Entertainment-education

in science education

the monograph edited by

Grzegorz Karwasz & Małgorzata Nodzyńska

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Introduction

Jan Amos Komensky in „Great Didactics" (Amsterdam, 1657) defined didactics not as a mere process of teaching, but as teaching efficient, lasting and pleasant. He wrote (p. 131) "The school itself should be a pleasant place, and attractive to the eye both within and without. […] If this is done, boys will, in all probability, go to school with as much pleasure as to fairs, where they always hope to see and hear something new." Further (p. 167) Komensky added: "The desire to know and to learn should be excited in boys in every possible manner."

The idea of linking the fun with didactics finds many followers, expressed also in tittles of activities like "Science is Fun" or "Physics is Fun". In (Karwasz, Kruk, 2012) we defined three complementary aspects of any bit of information (an exhibition object, a film, a lecture): entertainment ("ludico" in Italian), didactics, and science. The first aspect gives an impression to a student/ visitor/ listener: "how funny it is!". The didactical aspect induces: "How simple it is!" And the aspect of scientific curiosity induces in best students a question: "How complex it is!" These three functions add-up like three basic colors to give a full spectrum of enlightenment.

The entertainment function can be performed in different forms – school, extra-school, complementary to school. The target groups can be pre-school children, secondary school students, adults, and so no. Different approaches are needed for inducing interest in chemistry, in ecology, in physics. The present book shows some sampling of these different tasks.

A general introduction into forms and implementations of teaching by playing is done by Małgorzata Nodzyńska, Ewelina Kobylańska: educational games, "universities" for children, science festivals, science musea and exploratoria in Poland and Czech Republic. More examples of children universities in Poland and a study of motivations to follow them are given by (Małgorzata Krzeczkowska, Emilia Grygo-Szymanko, Paweł Świt and Patryk Własiuk). Apparently funny, but detailed in chemistry and serious in conclusions is the study of one popular beverage (Wiola Kopek-Putała and Małgorzata Nodzyńska). A special form of teaching by entertainment is a didactical excursion – and example of developing special paths in chemistry and ecology at different levels of teaching is done by Vlastimil Chytrý, Simona Čábelová and Martin Rusek. Examples of multimedia in Physics, Chemistry, Astronomy and Biology, available on Polish market are given by Anna Kamińska, Andrzej Karbowski and Krzysztof Służewski. Constructing of Live Action Role Play educational form is discussed by Zuzana Václavíková. Unusual ways of triggering interest in mathematics (tangrams, magic squares, futoshiki) are presented by Věra Ferdiánová and Petra Konečná. Effectiveness of using virtual labs and "competence-based" textbooks in chemistry are discussed

by Martin Bílek and Wioleta Kopek-Putała. An amusing study how insects are described (and personalized) in children literature is presented by Małgorzata Mielniczuk and Elżbieta Rożej-Pabijan. Finally, an extensive use of didactical fun with everyday objects in teaching optics is given by Krzysztof Służewski and Grzegorz Karwasz.

All these single contribution, spacing from the educational trends (Nodzyńska & Kobylańska) and pedagogical aspects (Chytrý, Čábelová & Rusek) to technical observations (Mielniczuk & Rożej-Pabijan, Kopek-Putała & Nodzyńska, Służewski & Karwasz) form an interesting overview how new, "pleasant" forms can enrich the traditional didactic.

Please, enjoy reading!

Grzegorz Karwasz & Małgorzata Nodzyńska

Comenius, J. A. (1967) *The Great Didactics*, trans. by M. W. Keatinge, Russell & Russell, New York,

Karwasz, G. P. & Kruk, J. (2012) *Idee i realizacje dydaktyki interaktywnej. Wystawy, muzea i centra nauki.* Wyd. Naukowe UMK,

The Role of the Fun in Science Teaching

Combinatory play seems to be the essential feature in productive thought.

Albert Einstein (1988)

"Learning is a process of acquisition of specific knowledge, skills and habits by the learner. Quantitative and qualitative result of this process depends on multiple factors, among which a very important role is played by motivation and activity" (Kupisiewicz, 2000, p.25). Therefore, subject didactics should continuously seek the best didactic solutions in order to present difficult problems within the field of a given life science (Paśko, 2012) in the easiest possible way, which will at the same time motivate and activate learners to study.

Motivation

A driving force for a learner, both to act and learn, is motivation. Motivation is defined as: "... the state of internal tension, which determines the possibility and direction of the body's activity..." (Tomaszewski, 1963, p. 187). The essence of motivation is best determined by the following quote: "Motivation is like breathing – if we live, we are motivated" (Nodzyńska & Paśko, 2010); in turn, it depends on teachers how and whether they will properly motivate their students to make the acquisition of knowledge enjoyable for them. Motivation has an impact on the course of acquisition of knowledge by the students and their engagement in learning. Whether the information will be remembered permanently by the student depends on their interest in the concept or phenomenon. The student should treat knowledge and specific actions as self-improvement, self-realization, through assigning to them their own sense or value, significance. The role of the teacher is to strengthen the student's internal motivation by the appropriate selection of teaching methods and the proper work with them, thereby shaping their willingness to learn and acquire knowledge. It should be remembered, however, that every student is an individual having their own learning style, and speed and durability of acquisition of knowledge (Nodzyńska, 2008). Therefore, the teacher faces a responsible and difficult task that requires from them not only flexibility in their action but also patience, consistency, and perceptiveness to adequately direct the student's motivation to learn (Niemierko, 1999). The way in which the teacher conducts lessons should affect the students' interest in the subject and develop their enthusiasm for chemistry (Nodzyńska, 2003), which increases the students' motivation.

Since chemistry is becoming increasingly important in everyday life, this fact can be used in the teaching of chemistry by showing students the usefulness of acquired knowledge and directing their attention to the practical value of the knowledge (Baprowska, 2010) – also such actions affect the growth of motivation

to learn chemistry because people are eager to learn when they see the usefulness of the knowledge. These days, thanks to the pervasive use of chemicals, it is easier for the teacher because they can arouse certain emotions or needs in the students. Additionally, according to Mrowiec (2008), the process of the creation of an interest in concepts, phenomena or chemical compounds should be based on showing a special role they play in the daily life of every one of us. The question is: What can be done to increase the motivation of students? This is a challenge for teachers, science educators, and also the authors of curricula, whose main objective is to make lessons and extra-curricular activities more attractive, so that they could not only arouse the curiosity of young people but also meet their expectations (Obrębska, 2011).

It should be remembered, however, that the nature of motivation and interests of students change with their age. It is easier to motivate younger students and more difficult to motivate older adolescents (Matyszkiewicz & Paśko, 2009). Younger students are inspired by their natural curiosity to explore the world and the need to explore the unknown. Then their passion for learning is at its highest level because learning is connected with play. It gives them satisfaction, expanding their personality with newer values. However, with students' age, an interest in learning decreases because it begins to involve greater difficulty and no joy or fun, and here, apart from the individual abilities of the young man, a proper motivation is needed. It is of great importance because it largely affects the performance of knowledge acquisition by students (Nodzyