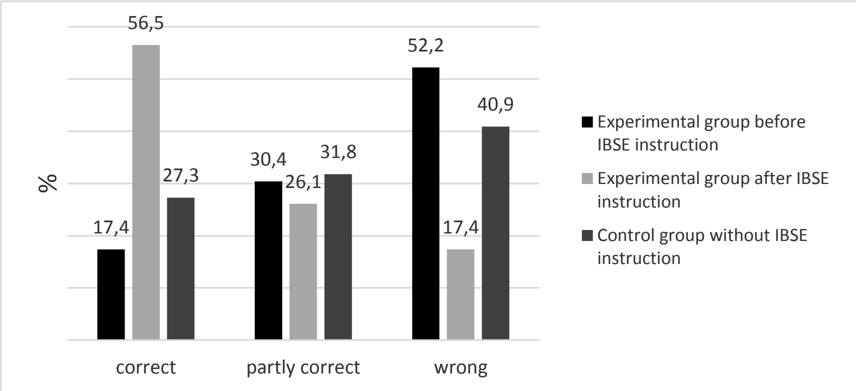

Fig. 02. Percentual answers of students to the question: “Would you buy this product, if you decided to do something beneficial for your health?”

In the experimental group 17,4% of students answered correctly before the instruction with inquiry-based activities. After the instruction 56,5% of the students answered correctly [with reasoning and argumentation]. In the control group 27,3% of the students answered correctly, which is approximately 10% more than in the experimental class before inquiry activities. Higher number of correct answers corresponds to the fact that the control class was composed of students with better grades.

Sample answer of a selected student before and after inquiry-based science education:

Before: Yes, we can see on the package that the product contains fibre and a lot of vitamins, which are healthy and beneficial for us.

After: No, because it is high in fats, saccharides, and low in proteins, fibre and vitamins.

Conclusion

Samples of case studies will be a part of research base for effective use of tools of formative assessment for determining effectiveness of inquiry method in teaching. They also provide information about significance of implementation of formative assessment into teaching IBSE to solve Slovak students´ problems, which were found out in international testing PISA, such as increase of total success, development of communicative competence, inquiry skills, such as formulation of conclusions, development of argumentation skills, development of competence to learn how to learn etc.

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Mária Ganajová

Milena Kristofová

Zuzana Ješková

Marián Kireš

Katarína Kimáková

Faculty of Science

University of P. J. Šafárik in Košice, SL

maria.ganajova@upjs.sk, milena.kristofova@upjs.sk, zuzana.jeskova@upjs.sk

marian.kires@upjs.sk, katarina.kimakova@upjs.sk

Development and verification of formative assessment tools in inquiry-based chemistry education

Mária Ganajová, Milena Kristofová

Background

The results of international OECD PISA testing running in 2006, 2009, 2012 have shown low level of reading, mathematics and scientific literacy of Slovak students. In the assignments aimed at application of knowledge into real-life situation, in particular, Slovak students have gained statistically lower results compared with the average of OECD countries [Santiago et al., 2012]. The students of Slovak basic and secondary schools know a lot of separate knowledge that are often insulated without strong connections and relationships with other knowledge, they have problems in independent reasoning and investigating, creating hypothesis, searching and designing ways how to solve problems, interpreting gained results and collecting and presenting evidence in order to argue and draw reasonable conclusions [Núcem, 2010]. As to the education of natural sciences, it is one of the key questions regarding education not only in Slovakia. The European Commission put strong emphasis on the development of generic skills, such as critical thinking, abilities to solve problems, being active and independent in life and cooperation and communication with the others. In science these trends result in wide implementation of inquiry-based science education (IBSE), which emphasizes that student in science acts in a role of a scientist going step by step through the inquiry cycle. This way of teaching and learning can significantly help not only in deeper understanding of scientific knowledge, but in development of key and scientific competencies [Poráčová, 2010]. Nevertheless, there is still an open question of how to assess students´ performance in this environment. Dominantly used summative assessment tools are not any more sufficient for the evaluation of students´ performance [Poráčová, Zahatňanská & Takáczová, 2008]. The authors of the contribution created within the international projects 7. RP ESTABLISH (European Science and technology in Action: Building Links with Industry, Schools and Home) and SAILS (Strategies for Assessment of Inquiry Learning in Science) methodologies for inquiry-based activities in chemistry. In the process of their implementation into teaching, there are no tools how to evaluate this way of education.

We assume that formative assessment in its different forms (teacher, peer and self-assessment tools) can enhance development of scientific literacy and reasoning and inquiry skills. Formative assessment is focused on the process of evaluation itself, using the feedback, whose role is to determine the gap between the actual level of evaluated output and the required standard [Black & Wiliam, 2005]. The aim of this contribution is to inform community of teachers about possibilities and tools of formative assessment for teaching inquiry – based activities of the topic Properties of Plastics focusing on the understanding of curriculum content by self-evaluation of students.

Methods

The main research goal was to design and verify formative assessment tools integrated into inquiry-based chemistry education as a means of development of scientific literacy and inquiry skills of students. Research sample included teachers of natural science subjects and pupils of selected primary and grammar schools.

At the beginning of the research, we implemented teachers education concentrated on IBSE and formative assessment. In the process of teachers´ training we familiarised teachers with the following inquiry-based activities: Determining density of Plastics, Combustibility of Plastics, Thermal stability of Plastics, Resistance of Plastics to chemicals.

In the next part of the research, teachers used inquiry-based activities in the process of teaching and in order to verify its effectiveness, they used tools of formative assessment focused on the curriculum content by self-evaluation of students. The verification took place at 6 primary schools and 6 secondary schools in December 2013, with participation of 150 students.

Results

The following part mentions specific examples of the results of students´ self-evaluation after teaching with inquiry-based activities on the topic Properties of Plastics. The evaluation of students focused on their performance, on their work and on the recording of their progress, enables the pupil to regulate his further activity, which also influences the process of his learning.

Sample n. 1: Self-assessment table of a student after teaching inquiry-based activities

After teaching inquiry-based activities students filled in a short table, which they handed in before leaving the class. As an example, we present the answers of 22 students of High school in Bardejov after the teaching of inquiry – based activities Determining density of plastic, Combustion of plastics.

Tab. 01. Answers of students in self-assessment table after teaching inquiry-based activities

Self-assessment table of a student after teaching inquiry-based activities	
Things I have learnt today:	*Properties of particular plastics.* *What kinds of plastics exist. How to ignite the burner.* *How plastics are burning. Which plastics smell and drip during burning. How plastics are used.*
Things which were interesting:	*Behaviour of plastics during combustion.* *Burning of a Ping-Pong ball.* *Finding out how many things are made of plastics.* *The colour of flame during combustion.* *Smell.*
Questions which I still have:	*How plastics can be harmful to us.* *How to avoid problems with excessive amount of plastic waste.* *Why plastics burn in this way.* *Why you do not teach in this way more often.* *14 students had no question.*

In this way, teachers might get feedback on the lesson and they can provide answers to not-covered questions in the next lesson. The most interesting activities can be repeated or extended.

Sample n. 2: The evaluation of understanding OR "What have I learnt thanks to inquiry-based method about density and properties of plastics?" based on the self-evaluation table.

Self-evaluation card was filled in by 28 students of the second class at a grammar school. Their answers were recorded and their assessment expressed as a percentage can be found in the Table 02.

Tab. 02. Success rate of students´ answers based on the questions asked in the self-evaluation card of the pupil

	very well	with a few imperfection	I am not good at it yet
I succeeded in formulating a hypothesis about density of plastics compared to water	28,57%	57,14%	14,29%
I am familiar with the way how to compare density of plastics with water density	89,29%	10,71%	0,00%
I am familiar with the way of comparing density of plastics mutually	89,29%	10,71%	0,00%
I am able to determine the volume of irregular solid (plastic)	85,71%	14,29%	0,00%
I am able to calculate density of a specific plastic, based on its volume	89,29%	10,71%	0,00%
I am familiar with the chemical basis of PVC and other plastics.	53,57%	32,14%	14,29%
I am able to demonstrate Beilstein´s test in practice	75,00%	21,43%	3,57%
I am able to explain the cause of the flame´s green colouring during Beilstein´s test	67,85%	14,29%	17,86%

The mentioned self-evaluation table is of significance for the teacher as well as for the student. It may help students to realize their shortcomings and work on their elimination on the future. It is of similar importance to teachers, who may reveal students´ problems with mastering the explained curriculum and consequently, they may help their students to understand the problem better.

Conclusions and implications

At the end of teaching, we asked teachers to fill in a questionnaire where they were asked to express their opinions on the self-evaluation of students.

The verification showed that teachers consider this means of assessment very important, because students learn how to assess their knowledge objectively and to compare it with their classmates. Teacher can better assess the level of student´s knowledge and on this basis, teacher can plan the next teaching activities. The importance for the students is that they have a possibility to improve their performance, to improve their output and their results, which are then assessed with a grade. Teacher gains knowledge about subjective feelings of students, e.g. about work in groups.

As a problem in the process of using tools of formative assessment after teaching with inquiry-based activities teachers state that most students cannot evaluate themselves objectively (they either overestimate or underestimate themselves), and they also have problems to express their opinions. It may be caused by the fact that students were not used to this type of feedback and they have to learn how to evaluate themselves objectively. According to teachers, another problem is time demanding character of formative assessment.

The mentioned way of teaching and self-evaluating is a way how to develop a very important competency for the 21st century "To learn how to learn".

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Mária Ganajová

Milena Kristofová

University of P. J. Šafárik in Košice

Faculty of Science, SL

maria.ganajova@upjs.sk, milena.kristofova@upjs.sk

“How to use cleaning products in an effective and safe way?” realization of the module PROFILES using the teaching method by discovery – IBSE

Agnieszka Kamińska-Ostęp

The context and purpose of the framework

Reorganization of the Polish Educational System has changed the way of teaching science subjects including chemistry. First of all there should be applied activation methods with particular attention paid to individual performing of experiments by pupils, making observations as well as critical analysis of the results. These aims can be achieved applying educational project methods and conducting lessons in groups in the rooms equipped with suitable devices and chemical reagents.

The IBSE method suits perfectly the expected changes in education – Inquiry Based Science Education consists in the teaching science subjects be discovery that is scientific inquiry. “Scientific inquiry is a potential process consisting in diagnosing problems making a critical analysis of experiments and finding alternative solutions, planning research, verifying hypotheses, searching information, constructing models, discussion with colleagues and formulating coherent arguments – the definition [Linn, Davis, & Bell, 2004]. In Poland the first outline of this type of teaching was presented by Wincenty Okoń in the paper entitled „Many-sided learning and a problem of pupils activity” in the 60s of the twentieth century. The expanded version of this theory is presented in his two successive books: „Foundations of general education” (1967) and „Problem teaching at contemporary school” (1975). However, IBSE is based on its primary conception that school education should reflect some investigations. The IBSE method enables flexible approach to teaching through work on full understanding of a research problem be pupils using science subject integration. Its main idea is to focus on activity and creativity of learners and team work in the classroom and outside it. Pupils should ask questions, formulate hypotheses, make observations, gather and accumulate data, draw conclusions, share ideas, solutions etc.

Unconstrained thinking shows novelty and causes „opening” of mind, simulates activity, raises self-confidence which results in the increasing self-awareness and interests in science subjects as well as positive approach of learners. The teacher’s role is to develop and determine pupils’ interests, asking questions probing the problem as well as those helping to understand it. He also gives support, helps pupils evaluate their note of development, progress and creates the learning friendly environment. The simplified research cycle of the IBSE method would include the following elements:
- asking a question helping find a problem solution,
- finding methodical and technical solutions which would allow to collect data,
- analysis of the obtained data,
- inference share of the results.

In each above described stage pupils have conditions for creating their own thinking models through understanding their experiences [Llewellyn, 2002]. Based on the above research model, presently there works a five-stage cycle of learning which proves to be an effective and very popular tool of learning and organizing lessons for science teachers based on inquiry.

Fig. 01. Five-stage cycle of investigations and modelling based on scientific inquiry.

(http://journeyintech.blogspot.com/2011_01_01_archive.html)

The first stage is engagement where the teacher's task is to arouse interest and curiosity in the research subject which is the basis for further inquiries about a given phenomenon. The teacher has a possibility of learning activation, making pupils aware of the knowledge they already possess and share their experiences. The second stage is searching during which pupils ask questions, develop hypotheses and work individually. They collect data, write down information, exchange observations and work in groups. When the work is over, the teacher makes analysis and pupils discuss with each other what was discovered and what they learnt during the search. The third stage includes explanation. The information acquired earlier is discussed with the teacher who explains scientific terms thus enriching pupils' knowledge. The fourth stage is development. The teacher helps generalize and develop the acquired knowledge e.g. applying it in new situations. Pupils can modify their understanding of the studied phenomenon. The fifth stage refers to evaluation. The teacher asks more complicated questions which help pupils make analysis and evaluation as well as express opinion about their own work. Then evaluation of understanding notions and skills by pupils takes place [Guide for developing Establish Teaching and Learning Units, 2010].

The skills developed using the „teaching by discovery" method include employing critical thinking, logic and developing skill of solving problems, communication skills working in a team as well as technical, mathematical and measuring skills. The IBSE method creates also conditions for the activities aimed at formation of key skills such as studies of the way of thinking, learning how to teach, creating new solutions, collaboration with other pupils, responsibility for the own learning and its results as well as presenting the results of pupils' work [Bybee, & Crissman et al., 1990]. The IBSE method focuses on practicing skill contained in the context, applying methods and ways of studying natural phenomena and developing creativity. Of essential importance is also analysis and synthesis of data, sharing conclusions and ideas with the teacher and with other [Jorgenson, Cleveland, & Vanosollal, 1996]. The IBSE methods include questions and inquiries based on new solutions, independent expression of definitions and dependences as a result of reasoning, laboratory procedure and experiment as a tool of problem solving. The experiment is invaluable in knowledge acquisition and skill development. During the lesson it intensifies interest of both gifted and poor pupils, increases their motivation, strengthens positive relations in the group and develops understanding what scientific knowledge is and how is created [Hofsein, & Lunetta, 2003].

Methods

According to the based methods assumptions of the project PROFILES the science subject lessons should take into consideration interests and needs of pupils, include references to everyday situations, based on knowledge from other science subjects and employ the methods of learning by discovery. It is also important to direct the education process to acquire by pupils skills of critical thinking and making decisions as well as developing their inner motivation for further independent education. Studies of cleaning agents provide an opportunity for getting pupils familiar with properties of many substances which are their components and with the rules of their action. To achieve this aim, there will be conducted many interesting experiments. As a result, besides consolidation and complementing their chemical knowledge, pupils will become convinced that chemical knowledge can be applied in everyday life.

In the school year 2012/2013 with a group of pupils from the third form of junior secondary school I realized one of the modules of project PROFILES: "How to use cleaning products in an effective and safe way?" The module was realized during 8 lessons and the teaching contents included acids, bases, salts, solution reaction, saponification of fats and bactericidal properties.

Generally the realization of the module proceeded in the following way. At first pupils searched for information in available sources (packages, journals, books, the internet) about composition of cleaning agents, properties of their main components and ways of studying them. The analysis of the obtained information resulted in planning the experimental ways of studying individual kinds of cleaning agents as well as required equipment and reagents. Cleaning agents were divided into four groups with respect in their assignment and function of the substances responsible for them: agents removing stone and rust (Cilif), whitening agents (Ace, Vanish), agents for opening a passage in sewage system pipes (Kret) and detergents (shampoos, gels). Each group of students studied one kind of agents. In the next stages pupils conducted the experiments which were planned earlier and presented the obtained results in the form of tables and diagrams. Finally, there was presentation summing up the investigations and discussion of results with other groups.

Fig. 02. Pupils from Junior secondary school No. 1 named after Pries Stanisław Konarski in Lublin supervised by teacher K. Osińska realize the module "How to use cleaning products in an effective and safe way?"

In order to show the course of classes there is presented below the detailed script for realization of the module “How to use cleaning products in an effective and safe way?” It includes aims, methods of work, required materials and course of the classes.

First classes

The aims:
- introduction of the problem concerning cleaning agents referring to the homework which dealt with household cleaning agents
- developing the knowledge about cleaning agents applied in everyday life
- pointing out the usefulness of acquiring knowledge of properties of chemical substances being components of cleaning preparations
- arousing interest in the subject and motivation for work

Methods of work:
- lecture by the teacher and discussions with pupils

Materials:
- cleaning agent preparations with the information about them

Course of classes:
1. Display of the preparations prepared by pupils as their homework.
2. Lecture by the teacher giving arguments for dealing with this subject and presenting the aim.
3. Discussion with pupils – making presentation about preparations (composition, action, main active substance).
4. Division of preparations into groups and assignment of pupils to individual groups.

The second classes

The aims:
- familiarization with chemical properties of substances being components of preparations
- training skills of choosing chemical experiments, reagents and laboratory equipment in order to achieve the assumed aims
- elaboration of the procedure to study individual preparations
- proving that properties of preparations depend on a chemical substance which is their main component
- bring back to mind the reactions characteristic of chosen groups of chemical substances
- developing skills of creative problem solution

Method of work:
– brainstorming, group work, dialogue

Materials:
– chemical reagents, laboratory equipment, preparations of cleaning agents

Course of classes:

1. Group work
- choosing main chemical substances responsible for properties of preparations based on labels and information prepared as homework
- choosing experiments in order to study basic chemical properties of substances in individual preparations
- planning experiments to show chemical properties of substances being components of preparations which affect their application
- elaboration of procedure of studying-individual preparations
- recording the results of work in individual groups on the poster

2. Work which the whole class
- individual groups present their proposals along with motivation
- approval by the teacher or possible corrections.

3. Group work
- preparation of reagents and laboratory equipment according to the procedure

The third classes

The aims:
- training skills of performing chemical experiments
- training skills of observation, synthesis, analysis, reasoning
- training skills of description of chemical experiments
- training skills of recording the works
- training skills of collaboration in the group

Method of work:
- experiments performed by pupils, team work

Materials:
- reagents, laboratory equipment, cleaning agents preparations

Course of classes:
1. Performing planned chemical experiments.
2. Description of experiments (actions, observations and conclusions).
3. Recording the work (films, photos).

The fourth classes

The aims:
- training skills of reasoning and summing up
- training skills of presenting the results of work
- training skill of elf-evaluation and evaluation of others
- making aware of usefulness of chemical knowledge in everyday life

Method of work:
- presentations of pupils – representatives of individual groups

Material:
- films, photos, posters – recording of work

Course of classes:
1. Presentation of results of work – conclusions from experiments.
2. Summing up by pupils and summing up by the teacher.
3. Evaluation according to the earlier established criteria (self – evaluation by pupils / evaluation by pupils/ evaluation by the teacher.

Group I - Agents Removing Stone and Rust

Examples of preparations:

Cillit – hydrochloric acid as an active component, Tytan – phosphoric acid (V), WC Sansed – phosphoric acid (V)

Getting to known Industrial Safety regulations (BHP).

Making out pictograms on packages before starting work. Supply of protection equipment – gloves, apron, glasses. Preparation of techniques and regulations to study individual measures.

Experiment 1. What is the reaction of aqueous solutions removing stone and rust?

Equipment and reagents:

4 test tubes, tea-spoon, test tubes stand, 3 glass rods indicator paper, red cabbage brew, distilled water, a tea-spoon of Cilit, Tytan, WC Sansed each.

Experiment:

Activities: A tea-spoon of Cilit, Tytan, WC Sansed each is added to test-tubes with distilled water. The content is stirred with a glass rod and the indicator paper is immersed in the test tubes, then its colour is compared with the coloured indicator code. Then a few drops of red cabbage brew are added to the solutions.

Observations: Both, the indicator paper and red cabbage brew changed the colour into red.

Conclusions: Aqueous solutions of the agents removing stone and rust have acid reaction.

Experiment 2. Why does Cilit clean?

Equipment and reagents: calcium carbonate, Cilit 5 cm^3, glass rod.

Experiment:

Activities: Calcium carbonate samples were subjected to the action of a few drops of Cilit.

Observations: After the addition of Cilit, bubbles of colourless gas are evolved. Foam formation is observed.

Conclusion: Cilit contains hydrochloric acid which reacts with calcium carbonate according to the equation:

$CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Calcium carbonate does not dissolve in water but the reaction product does.

Fig. 03. Exemplary work card worked out and realized by one of the pupils' team studying the agents removing stone and rust.

The teacher realizing the modules of the project PROFILES can use the professionally prepared materials such as: the script of classes which includes the detailed course of module realization, tasks for pupils and methodological instructions that is suggestions how to conduct classes (http://umcs.pl/plmoduly-2014,5974.htm).

During the classes there are practiced skills how to do reasoning according to the regulations of scientific experiment, behavior according to the given procedure, collaboration in a group, preparation and presentation of the results. After accomplishment of the module, pupils acquire knowledge about advantages and disadvantages of different kinds of cleaning agents and explain why the proper use of cleaning agents and safety depend on getting to know properties of substances which are their components.

Chemistry lessons conducted according to the assumptions of the project PROFILES take into account pupils' interests and need as well as develop motivation for learning. Owing to reference to everyday life and application of experiments, they arouse pupils' curiosity and make them more active. Learning by discovery also develops key competences of learners as well as skills of critical thinking and making decisions. Besides great fascination of the classes conducted based on the modules of the project PROFILES pupils get convinced that chemical knowledge can be very useful in everyday life.

Results

From the teachers' point of view the method "teaching by discovery activates learners to a large extent. It requires their involvement in every stage of work, creativity, skills of searching for information and their exploitation. Besides individual development of the learners, this method creates conditions for developing team work skills. Planning experiments and their performance give pupils possibility of checking hypotheses and their experimental verification that is acquisition of knowledge by the trial and error method. Observation of the experiment being carried out, making its description and drawing conclusions make pupils play the role of a researcher which, in teachers' opinion gives satisfaction to the learners. Summing up the work and its presentation help pupils gain knowledge and make generalizations. However, evaluation combined with self – estimation on one hand, arouses many emotions in pupils and on the other hand, is inspiring and supporting. Work using this method requires reorganization of the lesson by the teacher and suitable equipment of the laboratory. Besides, the role of the teacher is changing. He is not a source of knowledge for pupils but plays a role of a guide who supports and supervises their work. Pupils are not only recipients of the information provided by the teacher but first of all they acquire knowledge independently. It was difficult for teachers to cope with too dynamic and active team work of pupils, loud discussions and large spontaneity while doing tasks.

In pupils' opinion the work using the method "teaching by discovery" required complete involvement in the problem and all activities connected with it. It enabled pupils active participation in classes in each stage. They identified themselves with the research subject which drove them to earnest and systematic work. The work using this method promoted the will to discover the world through which pupils had a chance to become aware of their talents and develop them. They felt responsible for acquisition of knowledge therefore the collaboration in the group caused the greatest difficulty. Although not all of them worked with the same rate which, in turn, led to conflicts. In pupils' opinion the factor affecting significantly involvement was the possibility of experimental work and its independent planning. Then they realized that problem solving depends only on their skills, conscientiousness and engagement. In their opinion, the final evaluation made by pupils of the same age and teachers was objective. The pupils were anxious about the best possible presentation summing up all stages of work therefore each group devoted much attention and focus on preparation of posters, films and presentation.

In order to introduce IBSE to Polish reality it is indispensable not only to provide teachers with knowledge, skills and suitable materials but to change their mentality. The skills mentioned in the paper acquired by pupils during teaching by enquiry i.e. investigations match the new trend of teaching in the Polish educational system. Analyzing the documents of basic teaching program it can be concluded that it is essential to popularize in science subject teaching the methods promoting pupils' research activity (learning by discovery) with simultaneous stimulation of pupils' interest in science knowledge showing its importance in everyday life.

Conclusions and implications

IBSE is a strategy preparing pupils for making decisions in their lives based on rational assumptions. However, using IBSE the teacher's work requires giving up traditional approaches and division of roles (the teacher speaks and the pupil listens), introduction of interesting context and opening to new experiments. The teacher applying IBSE should be aware that knowledge can be found everywhere, not only in textbooks and it is not necessary for the teacher to know the answer to every question. However, he or she should adopt skeptical, critical approach to information, theory and truth. He or she should combine different fields of science and apply interdisciplinary teaching [Blaine, 2001]. The lessons using the IBSE method can proceed as follows. At the beginning there should be done something which is not the standard that is show or tell something to provoke asking questions or rousing interest in pupils. There should be created possibilities of searching for replies, formulating conclusions together and understanding processes and rules underlying them and finally of formulating a comprehensible definition of a process or a phenomenon. It is also one of the methods allowing accomplishing requirements of new basic program as regards formation of skills, scientific thinking and team work. Arousing intellectual activity and creativity of pupils using this method promotes achievements of very good teaching effects and preventing decrease of interest in science subjects. IBSE introduces factors proper for investigations, based on the activity scheme: hypothesis – experiments – conclusions into teaching at school.

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The module described in the paper was worked out by the team for the project PROFILES at Maria Curie-Skłodowska University based on "Teaching – Learning Materials Tool as the effect of the project PARSEL financed by the European Committee within 6 Outlined Program (SAS6-CT-2006-042922-PARSEL). Detailed information about the project PARCEL as available: www.parsel.eu

Agnieszka Kamińska-Ostęp

Faculty of Chemistry, Department of Chemical Education

Maria Curie-Skłodowska University PL

aostep@poczta.umcs.lublin.pl

Inquiry-based teaching – color light

Lenka Ličmanová, Lucie Zárubová

The context and purpose of the framework

In Czech Republic, the pupils are not interested in science today. The research said that pupils want to use ICT in learning and also want to do experiment it yourself [Kekule, 2008] Use of information and communication technology in pupil's experiments seems to be a good and interesting idea. Worksheets are designed for secondary school pupils (15 - 18 years old) in optics.

Methods

The pupils used the worksheets including inquiry-based teaching during measurements. Inquiry-based teaching is called as a methods of scientific knowledge [Mintzes H Wandersee & Novak, 1998, Redish, 2003] „Pupils re involved in their learning, formulate questions, investigate widely and then build own new understandings, meanings and knowledge. That new knowledge is new to the pupils and may be used to answer a question, to develop a solution or to support a position or point of view" [Alberta, 2004].

The tasks of photometry for pupils' measurement are inspired by everyday life and using of modern sensors. The pupils did an experiment, they measured with the spectrometer SpectroVis Plus, Light Sensor and Motion Detector by Vernier [Vernier, 2014] and then evaluated the measured data using some program such as Excel and they created a protocol.

The pupils worked in the groups. According to E. Mechlová the optimal size of a group in secondary school is 4-5 members [Mechlová, 1984]. Currently, the pre-research was carry out about 30 pupils (15-18 years old). Pupils said that experiments were interesting.

Results

For pupils were created worksheets on various topics, such as the question: What is light? How do we gain white color? Why do you see color? Why we see this table in brown and this wall in white? What light is reflected from the blue background? How much light is reflected from shiny surfaces in comparison with a rough surface? The pilot study found that pupils often have a misconception about what happens when light passes through a colored foil.

<u>TASK</u>

What is a light? How do we gain a white light?

Why do you see a color?

Teacher explains to pupils the necessary concepts before measuring (light, spectrum, etc.).

Some interesting misconceptions of pupils were found after the evaluation of the worksheets. The pupils think that white light passed through a red foil will be have the higher intensity in the red part of the spectrum. Very often the pupils could not describe correctly what is a white light.

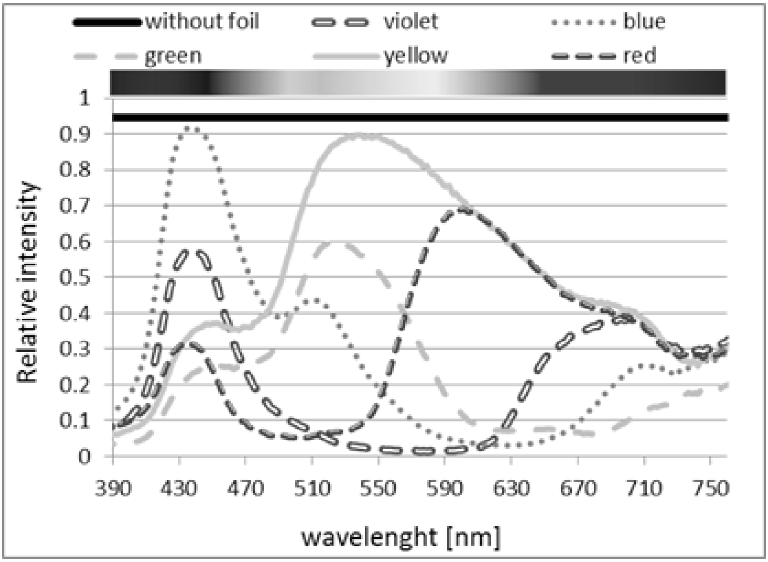

Fig. 01. Light passes through a color foil

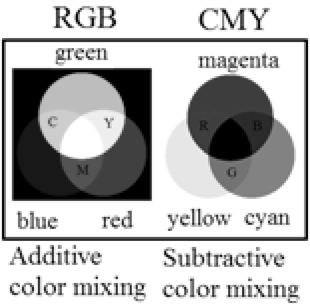

Fig. 02. Model RGB and CMY

Pupils get a foretaste of a color mixing, learn about the two models: RGB and CMY.

The pupils learn that human sees in color because each subject reflected the light to the eye. The color of object depends on the light which is reflected from the object.

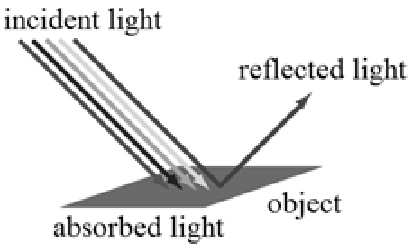

Fig. 03. Reflection

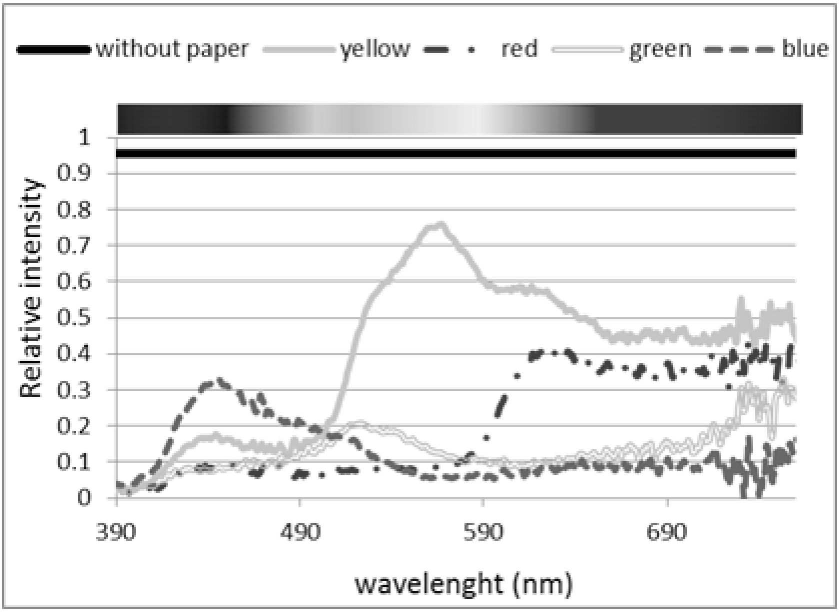

Fig. 04. Light reflected from surfaces of different color

These tasks can be used in our everyday life. A light transmission through the sunglasses can be measured by this method.

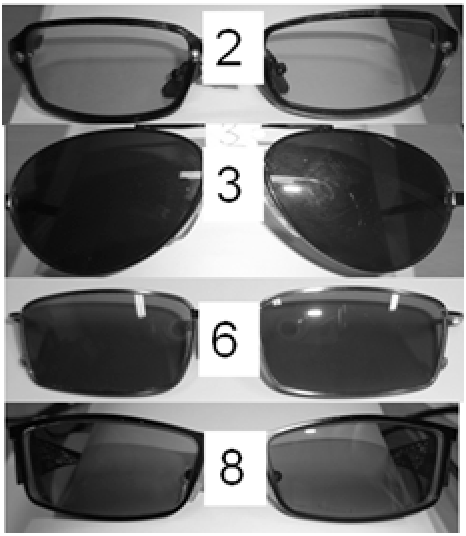

Fig. 05. Sunglasses

The pupils can measure the amount of transmitted light and the spectral properties of the transmitted light.

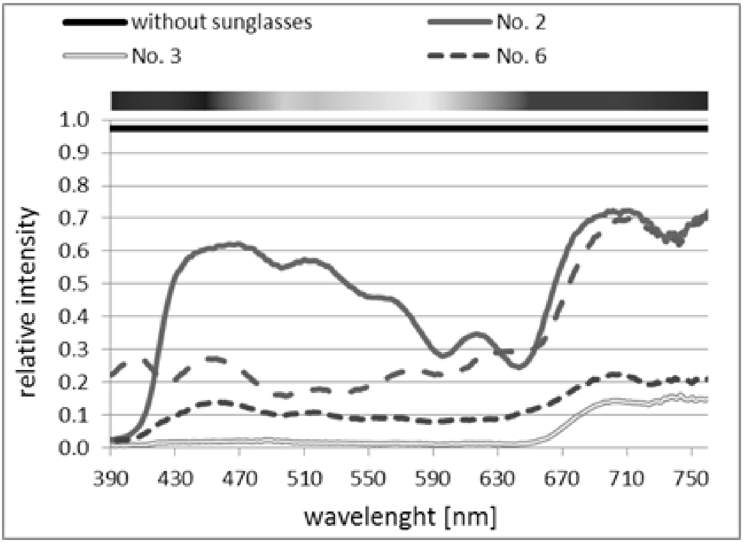

Fig. 06. Light passes through the sunglasses

As you can see from figure 06, sunglasses have a different light spectrum. Light spectrum corresponds to the color of glass.

Tab. 01. Light intensity passes through the sunglasses

Light transmission				
No.	light intesity (illuminance) [lx]	%	UVA [mW/m^2]	shop
	1670	100	515	
2	970	58	0	market
3	93	6	0	market
6	360	22	0	optician shop
8	540	32	60	optician shop

As you can see from table 01, some sunglasses are not so good for the human eye. UVA was passed through some sunglasses. These sunglasses were bought at optician shop. It is very surprising.

Conclusions

The pupils appreciated the modern equipment during measurement and appreciated that the tasks relate to their everyday life. Currently, the pre-research was carried out on about 30 pupils (15-18 years old). Pupils said that experiments were interesting. These experiments should develop creativity, increase the level of knowledge, and develop natural-science skills with the aid of information technologies of pupils at the secondary school [Mechlová, etc. 2012]. Inquiry-based teaching should contribute to the overall development of students, both in terms of knowledge and skills to develop creativity, as well as to develop skills for learning, problem solving, social and personal, communication and working. These tasks can be used as for secondary school pupils (15 - 18 years old) and also for physical group of pupils at leisure time.

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Lenka Ličmanová

Lucie Zárubová

Faculty of Science, University of Ostrava, Ostrava, CZ

lenka.licmanova@osu.cz; luciezarubova@seznam.cz

Experiences with implementation of project-based learning enriched by rubrics based assessment in teaching chemistry

Gabriella Németh, Miroslav Prokša

Context and purpose of the framework

The potential of implementing project-based learning (PBL) into the basic teaching methods is more and more recognized during the last two decades in Slovakia. However, most of the teachers implementing PBL have no first-hand experiences from their childhood or student´s year the idea of implementation of the PBL is not unknown for the Slovakian teachers. The motivation behind implementing PBL can vary, but the whole process can cause difficulties for the teachers. The whole method of PBL and the implementation process at first sight can be really confusing and can appear difficult and complicated. Because of the complexity of the implementation the teachers can forget or not understand the importance of some steps (e.g. enrich the PBL with several hands-on activities and do not limit it to collecting and evaluating information, preparing a more complex assessing system), which represents an active part of projects implemented abroad [Bidwell & Sheri, 2000, BIE, 2003, Fleming, 2000]. Because of the above mentioned situation among our aim´s were:

To design and implement a project-based approach for chemistry lessons enriched by hands-on activities and assessment system concentrating on evaluating the gained skills of students.

Collect and summarize our experiences of implementing the assessing system from the teacher´s point of view.

Evaluate the student´s opinion about the implemented projects.

With the help of several participating teachers we have planned and implemented in different high schools totally of four projects in the last school year (2012/2013). The implemented projects differ in the main theme of the project, in the age of the participating students, in the type of participating schools, but the main approach of planning and implementing the projects was the same. In the following table (Tab. 01. Overview of realized projects) you can see a summarization of the main characteristics of the discussed projects.

At planning and implementation we followed the commonly known steps of preparing and implementing projects:

Developing the idea of the PBL by the help of the participating teachers, while as a basic material we used the educational program of the chosen classes and tried to respect the student´s interest.

Planning the products, or more correctly planning our expectations about the products. In our projects the products could be divided into 2 main types, as the main products which have elemental role in the final presentation, and the additional products which are usually materials to help students continuous work (e.g. planning forms, work diaries), or other controlling materials [Bidwell &Sheri, 2000, Fleming 2000, BIE 2]. One of the main differences of our projects was the idea of preparing products, which differ from the average end products of PBL. Our aim was to present an opportunity in which students could be creative and have to do more unusual tasks than they are accustomed to in normal teaching. So one of our main criteria of the project was to design and prepare an unusual three dimensional (3D) product. That product could be any kind of model (e.g. model of a polluted ocean or a clean ocean), posters with movable parts, chemical experiments, etc. Students could come up almost with any idea, but preparing a simple presentation.

Tab. 01. Overview of realized projects

School	City of the school	Age of students	Project Theme	Past experiences with projects	Total number of groups	Number of students in groups
7. year of a high schools with 8 year duration	Bratislava	17	Obesity	Limited	6	3
2. year of a high schools with 4 year duration	Bratislava	15-16	Carbon dioxide	No	12 (in two parallel classes)	3-4
6. year of a high schools with 8 year duration	Bratislava	15 - 16	Water	Limited	12 (in two parallel classes)	4-6
2. year of a high schools with 4 year duration	Dunajská Streda	15 - 16	Chemical Show – Harry Potter	No	4	5 - 10

Planning an assessment system which concentrate on the evaluating of the student´s gained skills rather than the gained facto-graphical knowledge. As our expectations of the prepared products extended to the field of other non-usual skills evidently we had to find and implement suitable assessing and controlling methods [Németh, 2011, Németh, 2012, Németh Šafránková & Prokša, 2013]. As an example of the applied tools we usually gained inspiration from various publications [Bidwell & Sheri, 2000, Fleming, 2000, BIE 2].

In the following table (Tab. 02. Final assessment system) we describe the final assessment system based on the different phases of the PBL.

Tab. 02. Final assessment system

Type of assessment	*Phase of implementation*	*Form of the material*	*Used in Grading*
Verbal assessment – during the lessons conversations Subjective assessment – based on the student made notes	First lesson after collecting the information – controlling lesson	Student made notes of researched web pages	1 independent grade
Verbal assessment	During the lessons – forms of consultation and giving instructions	Student´s planning materials	Not graded independently, but were considered at grading the work flow
Assessment with rubrics	Final presentations and the main products	Presentation rubrics and rubrics to evaluate posters and models	1 independent grade at the end of the project – after the presentation days
Teamwork rubrics - questionnaires	Final evaluation of the project – meeting after project	Self-assessment and peer-assessment questionnaires and students reflections about the project	1 independent grade based on the students self and peer reflections of the group work also enriched with teachers opinion

Steps of project implementation

In this section we shortly describe the phases of implementation of our projects by concentrating on the implementation of the several assessing tools.

1 Lesson – Meeting with the project - Students got general knowledge about the main theme of the project and they were divided into groups. After the first lesson students had 2-4 weeks to research the web pages and prepare notes about the content of the web pages.

1 Lesson – Controlling the knowledge – We controlled the knowledge by the help of group discussions in which every student had the opportunity to describe their gained knowledge and also the teachers were able to control the level of gained knowledge.

1 Lesson – Planning the main products and dividing tasks among group members - The teachers describe the expectation about the main products. The main role of the several groups is to choose 3D product (or products) to produce, which serves as an appropriate example in their researched field and later divide it among each other into smaller tasks. As a helping tool the students get the instruction how to work with the planning form. The planning form was enriched by some questions concentrating on the main points of planning.

2-4 Lessons – Preparing the products - The student began to prepare their products based on their own planning. During the process of their meeting and preparing the products minimally 2 lessons (max. 4 lessons) were dedicated to consult with the groups about their progress. At the end of the last lesson, when the groups had their products ready based on the provided rubrics for assessing the presentation they were informed in details about the presentation day.

1 Lesson – Test presentation – Before the big day - Usually a week before the performance in front of the bigger audience the students had opportunity to test their presentation skills and for the teachers it gave a last opportunity to help the groups to become better.

1-6 Lesson – The big day – Presentation in front of the audience - On the last day several groups performed their presentations with the help of their 3D products. After every presentation there was a short 5 minutes conversation, when the audience could ask questions about the students' project.

1-2 Lessons – Evaluating the project - At the end of every project we realized a final meeting, where students could give a feedback about the whole project. The students also were asked to carry out self assessment and peer-assessment of their work during the projects with the help of prepared questionnaires.

Methods

Among our methods of gaining knowledge about the implemented projects and assessing system were using questionnaires for self assessing, peer assessing of student´s and student´s assessing of the project. We get a totally 135 student´s opinion by the help of these questionnaires, while we oriented on the following questions:

Self and peer assessing tool, where the students have to evaluate their work by grading it on a 5 degree scale where 5 represented the best value. The students gave their opinion in the following areas: level of completing of all their tasks, asking for help when needed, level of cooperating and collaborating with the working team, level of cooperating in the planning phase, level of cooperating in creating of the main products, level of cooperating in collecting of the information and level of cooperating while preparing the end presentation.

By the help of a questionnaire for student´s project evaluation we managed to gain more complex knowledge about the student´s opinions. We used a questionnaire where students could freely answer the following questions: What is the most important thing you learned in this project?, What do you wish you had done differently?, What part of the project did you do your best work on?, What was the most enjoyable part of this project?, What was the least enjoyable part of this project? and How could your teacher change this project to make it better next time?

Collecting the teacher´s subjective experiences by collaborating with the teachers during the whole project.

Results

Evaluating the questionnaires we managed to assess the student´s opinion about the collaboration, while we get a relevant feedback from the student´s project assessment. Our results we summarize in the next points.

Evaluating the self and peer assessment tools we realized, that most of the students think they have completed all of their tasks (89,63 % in self assessment, 80,10% in peer assessment), and (88,15 % in self assessment, 79,32 % in peer assessment) were collaborating maximally. On the other areas, like level of cooperating in the planning phase, level of cooperating in creating of the main products, level of cooperating in collecting of the information and level of cooperating while preparing the end presentation student´s were using criticism and they evaluated their level of collaborating around 50%. According to the evaluation of these questionnaires we realized, that the students mostly were collaborating, and taking part at the beginning of the project, while the later phases they collaborated by lower level of interest. Comparing the results of the peer and self assessment we realized, that the students were assessing their team members slightly more strictly, than themselves.

In the project evaluations students were allowed to describe their opinion freely, which resulted in many different type of description. The different opinions we categorized for every questions. We summarize the main categories (categories, which were represented at least 8% of student´s opinion) in the following table (Tab. 03. Student´s characteristic opinion about the project).

During our projects we implemented several rubrics and questionnaires for assessing the gained skills of students. Using these materials for the collaborating teachers had been a relatively new experience. After they managed to identify with the purpose of using these materials (mostly they needed to understand, that with the help of these tools mainly concentrated on the gained skills, and not on gained knowledge), they had no difficulties to assess students performance by the help of these tools.

Based on the everyday collaboration by the students we could evaluate that the students viewed the implemented assessing system as an equitable system, which provided plenty of opportunity to express they opinion.

Tab. 03. Student´s characteristic opinion about the project

Question	Type of answers	%
What is the most important thing you learned in this project?	Improving presentation skills	*10,37*
	Improving communication skills	*15,56*
	New knowledge	*37,04*
	Improving the ability to work together	*32,59*
What do you wish you had done differently?	Improve end presentation	10,37
	Nothing	37,04
	Begin to work on the products earlier	8,15
	Collaborate more	14,07
What part of the project did you do your best work on?	*Creating non-traditional products*	*62,22*
	Preparing the end presentation	14,07
What was the most enjoyable part of this project?	*Working on the non-traditional products*	*45,93*
	Presenting in front of the audience	17,04
	Collaborating	17,78
What was the least enjoyable part of this project?	Collecting information	8,89
	Nothing	14,81
How could your teacher change this project to make it better next time?	Do not apply any change	29,63
	By choosing another theme for the project	8,15

Conclusions and implications

Based on our experiences the implemented assessing system showed to be useful in evaluating the student´s gained skills. Also according to the student´s opinion these tools provided an opportunity not just express their opinion about the project, but also they viewed the assessing system as an equitable system.

Evaluating the project and giving self or peer-assessment was a new idea for the students, but they managed it easily. We expected in their evaluation and mainly at the self and peer assessment some level of dishonesty, but at the end it was not a common occurrence. Most of the students used this opportunity to describe what they did not like in the project and they tried to give us a better view of their real group work. Of course some students were not so respectful with each other, they were exaggerating, but these cases have been easily identified.

Based on our experiences the implemented tools with minor modification to match each projects and classes individual requirements could be useful tools to help teachers in providing more complex and equitable evaluating of projects.

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Gabriella Németh

Miroslav Prokša

Comenius University in Bratislava, SL

nemeth@fns.uniba.sk proksa@fns.uniba.sk

ESTABLISHing Students' Interests in Everyday Science

Eva Stratilová Urválková, Petr Šmejkal, Hana Čtrnáctová, Věra Čížková

Introduction

ESTABLISH (European Science and Technology in Action Building Links with Industry, Schools and Home) is a four year European project finishing in year 2014. The consortium with more than 60 partners from 11 countries worked on encouraging and implementing inquiry-based approach to science education for second level students across Europe by bringing together the specific key stakeholders in science education. Science education researchers, teacher educators, scientific and industrial communities, policy makers and parents were involved in a process creating more authentic learning environment for students and teachers in science education.

The innovation in classroom practice was achieved by focusing on two aspects: (1) preparation of appropriate teaching and learning inquiry based science education (IBSE) units and (2) support of IBSE itself and developed IBSE units for both in-service and pre-service teachers. All materials created within project ESTABLISH are available on project website http://www.establish-fp7.eu/ and 18 translated units in Moodle environment as well: http://ibse.establish-fp7.eu.

Methods

Framework for IBSE teaching and learning units

Created teaching and learning materials follow the concept of inquiry-based science education (IBSE) as the main teaching strategy that supports constructivist learning and provides students' opportunities to plan their own inquiries or to construct meaning from the real world based on their experiences [Llewellyn 2002].

The consortium agreed on a unit framework that will consist of two parts: (a) teacher information including Unit description (student level, discipline involved, estimated duration), IBSE character, Science content knowledge, Pedagogical content knowledge, Industrial content knowledge, Learning path(s), Assessment and Detailed description of student learning activities (activity, learning aims, materials, suggestions for use). Second part (b) classroom materials provides materials, mostly worksheets that can be used in science lessons. A tool for authors, Guide for developing ESTABLISH Teaching and Learning Units had been created as one of the project outputs.

Evaluation of ESTABLISH units

The testing and implementing of ESTABLISH units was evaluated with developed tool mostly based on Intrinsic motivation inventory, IMI [Ryan & Decim, 2000] and Constructivist learning environment survey, CLES [Taylor, Fraser & White, 1994]. The authors of the tool were researchers from Charles University, the Department of Physics Education [Kekule & Žák, 2011].

Framework for Teacher Education Programme

The ESTABLISH aim is to implement an inquiry based-approach in the teaching and learning of science and technology across Europe with second level students. To facilitate the aim, science teacher educational workshops were developed in a framework of ESTABLISH. Based on the project report Main obstacles to implementation IBSE, the framework of teacher education programme was divided in two levels containing core elements and supporting elements. Core elements include I. ESTABLISH view of IBSE, II. Industrial Content Knowledge (ICK) - authentic experiences informed by industry or real applications, III. Science Teacher as Implementer & Management – prepare teachers for implementing, identify the challenges and IV.

Science Teacher as Developer – teachers change their own materials into inquiry based materials. Supporting elements help teachers to overcome the challenges and barriers: V. Classroom Management & ICT, VI. Argumentation in the classroom & Questioning Skills for Inquiry, VII. Research and design projects for students & Evaluating Evidence and VIII. Assessment of IBSE. The framework and the content was designed by partner Dublin City University, each partner has modified the programme according to local conditions.

Results – The Czech Republic

Charles University in Prague represents a partner from the Czech Republic. The testing and development of ESTABLISH units were coordinated by the Department of Physics Education (Faculty of Mathematics and Physics), Department of Teaching and Didactics of Chemistry and Department of Education and Didactics of Biology. The contribution focuses on results of researchers from Faculty of Science, although Department of Physics Education took part on developing the unit Direct current electricity together with Institute of Physics from Pavol Jozef Šafárik University in Košice.

Chemistry activities - developed and tested units

The unit Polymers around us was developed by researchers from Department of Teaching and Didactics of Chemistry, Charles University in Prague. The work began in 2011 and in year 2012 continued in cooperation with the partners from P. J. Šafárik University in Košice and an extensive material was created. Three subunits, Plastic, Plastic waste and Polymers around us are applicable both in lower and higher secondary school (11-18 years old students) depending on particular activity. The activities are focused on distinguishing plastics and studying their physical and chemical properties, labelling the plastics and treating plastic waste. Activities from developed unit were tested at four schools with total amount of 126 students: one primary school (Basic school Žernosecká, Prague), three grammar schools (Grammar school of Pierre de Courbertin in Tábor; Grammar school Písnická, Prague; Grammar school Zatlanka, Prague) and one secondary vocational school (Masaryk Secondary School of Chemistry, Prague). After pilot run the activities were adjusted and tested at the beginning of 2013. Polymers around us was also implemented into pre-service teaching programme, where future teachers worked with ESTABLISH materials and practised IBSE for whole semester (2 lessons per week).

Beside own developed unit, Charles University was involved in testing other chemistry units: the unit Exploring holes (authors from Dublin City University) was tested in basic school Žernosecká in Prague, grammar school Písnická in Prague, grammar school Tábor and Masaryk Secondary School of Chemistry and unit Chemical care (authors from Institute for Science and Mathematics Education, Leibniz) was tested in grammar schools Malá Strana Grammar school in Prague, Botičská Grammar School in Prague and Masaryk Secondary School of Chemistry.

The ESTABLISH outputs and IBSE approach was disseminated among chemistry teachers during in-service courses: in 9 courses totally 128 teachers were supported with teaching method and materials. The course and IBSE principles were positively accepted, nevertheless, the obstacle of time and students' motivation was mentioned.

Biology activities – developed and tested units

A team of researchers from the Department of Education and Didactics of Biology developed ESTABLISH unit Water in the life of man, for target group of students aged 12-18 years. The unit consists of twelve activities with estimated duration 12-14 lessons and it covers biological issues, such as importance of water, water intake, water in the human body, importance of kidneys, and also issues comprising technology or chemistry, such as production of drinking water, tap x bottled water, analysis of beverages, formation of urine. The main topic of the unit is fluid intake, a relationship between man and water and importance of kidneys for the life of man. Water in the life of man was tested on five Prague schools (Grammar school prof. Patočka, Grammar school

Na Vítězné pláni, Business Academy Kubelíkova, Private high school of Tourism Arcus and High school of nursing Ruská), on 126 students in total. In Slovakia pilot group of 9 experienced teachers took part in meetings with duration over 6 six hours; the unit was also tested in Ireland. Water in life of man was implemented into tertiary education as well: for three years pre-service biology teachers (in total 36 students) were working with ESTABLISH units and this testing brought important feed-back for upgraded versions.

Partners in the Czech Republic were also involved in testing of other units: unit Blood donation (authors from Pavol Jozef Šafárik University in Košice) was tested at five secondary schools in Prague, mentioned above. Five teachers and 118 students were involved in the testing of nine activities. ESTABLISH unit Disability (authors from Umea Universitet), three activities out of twelve, were tested at two Prague schools with 48 students: at High school of nursing Ruská in Prague and Business Academy Kubelíkova.

Cooperation with companies, excursions

Positive aspect of ESTABLISH project is developing cooperation with industry fields at various levels. Some companies provided materials from their own sources for the teachers (Meopta, a.s., Silon, s.r.o., etc.) or material for developing the unit (Meopta company supplied lenses, mirrors and other optical elements; Silon s.r.o. helped with unit Polymers around us, AV-media, Profimedia and Edufor helped with sensors and accessories, educational tools etc.). And further cooperation with museums and state organizations were evolved during excursions in both teaching educational programmes. Teachers highly evaluated these practical excursions that can be employed in their school practice as well.

Conclusion

Four year project promoted IBSE methodology in the classroom when a large team of science teachers across Europe who are skilled in IBSE methodology was established. Pre-service and in-service teachers were supported by developed units, 18 from all science branches, now available at http://www.establish-fp7.eu/dissemination-en/publish-material. Various stakeholders, especially from industry field, were involved in the project and a fruitful cooperation was established.

In the Czech Republic, thanks to the ESTABLISH project, the awareness about IBSE was successfully disseminated: among students, especially during the testing and the implementation of units by teachers, among teachers, both in-service teachers through teacher courses and pre-service teachers through specialized periodical lessons. Moreover, promotion and expansion of inquiry approach in science education supports development of scientific knowledge and key competencies that also represent outputs in Czech curricular document, Framework Educational Programme.

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Eva Stratilová Urválková

Petr Šmejkal

Hana Čtrnáctová

Věra Čížková

Charles University in Prague

Faculty of Science

Prague, CZ

urvalkov@natur.cuni.cz, psmejkal@natur.cuni.cz, hana.ctrnactova@natur.cuni.cz, vera.cizkova@natur.cuni.cz

Natural compounds in Project Based Learning

Petra Lechová, Mária Ganajová, Milena Kristofová, Renata Šulcová

Background

The current approach in the education process in schools is mostly characterized by the persistent dominant position of a teacher and passivity of students. Students acquire knowledge by passive form, which does not allow its application and use in practice.

In solving tasks which are aimed at everyday life problems, our students´ accomplishments are consistently statistically below the average of OECD countries [Holec et al., 2006; Santiago et al., 2012]. Students have mastered a lot of knowledge, but they have difficulty in independent thinking about scientific problems and in investigating the problems on an appropriate mental level, including formulating hypotheses, looking for and suggesting possible solutions, interpreting collected data, making conclusions and stating arguments. [Núcem, 2010]. One of the solutions that could contribute to increasing scientific literacy is undoubtedly changing the way of teaching science school subjects. A project-based teaching is considered to be an appropriate method which can make pupil active and interested in science. Project teaching is based on the solution of theoretical or practical problems under the active work of the students. It is meant to overcome the shortcomings of the typical teaching like isolation, detachment from practical life, mechanization and stiffness of school work, alienation from the interests of students, unilateral memorization and low motivation. It is now seen as a complementary supplement of classical teaching [Ganajová, 2010].

In the contribution we want to point out on the effectiveness of project learning in comparison to traditional way of teaching, as well as on the impact of project teaching on the change of students´ opinions and attitudes to natural science subjects after the project-based schooling.

Methods

The main research method was a pedagogical experiment, in which we verified the effectiveness of teaching (the level of knowledge, durability of knowledge and change of students´ attitudes towards the natural science subjects) after the implementation of project based learning. The pedagogical experiment was realized at the Grammar school in Košice. The research was conducted in control and experimental groups with total participation of 50 students. In the experimental group, the teaching on topics of Saccharides and Proteins was done by project method. The teaching in the control group was carried out in the traditional way. Students in experimental group were working in the small groups of four, they were solving out the given tasks (searching, sorting out and organising available information about the given topic). They met regularly, formed hypotheses, searched for partial solutions, realized experimental activities and processed the results into required outputs. They used a PowerPoint Presentation to present the results of their project to their classmates. During the whole project, they had opportunity to express their own opinion, their ideas, and they could show own initiative. The teacher performed in the background as a partner, advisor or consultant, she helped students in learning and motivated them [Lechová et al., 2013].

We used didactic tests to verify the effectiveness of the teaching. The didactic knowledge tests for topics Saccharides and Proteins were non-standardized, objectively graded and cognitive. The aim of the tests was to measure and compare the knowledge of students in the experimental and control groups. Durability of students' knowledge was measured by the same tests, after four months again on the topic of Saccharides, and after three months on the topic of Proteins [Lechová, 2014; Poráčová, J., Zahatňanská, M. & Takáczová, 2008]. We were finding out the students´ attitudes and opinions about science school subjects on the basis of a questionnaire method after the project-based schooling. We used the scale questionnaire of our own construction. We were also finding out their opinions about project-based schooling on the basis of a scale questionnaire.

For the verification of set hypotheses we used statistical methods. As the statistic tool, we used MS EXCEL 2010 application. Kolmogorov-Smirnov statistical tool of dual-selection enabled to test compliance of the two cumulative distribution functions. Comparing the statistical significance of differences between the individual sets of data, we analysed at first the results with dual selection Fisher-Snedecor F-test of the equality of variances. On the base of the F-test results, we applied Student´s t-test of the equality or inequality of variances [Lechová, 2014].

Results

Since not respecting the principle of succession and sequence of the subject matter is considered to be a problematic aspect of project teaching, we set the following hypothesis as the first one:

Hypothesis 1: We expect that by implementing the project teaching in chemistry, at the end of the experiment students will obtain a higher level of knowledge than by the traditional way of teaching.

For the purpose of the statistical verification of the hypothesis we used knowledge tests for topics of Saccharides and Proteins. The results of the students' output tests have undergone testing by Kolmogorov-Smirnov statistical tool of dual-selection compliance test. We compared the calculated value of the test criterion D(test) = maximum |FES-FKS| with the critical value D(crit), on the significance level $\alpha = 0.05$. Since the value of the test criterion was $D_{test} < D_{crit}$, we could not refuse the null hypothesis H0. The unconfirmed hypothesis H1 can be interpreted by the fact that basic knowledge of this topic needs to be explained to students with respecting the principle of succession and sequence. These are matters which contain many technical terms, which we should make available systematically. Based on the evaluation of the results and statistical analysis, we can state that students reached a comparable level of knowledge through the project method as students which were taught by a traditional manner.

Hypothesis 2: We expect that the durability of knowledge of students taught by project method will be higher than of students taught by a traditional manner.

For the purpose of the statistical verification of this hypothesis we used knowledge tests for topics of Saccharides and Proteins after 3 months. Students' test results on durability of knowledge have undergone testing by Kolmogorov-Smirnov statistical tool of dual-selection compliance test. The evaluation of the results and statistical analysis showed that project method had a positive impact on durability of acquired students' knowledge. We also verified attitudes and opinions of students on project based learning and the change of their opinions on natural science subjects after using the project method.

Hypothesis 3: We expect that at the end of the experiment, students will positively evaluate project based learning and will recommend continuing of teaching chemistry and other subjects in this way.

The analysis results of the responses of students in the experimental group after ending the teaching experiment confirms the hypothesis 3: students positively evaluate this method of teaching. More than 88 % of the students expressed the view that the project teaching is more interesting than the traditional method of teaching and 90 % of students were captivated by the work on school projects. 72 % of students expressed the view that they would like to continue learning the chemistry by project method and 64 % of students suggested to use project based learning in other subjects as well. All students in experimental group confirmed that the knowledge acquired during the project are for them easier to remember. It has the relevance to their way of life and helps them clarify ambiguities, which they encountered in their life. More than 70 % of students are interested in the subject of chemistry and it seems more interesting to them by the implementation of project works.

Selected results are presented in the following figure 01., figure. 02.

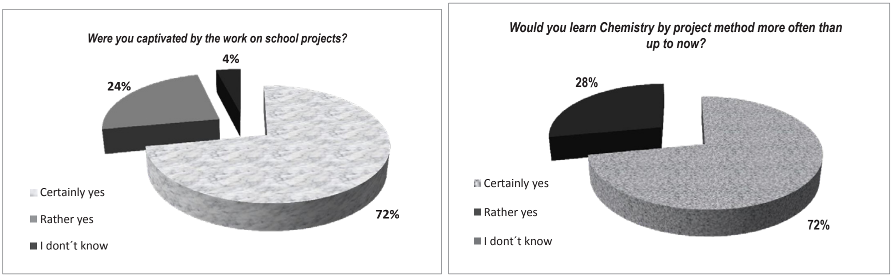

Fig. 01. 02. Opinions of students from the experimental group on project learning

Hypothesis 4: We expect that interest in natural science subjects will be higher with students taught by project method than with students taught in a traditional manner.

The hypothesis was verified with the scale questionnaire, which was filled out by students both from experimental and control group after the completion of the experiment.

Selected results are presented in the following figure. 03, figure. 04.:

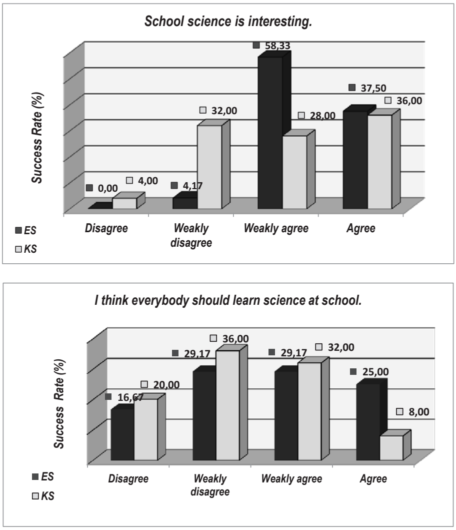

Fig. 03. 04.– Opinions of students both from experimental (ES) and control group (KS) on natural science subjects

Answers of students were statistically verified by statistical methods F-test and t-test. The results of the analysis confirmed the hypothesis that project based learning contributes to the development of interest in natural science subjects. Both test groups of students feel that natural science subjects are more difficult than other subjects (60 % students of experimental group, however 90 % of them confirm that they are interesting). In the experimental group more than half of the students agree with the statement that all students should learn natural science subjects at school and 70 % state the opinion that what students learn at natural science subjects will help them in everyday life. Natural science subjects also show them how important the science is for their way of life (87,5 % of students).

Conclusions and implications

Following conclusions resulted from the research:

By implementing the project based learning in chemistry students obtained the level of knowledge comparable with students taught in a traditional manner.

Project based learning has a positive impact on durability of acquired students' knowledge.

Project based learning contributes to increasing the interest in natural science subjects.

At the end of the experiment students positively evaluated the project method and recommended continuing of teaching chemistry and other subjects in this way.

Project based learning increases interest of students in the chemistry subject.

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Petra Lechová[1]

Mária Ganajová[2]

Milena Kristofová[2]

Renata Šulcová[3]

[1] *Grammar school Šrobárova 1, Košice, SL*

[2]*University of P. J. Šafárik in Košice, Faculty of Science, SL*

[3]*Charles University in Prague, Faculty of Science, CZ*

petralechova@gmail.com, maria.ganajova@upjs.sk, milena.kristofova@upjs.sk

rena@natur.cuni.cz

IBSE strategy in connection with art: discovery biological contents and processes by modelling in school education practice

Paulina Zimak

Introduction

Education strategy, which was implemented in Social STO Gymnasium and High School in Zakopane, is the strategy of teaching science through scientific inquiry and discovery (IBSE, called Inquiry Based Science Education) in conjunction with the scientific and artistic approach (Zimak, 2013). The aim of it was to demonstrate the opportunities offered by the coherence of science, technology and art in the school education. The inspiration for this type of activity was a science project Allosphere'a conducted at the University of Santa Barbara, California.

This article presents examples of sequences of photos of modelling biological processes used within the natural learning in our school. It is recommended especially for students of modalities: visual or kinesthetic in the framework of the questionnaire VARK learning styles (www.varklearn.com). The impact of learning-teaching styles on education processes Nodzyńska (2008ab) revealed in her research.

In school education during biology lesson we learn e.g. cell structures, molecular genetics construction and biological-chemical mechanisms of life including: DNA replication, protein synthesis (transcription and translation) and cell division. Students have a lot of problems with micro world and understanding it. We try to solve the problem by connecting science with art and working IBSE strategy in daily school practice. During our interactive show we analyze problematic questions, what help pupils in learning and understanding.

This article is a proposal for the above-mentioned methodological activities within the framework of the natural sciences.

Framework and methods

In the first class of gymnasium pupils learn about Cells - a unit of life. They learn comparative analysis of cell organelles, what should provide them to distinguish different types of cells: plant, animal, bacterial and fungus. I observed difficulties in recognition of cellular structures, so during these lessons we decided to create our own models of cells. Students analyze in detail the properties of an object, collect the materials necessary for creating model of cells.

Students create cell's models with the plastic cups, boxes for breakfast, ground salt, plasticine, shells or food products that mimic the appropriate cellular organelles e.g.: jelly (equivalent to the cytoplasm), coffee beans (the nucleus), poppy seeds (ribosomes). Others use sponge to create inner mitochondrial membrane, which in reality is highly wrinkled

(Fig. 1). Each student present how they make model, which materials are used and explain why use them. Other pupils classify the cell to appropriate Kingdom point to the absence or presence of cell organelles.

Noteworthy is the fact that students very quickly and very easily recognize organelles, differentiate cells within the further lessons (Kingdom: Bacteria, Protists, Fungi, Plants, Animals). Also pupils note that the organelles are imaginary color (ribosomes are not as black as poppy seeds), unless they have some natural dyes such as chlorophyll in chloroplasts.

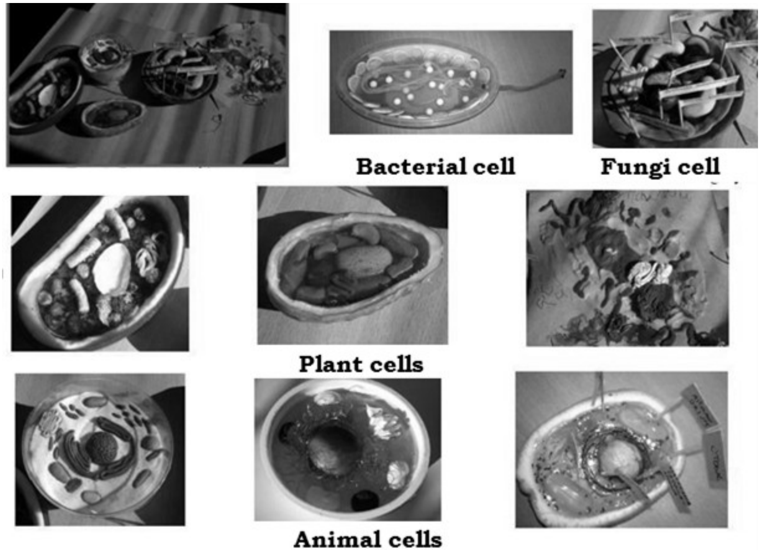

Fig. 1. Cells models: bacterial, fungi, plant and animal (students' work, STO Zakopane)

In higher education level (third class of gymnasium / high school) during genetic lessons students learn molecular structure and bio-chemical mechanism of life: like DNA replication, biosynthesis as well as cell division. Pupils are eager to: create the structure of DNA molecules (Fig. 2), tRNA with jellies, define range of conceptual: gene, genome and structure of eucaryotic genes using blocks (Fig. 3), explain role of enzymes e.g. in DNA replication processes (Fig. 4), analyze diagrams and find their differences as well as learn about levels of organization of genetic material in division making artistic structures: nucleosome, solenoid with beads, threads, etc. (Fig. 7). During lessons we make detailed analysis of the object's properties, diagrams in books and the Internet (Fig. 5-6) to make our interactive show. Students willingly watch and participate in demonstrations. We ask problematic questions and try to solve them, for example:
1. In what form the genetic material occurs during the "bio-copy" - the replication process, and during the cell division? Why is this character? How the genetic material is organized in different phases of the cell cycle?
2. Why the genetic material replicates before cell division?
3.What is the function of enzyme topoisomerase in the replication of DNA molecules?
4. How many molecules of DNA construct metaphase chromosome in diploid organisms,
e.g. humans? Count how many chromatids of a chromosome is presented metaphase kariogram? Examine patterns in the book / Internet, our show.
5. How to recognize homologous chromosomes?
6. What is the difference of mitosis and meiosis?

Examples of students' answers and explanations:
1. The genetic material is a loose while copying but condensed during cell division. It's easier to work on replicating enzymes strands loosely organized, and share strands of DNA molecules condensed.
2. Material replicates in order to be able to rise to daughter cells by dividing. "To share what you have to have to share"
3. Topoisomerase reduces the stress on the strands of DNA to not break the thread.
4. Dploid metaphase chromosome consists of two DNA molecules, two chromatids are visible on

karyogram. (Diagram 6 - lack of consistency between drawings)
5. Homologous chromosomes have the same gene loci, the same morphology (shape, size, position of the centromere)
6. Differs from mitosis and meiosis: the number of divisions arrangement of chromosomes in the metaphase plate

Practical examples: interactive shows, models

Students learn the principle of complementarity of nitrogen bases in the DNA (Fig. 2) by different colors of jelly - they make legend: green jelly - it is thymine, blue is adenine etc. or by shape - small jelly (pyrimidine - one ring molecule) or larger jelly (purine - two rings molecule). They control appending jellies - which color we can give opposite the blue one or shape we can have only free rings on diameter of DNA :) It is good for visual modality students as output ranges of biology contents using blocks (Fig. 3). Fig. 6 shows two version of karyotype, which is a set of chromosomes characteristic of the somatic cells (body cells without gametes) - students should find differences between two diagrams and link with

Fig. 5. to explain why first or second diagram is (un)correct. Karyotype is observed after cell division the replication phase so the first diagram is correct - metaphase chromosome consists of two chromatids (the circle on diagram, Fig. 6). Students, especially kinesthetic modality, can learn about role of enzymes by show with laces - they can feel tension in DNA, it is a place of enzyme action (Fig. 4).


Fig. 2. Sweet jelly DNA model

Fig. 3. Interactive show with blocks – gene-genome relations E – exon; I - intron

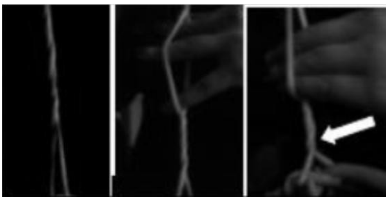
Fig. 4. What is needed topoisomerase?
Laces' show arrow indicates tension in DNA structure as well as localization of enzyme working

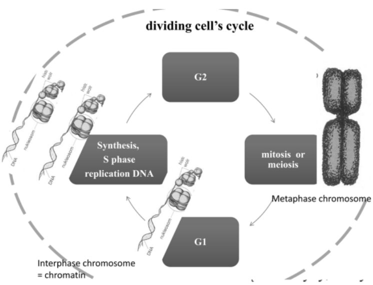

Fig. 5. The cell dividing cycle
Chromosome will never disappear,
but may no longer be visible

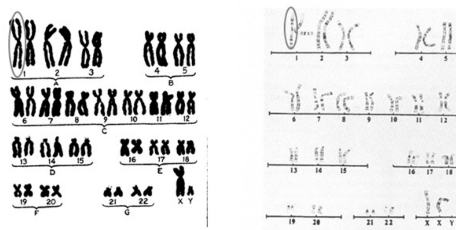
Fig. 6. Karyotype - comparative analyse between diagrams and Fig. 5.

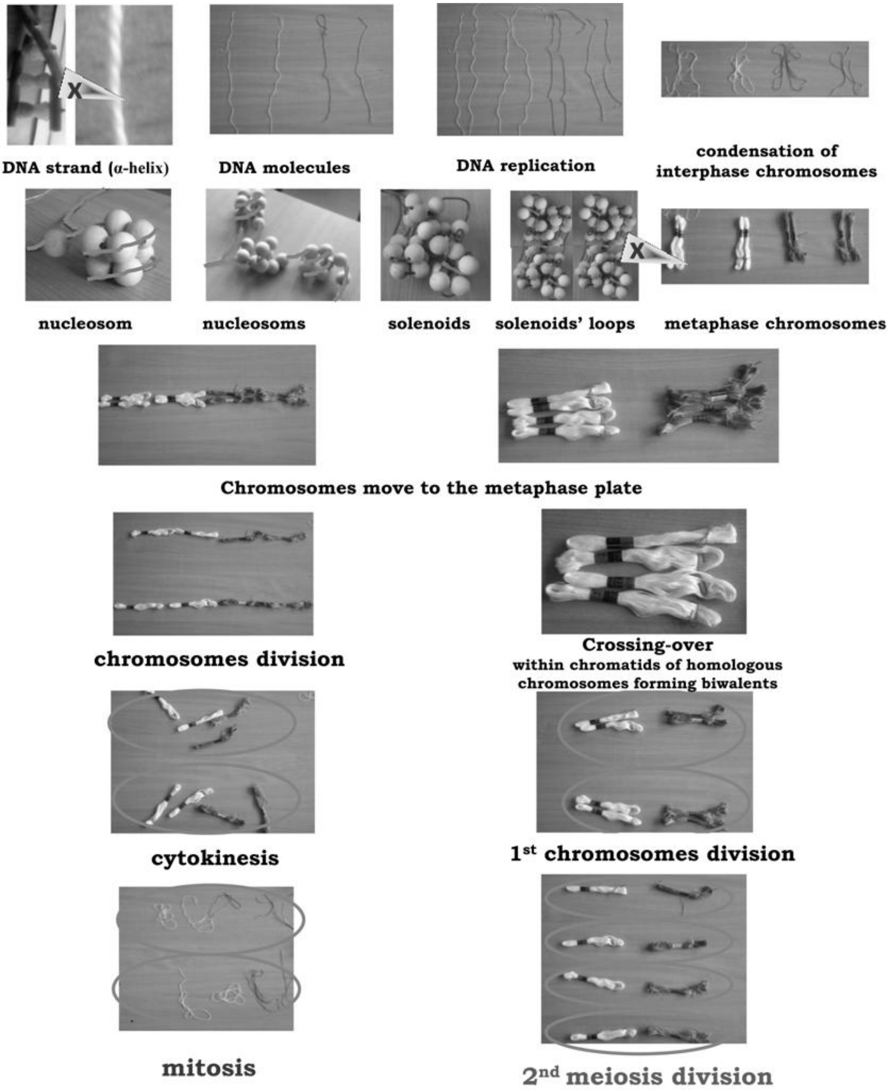

Fig. 7. Cell divisions - mitosis and meiosis - an interactive show

Notes: Colors of contractual molecules. Skipped proteins (histones) to the data stages. Kariokinetic microtubules spindle are represented by our fingers. It is important for the same time the genetic material separated during cytokinesis, rather than sequentially, idea arose not more divisions; X – magnification area, misses on next pictures.

Conclusions

Learning by discovery structure of cells and study mechanisms of cellular processes link with art modeling gave us a lot of pleasure. It was a great science and fun experience realized according IBSE strategy. Students remember analyzed content and processes for longer. It is worth for all students especially visual and kinesthetic modality, so term of students learning preferences for appropriate education process should be everyday school practice.

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http://www.vark-learn.com/english/index.asp

Model's authors:

Kurowski Tomasz (DNA model) & Maciej Florek (nucleosome and solenoid model)

Cells' models: Balon Łukasz, Gąsienica-Daniel Jan, Gąsienica Katarzyna, Gruszka Korneliusz

Guziak Paulina, Owczarz Jędrzej, Wierzchowski Łukasz, Wyrzykowski Dawid

Paulina Zimak

Gymnasium and Secondary School STO in Zakopane, PL

The National Gymnasium of Arts in Zakopane, PL

International Doctoral Studies In Natural Sciences At The Polish Academy Of Sciences in Cracow, PL

paulina.zimak@gmail.com

IBSE & pupils'/students' science skills

Hana Čtrnáctová, Věra Čížková, Dana Řezníčková

Introduction and purpose of the framework

The European Union, whose member Czech Republic has been for the last ten years, brings inspiration to the education systems of the individual countries, but it also brings new requirements. The recommendations and program statements of EU [Rocard et al., 2007] in period 2000-2010 directed the national school systems towards the reforms that EU demanded. The current curricular reform in Czech Republic was already being performed with accordance to EU demands. In particular, it determined the educational outputs on the primary and secondary schools level, mainly in the area of competencies and the skills that follow them [Čtrnáctová & Čížková, 2012]. In this study, we aimed to establish the required scientific skills of students at different levels of these schools and the hierarchy of these skills. The solution for the suggested skill system was IBSE (Inquiry Based Science Education) [Franklin, 2000, Establish, 2010].

The main method of our research was a questionnaire survey of teachers at primary and secondary schools, as well as colleges, aiming to find their opinion about the meaning and hierarchy of the suggested skill system for teaching of the scientific subjects of biology, chemistry and geography. This was followed by the use of didactic testing method in order to discover true skills of the students of primary and secondary schools (11-19 years) in these subjects as well as in the "Nature study" subject (6-10 years). In the last stage of the research we used the method of guided talk with primary and secondary school teachers in order to verify the understanding of the discussed term "skills" and their acquisitions by the tested students' teachers [Řezníčková et al., 2013].

The results of this research led to the final proposal for the skill system for the scientific subjects – biology, chemistry and geography – at the level of primary and secondary schools for the disciplines mentioned. The skill systems we developed became the starting point for the application of the IBSE method at schools in the Czech Republic, both for theme developers and for teachers who will be able to use this teaching method at school thanks to the training of necessary skills [Řezníčková et al., 2013].

This contribution will summarize the results of first and third stage of our research and we will more closely focus on the students' skill testing (process and results), using the example of the subject of chemistry.

Methods of the research

The current educational requirements reflect the change in the general approach to education: The fast increase of new scientific knowledge, the development of information and communication technologies, change of objective needs and perspectives in the development of society and new demands for practical applications.

One way to resolve this situation is to apply the IBSE approach in education.

Inquiry Based Science Education (IBSE) is an educational protocol based on students' own investigations with use of many activising methods. It is a process of problem diagnostics, experimenting, alternatives detection, research planning, stating and verifying of hypotheses, searching for information, model creation, discussion and argumenting. The advantages of IBSE are that the students learn active problem solving in teams, their interest in science increases, they acquire scientific methodology (like collection and comparison of data, use of IT and the Internet etc.) and they are much better prepared for their further life and lifelong education, both through the method of work and through the durability of acquired knowledge. However, IBSE education has also its problems. The teachers are worried about realization of experiment-based work in their own classes; they also fear the unknown and they lack training in "active" teaching since they are more used to lecturing, especially at secondary schools. Their superiors are also not always sufficiently convinced of the usefulness and effectivity of this type of teaching and there are worries whether the students have sufficient skills to make use of this new type of teaching or not.

The learning cycle can be used to create the structure of the IBSE education since it's one of the most common and most effective models for realization of teaching and learning; the most commonly used approach is the 5E cycle which contains the following learning phases [Čtrnáctová, Čížková, Hlavová, & Řezníčková, 2012]:
Engagement – arousing interest and curiosity, activating learning, evaluating previous knowledge, giving students a chance to make use of their previous knowledge.
Exploration – involving students in the inquiry, letting students ask questions and develop hypotheses, gathering data and information, suggesting and performing observations and experiments.
Explanation – processing data and evidence, discussion and explanation of scientific terms.
Extension – extending the evidence to new situations.
Evaluation – judging, analysing and evaluating their work.

This analysis of the IBSE teaching cycle shows the main goals of our research, realised as a part of the project "Students' skills in biology, geography and chemistry: research into planned, realized and achieved curriculum in implementation phase of curricular reform", funded by the grant agency of CR in 2010-2013. The project was performed by Charles University in Prague – Faculty of Science and Masaryk University in Brno – Pedagogical faculty. The results will be presented in: Student skills in the teaching of biology, geography and chemistry (a monography) [Řezníčková et al., 2013].

The main goal of this project is to propose an interlinked system of student skills based on their multi-level analysis. These are skills that should be acquired in geography, biology and chemistry at the end of primary school and at the end of lower and upper secondary schools (grammar school) in order for the pupils to be able to work using the IBSE method.

Partial goals of the project are to propose a subject skill system at primary/secondary level in biology, geography and chemistry, to analyse the teachers' opinions about this system, to test pupils´/students' skills at primary/secondary level and to interview the teachers about the pupils´/students' skills.

Results of the research

The first stages of the research were focused on finding out the opinions of educators at all levels about the proposed structure of students' skills in biology, geography and chemistry corresponding to the IBSE approach. A proposal of general/specific student skills in biology, geography and chemistry was compiled and presented to teachers at primary level (528 teachers), secondary level (191 teachers) and college level (119 teachers). The analysis of their responses reached the conclusion that the respondents in general agree with the suggested skill system for these subject; interesting fact is that the higher the school level, the lower the demands.

The second stage of the research was testing of common (IBSE) and specific skills of lower and upper secondary school students. In the subject chemistry, testing included 684 students: (lower secondary schools – 431, upper secondary schools – 253) from the Czech Republic.

The testing took place from May to June 2012. The focus of various tasks is shown in table 1. It is mostly about searching for information in various resources (text, tables, graphs), working with this information, posing scientific questions and seeking answers to these questions.

Tab. 01. Specification of chemical test tasks

Task	Skill type
1	information search in text
2	data search in table
3	data search in graph
4	analysis of data from multiple information sources (text, table, graph)
5	data transfer from text to table
6	data transfer from text to graph
7	asking expert questions
8	information search in text

The successfulness of the tasks (its percentage) in lower secondary schools and upper secondary schools is plotted in figure 01. You can see from the figure that the succesfulness of the pupils of lower secondary schools (black columns) was lower than the successfulness of the student of upper secondary schools (grey columns). Overall the successfulness of the solving of the tasks is satisfying and reaches over 50 %.

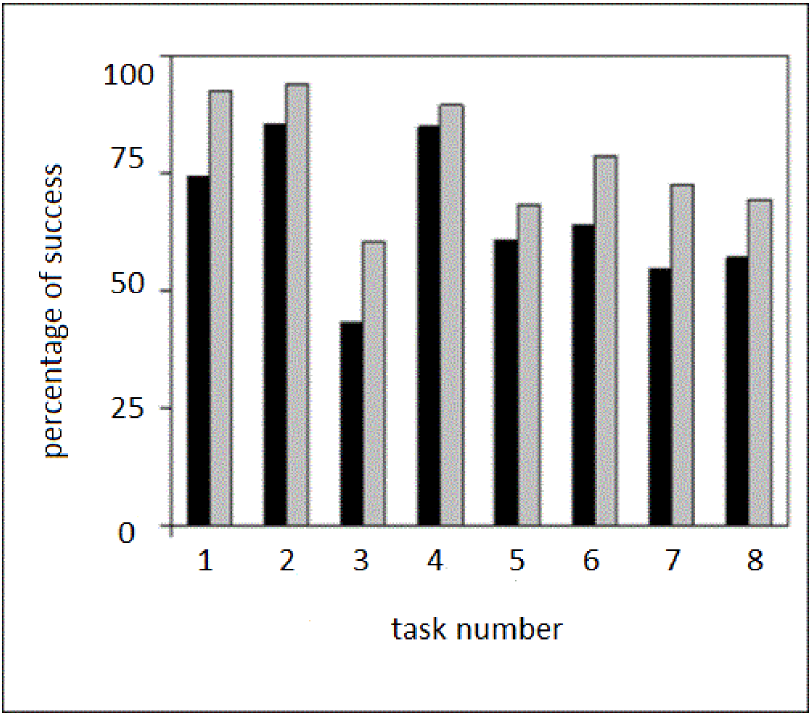

Fig. 01. The average success rate of students (%) in various problems of the test

The third part of the research aimed at teacher interviews about student skills. We have interviewed the teachers about the importance of general student skills and their acquiring in the science education. 27 teachers in total were interviewed (6 biology teachers, 9 geography teachers and 12 chemistry teachers). The analysis of the answers led to conclusion that the respondents generally lack a clear idea about these skills and the way to train them.

Conclusions and implications

The questionnaire investigation of the teachers shows that most of the teachers agree with the skill structure demanded by IBSE. The test results show that most of the students have the necessary skills for IBSE, at least at a basic level. The teacher interviews show that their idea about acquiring skills for IBSE are pretty problematic. The results acquired so far show that inquiry-based education could be in practice realized even now and students do not have to be specifically prepared for it; however, it's necessary to put more effort into IBSE training for the teachers.

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Hana Čtrnáctová

Věra Čížková

Dana Řezníčková

Charles University in Prague, CZ

ctr@natur.cuni.cz, veciz@natur.cuni.cz, dana.reznickova@natur.cuni.cz

Between theory and practice of teaching with the use of IBSE

Małgorzata Nodzyńska

Introduction

As a part of the subject “Teaching chemistry,” students of the second year of MA studies in chemistry and biology get to know various strategies of teaching, including IBSE. They are acquainted with the definition of the term[1], principles of the strategy, sample plans of such a type of lessons are discussed. During a parallel course “Chemical experiments planning” students learn practical planning of experiments: formulation of hypotheses, planning the experiment course, data verification... At the end of the course “Teaching chemistry” students are asked to prepare a plan of a lesson based on the IBSE teaching strategy.

Research

In the academic year 2013/2014, 60 students participated in the classes “Teaching chemistry.” It was the second, revised and amended edition of the course. Despite the fact that during the classes on methods of teaching chemistry and natural sciences much time was devoted to the discussion of the IBSE strategy, lesson plans prepared by students to get a credit were not satisfactory.

Students’ works were evaluated by taking into account their conformity with the 5E[2] cycle of learning and with the list of competences developed during a scientific inquiry, the so-called PTI [Pathways to Inquiry, Louisiana State University]. Students were informed about the evaluation criteria in advance.

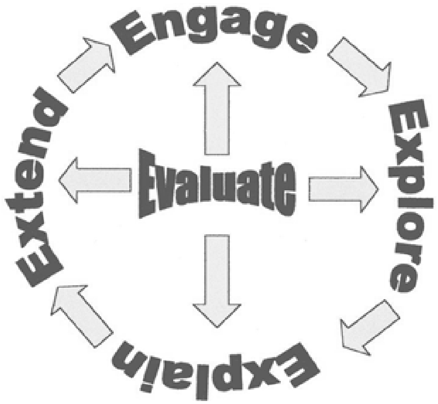

Fig.01. Model of a 5-stage cycle of learning (Guide for developing Establish Teaching and Learning Units)

1 The scientific inquiry is an intentional process that consists of problem diagnosis, critical analysis of experiments and finding alternative solutions, research planning, verification of hypotheses, construction of models, peer discussion and formulation of coherent arguments [Linn, Davis & Bell, 2004].
2 The 5E cycle of learning is one of the best known and efficient models of sciences teaching. It was first presented by Atkin and Karplus in the 1960s in the USA.

Results

Out of five stages of learning:

- Engage
- Explore
- Explain
- Extend
- Evaluate

all students covered in their lesson plans only the point one and three, that is (Engage) and (Explain).

Engage

In their lesson plans students efficiently planned the arousal of interest and curiosity in the subject of experiment among pupils by using various techniques of activation, presentations of experiments, presentation of problem situations, questions. However not all the students activated pupils' learning process by the evaluation of knowledge that pupils already have and by encouraging pupils to share their previous experiments, only 65% of students did so. 10% of students proposed in this part of a lesson a very interesting and inspiring teacher's talk with the use of various teaching aids.

Explore

It would seem that while using the IBSE strategy, the omission of this phase in lesson plans is impossible. However 5% of students completely skipped the stage of pupils asking questions and formulating hypotheses. 17% of students forgot that pupils should work without direct teachers guidelines (for example they planned detailed work charts for pupils, sets of ready-made questions for which pupils are supposed to find an answer). In all prepared lesson plans, students provided time for proofs and data collection by pupils, however as many as ⅓ of students planned in detail how the writing down and organisation of information prepared by pupils after lessons should look like. Only some students (20%) planned the exchange of observations between groups of pupils. Even more rarely (15%) the last element of this chain appears in students' plans – the stage of analysis, during which pupils discuss what has been discovered and what they got to know in the course of research. In total, only 13% of plans contained a well-described phase Explore.

Explain

All students planned this phase in their lesson plans however the main role there is played by the teacher: he explains pupils scientific terms and equips them with correct scientific terminology. Only 30% of students planned that the information acquired earlier would be discussed together.

Extend

At this stage, the teacher should help pupils to generalise a given term through broadening its application in new situations. However 12% of students completely skipped this stage, and another 22% gave only individual examples of usage that did not allow pupils to create correct generalisations. Only in 27% of lesson plans students planned a discussion with pupils, during which pupils could modify their understanding of the problem under investigation.

Evaluate

Formally, the last phase – evaluation – existed in every lesson plan. However 63% of lesson plans did not contain correct questions which would help pupils to analyse, evaluate and give a right right opinion on their own work during the lesson. Also questions evaluating the understanding of lesson's content concerned mainly definitions of terms, and not the evaluation of skills.

Summing up this stage of evaluating students' plans, it can be said that only 10% of works meet all the requirements of the 5E learning cycle.

Students' plans were evaluated also with reference to their concordance with the list of competences developed during a scientific inquiry, the so-called PTI because during learning through a scientific inquiry pupils should develop numerous competences.

Those competences were divided into 7 groups:

1. Identification of questions to scientific research;

2. Planning a scientific research;

3. Usage of tools and techniques to gather data;

4. Data analysis and description;

5. Explanation of results and drawing conclusions;

6. Taking into consideration alternative explanations or hypotheses;

7. Presentation of procedures and scientific explanations.

It has been verified in what ways students' plans develop the above-mentioned competences.

1. Identification of questions to scientific research

It assumes:

1.1 Identification of questions appropriate for a scientific research

1.2 Correction/ clarification of wrongly formulated questions

1.3 Formulation of hypotheses

In the majority of analysed lesson plans (83%) students did not plan the point 1.1 "Identification of questions appropriate for a scientific research" and the point 1.2 "Correction/ clarification of wrongly formulated questions" – assuming that pupils would give directly well-formulated research hypotheses. It proves small teaching experience of students taking part in the research (despite the fact that they had 80h of internship at schools) and too big expectations of students towards pupils' real competences – pupils hardly ever can formulate correct hypotheses. It also seems that the students themselves (despite having written and presented a BA thesis) have problems with selecting questions that could be analysed in a scientific research and with a correct formulation of those questions.

All evaluated lesson plans contained the point 1.3 "Formulation of hypotheses." It was accomplished with different techniques, students suggested for example discussions, "brainstorming," "mental maps," "carpet of ideas," "635 method," "nominal group technique (NGT)," "group passing technique," "question brainstorming."

2. Planning a scientific research

It requires the following activities:

2.1 Planning an experiment to verify the hypothesis

2.2 Determination of independent variables, dependant variables, and variables that must be controlled

2.3 Operational defining of variables depending on the observable properties

2.4 Finding possible mistakes in the research plan

2.5 Application of safety procedures

2.6 Carrying out multiple tests

In all the evaluated lesson plans only the first point “Planning an experiment to verify the hypothesis” was present. In individual lesson plans the points four and five: “Finding possible mistakes in the research plan” and “Application of safety procedures” appeared. None of the lesson plans contained the second and the third point “Determination of independent variables, dependant variables, and variables that must be controlled” and “Operational defining of variables depending on the observable properties” – it stems from the fact that students themselves have problems with it. It seems that the mere planning of an experiment in order to verify a hypothesis without determining independent variables, dependant variables, and variables that must be controlled and without verifying the research plans for possible mistakes is not sufficient to conduct the research in a proper way and in fact it proves that the experiment was not correctly planned.

The fact that the point six “Carrying out multiple tests” did not appear in the research procedure is very worrying. “Einmal ist keinmal” as German people say – and drawing conclusions on the basis of only one, not repeated experiment must make any scientific researcher feel anxious.

3. Usage of tools and techniques to gather data

It assumes:

3.1 Data collection with the use of appropriate techniques and tools

3.2 Making measurements with the use of standard measure units

3.3 Comparing, grouping and/or ordering things according to their properties

3.4 Creation and/or application of classification systems

3.5 Consequence and precision while gathering data

3.6 Description of an object with reference to other objects

Those competences appeared in the lesson plans with various frequency. Points 3.1 and 3.2 “Data collection with the use of appropriate techniques and tools” and “Making measurements with the use of standard measure units” were present in all the lesson plans. (The students remembered to use the SI units, for example that the unit of volume is dm^3 and not a litre).

The following two competences 3.3 i 3.4, “Comparing, grouping and/or ordering things according to their properties” and “Creation and/or application of classification systems” appeared only in few lesson plans, in which the main topic/ problem was the division / classification (for example distinction of metals from non-metals; differences between a mixture and a chemical compound; or classification of acids). In other lesson plans students did not include these competences.

The point 3.5 appeared in all plans – but often in a form of a short instruction: “measure carefully,” “weigh precisely.” None of the students did not point to the precision in measurements, for example, which tools are more precise (burette, pipette), and which are less precise (graduated cylinder), and which serve for approximate measurements (beaker). None of the lesson plans contained the estimation of errors that may be produced during measurements. What is more, not a single lesson plan suggests that experiments should be repeated at least 3 times and make an average out of the results obtained, all the lesson plans base on a single measurement, experiment. And the general results are drawn on the basis of such a single experiment.

“Description of an object with reference to other objects”, the point 3.6, appears in the lesson plans in the same way as 3.3 and 3.4, that is it appears only in those plans in which the main topic/ problem includes comparison (for example comparison of a substance properties to classify it to a correct group of chemical substances).

4. Data analysis and description

It includes:

4.1 Differentiation between an explanation and a description

4.2 Creation and usage of graphical forms of data presentation

4.3 Identification of substances and relations between variables in data

4.4 Usage of mathematical skills in data analysis and/or interpretation

Out of the four skills mentioned above, all the lesson plans included only "Creation and usage of graphical forms of data presentation" with the usage of a spreadsheet and/or presentation (often with the usage of Google.doc documents) [Nodzyńska, 2011].

Only 30% of the analysed lesson plans clearly differentiated explanation from description, the point 4.1.

The weakest aspect of all the lesson plans were the points 4.3 and 4.4 (that is "Identification of substances and relations between variables in data" and "Usage of mathematical skills in data analysis and/or interpretation") – they did not appear in any of the analysed lesson plans.

5. Explanation of results and drawing conclusions

It requires the following abilities:

5.1 Differentiation between observation and conclusion

5.2 Suggestion of explanations based on observations

5.3 Usage of proofs in order to draw conclusions and/ or predict trends

5.4 Formulation of logical explanations about cause and effect relations that occur between data from the experiment

The first two points (5.1 and 5.2) appeared in 87% of lesson plans. Those results could be considered as satisfactory but for the fact that during 3 years of studies these subjects were discussed on numerous occasions (both during laboratory classes in chemistry and teaching chemistry classes).

The point 5.4 "Formulation of logical explanations about cause and effect relations that occur between data from the experiment" was present in the majority of lesson plans (77%). However the ways of reasoning presented were sometimes not very precise and accurate, sometimes they did not show the subsequent stages step by step – but the final conclusions were drawn directly. Only individual people (ca. 7%) included in their plans the point 5.3 "Usage of proofs in order to draw conclusions" but no one included the last point "Usage of proofs in order to predict trends."

6. Taking into consideration alternative explanations or hypotheses

It contains:

6.1 Taking into consideration alternative explanations

6.2 Detection of a false reasoning, not supported by data

This point of skills developed during a scientific inquiry, the so-called PTI was the weakest out of all skills described in this paper. It did not appear in any of the lesson plans

7. Presentation of procedures and scientific explanations

It includes:

7.1 Presentation of methods and procedures concerning experiments and/or research

7.2 Usage of proofs and observations to explain and present the results

7.3 Presentation of knowledge gained from research in the oral form as well as in the form of written reports containing well-placed figures, diagrams, and graphs

The competences mentioned under the point seven that concern the presentation of the results found the best reflection in students' plans. The points 7.1 and 7.3 appeared in every lesson plan. The point 7.2 was present in the majority of plans (93%).

Summary of skills developed during the scientific inquiry, the so-called PTI.

Out of 28 skills that should be developed during a scientific inquiry as many as 7 skills do not appear at all in the analysed lesson plans; these are:

2.2 Determination of independent variables, dependant variables, and variables that must be controlled

2.3 Operational defining of variables depending on the observable properties

2.6 Carrying out multiple tests

4.3 Identification of substances and relations between variables in data

4.4 Usage of mathematical skills in data analysis and/or interpretation

6.1 Taking into consideration alternative explanations

6.2 Detection of a false reasoning, not supported by data.

It constitutes ¼ (25%) of all the activities.

The subsequent 8 activities (33%) appear in less than 20% of the evaluated lesson plans, and these are:

1.1 Identification of questions appropriate for a scientific research

1.2 Correction/ clarification of wrongly formulated questions

2.4 Finding possible mistakes in the research plan

2.5 Application of safety procedures

3.3 Comparing, grouping and/or ordering things according to their properties

3.4 Creation and/or application of classification systems

3.6 Description of an object with reference to other objects

5.3 Usage of proofs in order to draw conclusions and/ or predict trends

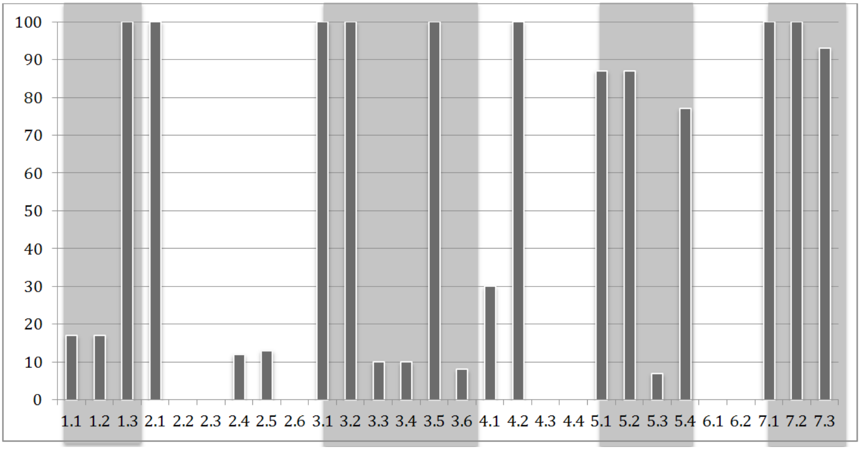

Fig. 02. The percentage of lesson plans in which there are the individual competences that pupils should develop during a scientific inquiry.

It can be stated then that as many as 15 competences (58%) that pupils should acquire during a lesson were not included in the lesson plans.

Only 8 skills (33%) are present in all the analysed lesson plans.

1.3 Formulation of hypotheses

2.1 Planning an experiment to verify the hypothesis

3.1 Data collection with the use of appropriate techniques and tools

3.2 Making measurements with the use of standard measure units

3.5 Consequence and precision while gathering data

4.2 Creation and usage of graphical forms of data presentation

7.1 Presentation of methods and procedures concerning experiments and/or research

7.2 Usage of proofs and observations to explain and present the results

It can be stated than that in students' lesson plans only a small part of skill that pupils should develop was taken into consideration. (see Fig. 02).

However, if we take into account the subsequent stages of the research:

1. Identification of questions to scientific research

2. Planning a scientific research

3. Usage of tools and techniques to gather data

4. Data analysis and description

5. Explanation of results and drawing conclusions

6. Taking into consideration alternative explanations or hypotheses

7. Presentation of procedures and scientific explanations

it turns out that only the last stage is sufficiently represented in students' lesson plans (see Fig. 03, Fig. 04).

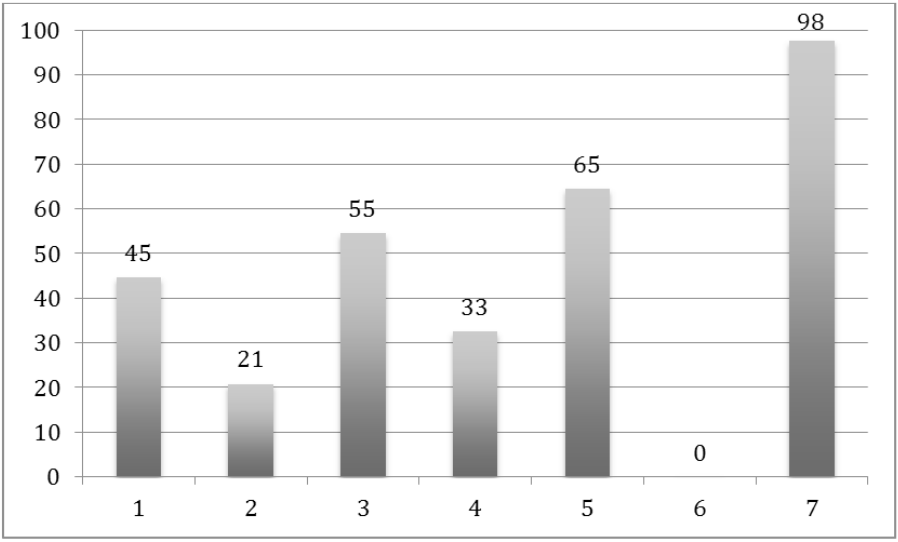

Fig 03 Average results for individual stages of education.

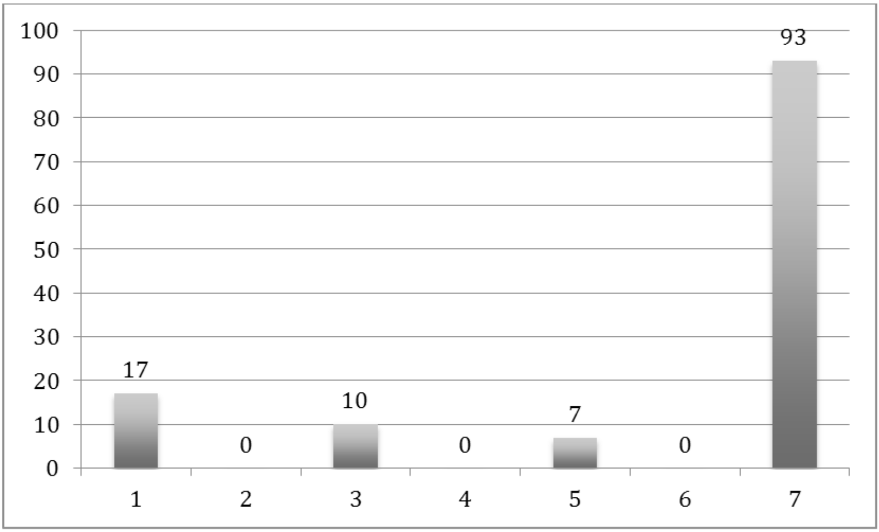

Fig 04 Percentage of correct lesson plans that contained all elements from a given stage of the research.

None of the lesson plans contained all the elements from the following stages: Planning a scientific research, Data analysis and description, Taking into consideration alternative explanations or hypotheses. All elements from the point one, three, and five are present only in few lesson plans (from 7 to 17%). Only the last stage was present in all the lesson plans.

Summary

Numerous research show that pupils obtain better results and are more motivated when in the process of education the IBSE strategy is used, that is when lessons are prepared in such a way so as to make pupils search for answers to interesting questions. As the research conducted proves – the ability of correct planning of this type of lessons is very poor among the teachers-to-be. In fact none of the lesson plans contained all the required elements, and only 5% of plans contained the majority of elements.

Despite the fact that on numerous occasions during classes on teaching methods, students were made aware of the necessity of creating independence among pupils, the majority of students in their lesson plans still reduces pupils' activity to the verification of information that were earlier on given by the teacher. Only in few lesson plans (5%) students allowed for pupils' greater control over the process of learning. None of the analysed lesson plans did not predict a situation that during lesson something does not work or works not according to the expectations.

It can be said than that despite a detailed presentation of the IBSE strategy to students and numerous exercises with them on how to use this method of work, their lesson plans do not correspond to the assumptions of this concept. It can be only hoped that teachers educated in this strategy during special courses are able to prepare better lesson plans that contain all the elements of this concept.

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Małgorzata Nodzyńska

Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

Myths about IBSE

Małgorzata Nodzyńska

IBSE – Inquiry Based Science Education is an education strategy, in Poland referred to as a "strategy of teaching sciences through discoveries/ scientific inquiries." This strategy is considered to be an innovative approach to the subject of teaching and is widely promoted. The scope of propagation of this notion is shown for example by the Google Ngram Viewer diagram that presents how often a given term (IBSE) occurs in more than 5.2 million books scanned by Goggle from 2012. It can be said then that the career of this notion began in 1994.

Fig. 01. Google Ngram Viewer - the frequency of the usage of the term IBSE throughout years.

Nowadays, in the Google motor search, there are 218, 000 results for the inquiry "IBSE." New books, grants and programmes based on this strategy of teaching are created. The point of departure for this strategy is the definition (Linn, Davis & Bell, 2004), which says that "A scientific inquiry is an intentional process that consists of problem diagnosis, critical analysis of experiments and finding alternative solutions, research planning, verification of hypotheses, construction of models, peer discussion and formulation of coherent arguments." With such a wording of the definition, a question arises: Does everybody is able to/ wants to be a scientist? (Compare fig. 02)

People promoting this method as a remedy for all education problems forget that the natural research attitude of a child and his natural interest in the world disappears in the majority of children with a child's development and it is not merely an effect of wrong education at kindergarten or school. It stems from subsequent phases of child's development. In their teens, the majority of pupils is not interested in "how does it work," they do not ask about the dependencies in the material world – they are more interested in ideas, feelings, emotions, especially between sexes.

Another element that limits the application of IBSE is the intellectual level of pupils. Individual diagnosis of problems, critical analysis of experiments and finding alternative solutions, research planning, verification of hypotheses, search for information, construction of models, peer discussions, and formulation of coherent arguments require from pupils quite big intellectual competences – and they appear only in the phase of formal thinking. According to Piaget, the formal thinking appears in pupils at the age of 11-13, and its development continues in their later life. However, there is research proving that only 40-60% of students, adult people fully achieves this phase of thinking development [Katra]. Then, for those people "scientific inquiry" is not possible due to intellectual reasons.

Fig. 02. The constructivist cycle of inquiry (a simplified version on the basis of Llewellyn, 2002 [Guide for developing Establish Teaching and Learning Units, project ESTABLISH, AMSTEL Institute, 2010]

Each society has a certain percentage of people (2-5%) who are interested the world , who measure the value of knowledge with knowledge itself. They get to know the world through the microscope, telescope, experiment or logical reasoning as opposed to the majority of people who get to know the world through the TV screen, Internet, or “power of their money.” It stems from the distribution of the intellectual potential in the population. If we have a look at the percentage distribution of IQ (see Figure 03), we notice that only for slightly more than 9% of the population the achievement of excellent results in creative domains comes easily – another 12% may achieve comparable results if they are diligent, motivated, and hard-working. It means that for the majority of the population (78%) creativity, novelty – being a researcher is not possible due to their intellectual possibilities.

Then no matter if we will base on the research results of Piaget’s theory or results of IQ distribution, it turns out that the majority of population cannot and does not want to be a scientist! Does it make sense then to use the IBSE strategy in teaching?

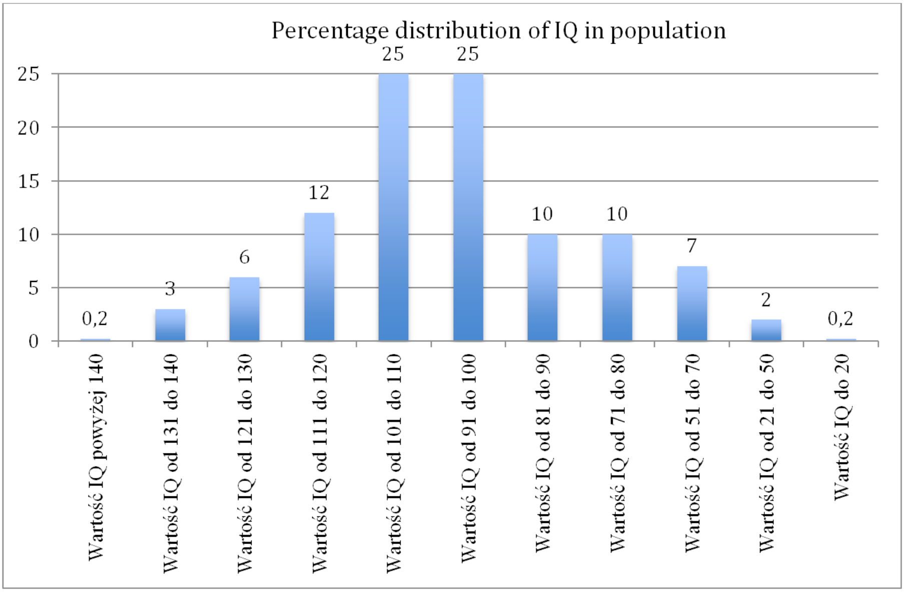


Fig. 03. Percentage distribution of IQ in population

Explanations to the graph:

IQ value above 140: Those people have excellent predispositions for creative activity and set the direction of development for others. They are geniuses of their epoch, they formulate theories and construct new tools.

IQ value between 131 and 140: People with those values are good managers or experts in their domains. They are also good scientists and researchers.

IQ value between 121 and 130: People with those values will easily graduate from a university and may achieve excellent results in creative and managerial domains.

IQ value between 111 and 120: For these people higher education and graduating from a university will not be a problem. If such a person is diligent, he can find a good post on the job market.

IQ value between 101 and 110: A person with such values will graduate from a university with difficulties, but if he is consequent and diligent he may find a good job.

IQ value between 91 and 100: People with those values easily pass their A-level exam and usually work in middle management.

IQ value between 81 and 90: Those people can graduate from the elementary school and they find a good job in manual professions and activities.

IQ value between 71 and 80: It is a lower level of mental retardation. Those people have difficulties to graduate from a primary school, but have no problems to graduate from a special school.

IQ value between 51 and 70: Those people can graduate from a special school if someone devotes them enough time and effort. They are able to take care of themselves, they manage everyday activities. It is a mild mental retardation (moron).

IQ value between 21 and 50: It is a medium mental retardation (imbecility). It is impossible to educate those people, but they are able to take care of themselves and live more or less independent life.

IQ value under 20: It is a serious mental retardation (idiot). Such a person is not able to get educated and brought up. He is often dependant on the help of other people, cannot take care of himself, he often lives in his own world, not understanding his surrounding. In the population there are 0.2% of such people.

Maybe instead of creating fiction that all pupils are themselves able to notice a problem and formulate a correct hypothesis (the school practice shows that it is always done by the same pupils, about 20% of the population), would it be enough to go back to the old, already tested problem teaching? According to Wincenty Okoń [1965] problem teaching is a set of teacher actions, such as organisation of problematic situations, formulation of problems, providing pupils with necessary help to solve problems and verification of those solutions, and finally managing the process of systematisation and strengthening the knowledge acquired in such a way [Okoń, 1965]. However in problem teaching the weight of work is on teacher's shoulders and does not require from pupils independence in situations where this independence is not possible for the majority of pupils.

Problem teaching has yet another advantage over IBSE – it does not pretend that the teaching process reflects the research process. Teaching (from dogs, dolphins, through monkeys to humans) was invented so that every individual was not supposed to discover/explore the world from scratches, so that he receives in a ready-made form what previous generations had already achieved.

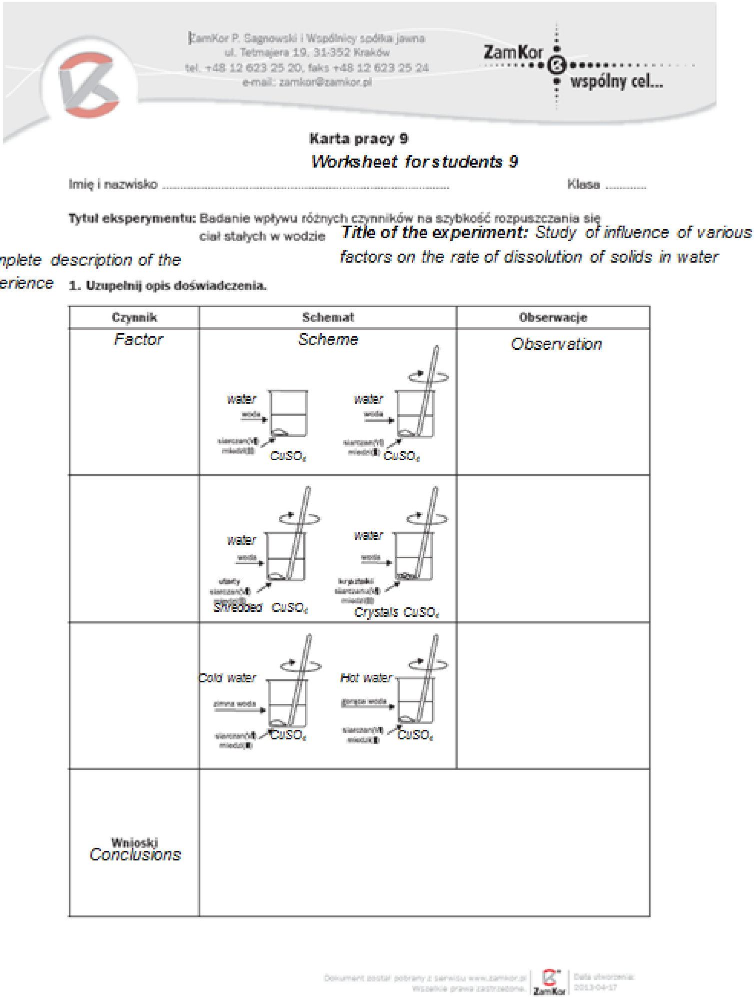
Of course it is necessary to maintain and create in a pupil the interest in the world by showing him different problems to solve. However a statement that such a manner of teaching corresponds to the research process brings many damages to education.

Let us have a look at one of the simplest problems, which is one of the few to be solved in Polish schools through an experiment. Let us check: on what does the solvability of a substance depend? In the majority of course book there is a description of an experiment:

"a) The same amount of water and copper(II) sulphate(VI) was put into two beakers. The content of only one beaker was stirred with a stirring rod.

b) To another two beakers the same amount of water was poured. To one beaker powdered copper(II) sulphate(VI) was added, and to another one the same amount of this substance but in the form of bigger crystals. The content of both probes was stirred with stirring rods.

c) To one beaker cold water was poured, and to the other one the same amount of hot water was poured. Next, the same amount of copper(II) sulphate(VI) was added and stirred with stirring rods." [Zamkor]


ZamKor P. Sagnowski i Wspólnicy spółka jawna
ul. Tetmajera 19, 31-352 Kraków
tel. +48 12 623 25 20, faks +48 12 623 25 24
e-mail: zamkor@zamkor.pl

ZamKor wspólny cel...

Karta pracy 9

Worksheet for students 9

Imię i nazwisko .... Klasa ....

Tytuł eksperymentu: Badanie wpływu różnych czynników na szybkość rozpuszczania się ciał stałych w wodzie

Title of the experiment: Study of influence of various factors on the rate of dissolution of solids in water

Complete description of the experience

1. Uzupełnij opis doświadczenia.

Czynnik *Factor*	Schemat *Scheme*	Obserwacje *Observation*
	water / woda; siarczan(VI) miedzi(II) $CuSO_4$ — water / woda; siarczan(VI) miedzi(II) $CuSO_4$	
	water / woda; utarty siarczan(VI) miedzi(II) Shredded $CuSO_4$ — water / woda; kryształki siarczanu(VI) miedzi(II) Crystals $CuSO_4$	
	Cold water / zimna woda; siarczan(VI) miedzi(II) $CuSO_4$ — Hot water / gorąca woda; siarczan(VI) miedzi(II) $CuSO_4$	
Wnioski *Conclusions*		

Fig. 04. A sample working chart for the experiment: on what does the solvability of a substance depends? [Zamkor]

On the basis of this experiment, pupils draw the conclusion that stirring, increase of temperature, and powdering accelerate the process of solution.

Let us point to the fact that on the basis of a behaviour of two substances towards one another, pupils draw general conclusion on the speed of the solution process as a whole. Unfortunately those conclusions are not true – one needs to recall only the curve of NaCl solvability (almost unchangeable with the increase of temperature) or caesium sulphate(VI) (decreasing) or sodium carbonate (decreasing from 35°C), sodium sulphate(VI) (decreasing from 20°C). During this experiment no one mentions (does not perform experiments) the solvability of gases in liquids – which is why in pupils minds a belief is fossilised that all substances dissolve more quickly with the increase of temperature.

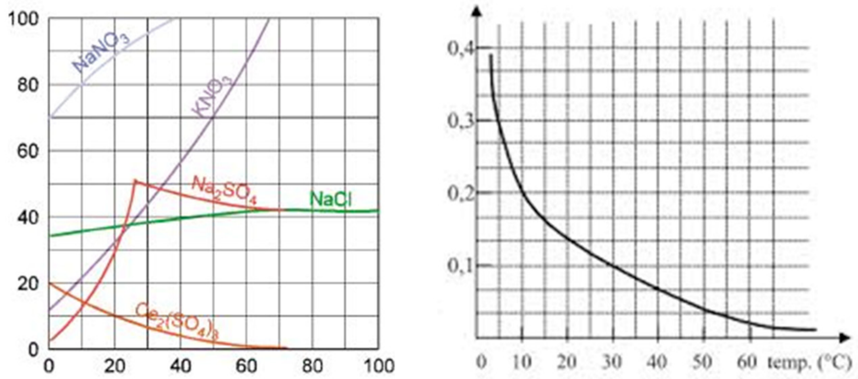


Fig. 05. Curves of solvability of (1) solid bodies (2) gas: carbon (IV) oxide.

It is difficult to call such imperfect intellectual activities as the description above a scientific process. It may cause among more talented pupils who plan a scientific career that they will not associate scientific research with hard, time-consuming verifications of all hypotheses, but only one flashy show that supports their concept. It seems that it would be a negation of the aim of the introduction of IBSE to the teaching practice.

It cannot be denied that while teaching natural sciences, a teacher has to use different experiments (illustrative, introductory, problem-discovering, problem-verifying), he has to use problem teaching – arousing pupils interest, he has to teach pupils independence in learning, searching for information and verifying them (for example, by using the method of projects), however it seems that the creation of new names for teaching methods that are already known and attributing them complex ideologies has no educative sense. (Perhaps it has a marketing sense – it is easier to obtain a grant for a new strategy than for something that has been already known for a long time.)

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Małgorzata Nodzyńska

Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

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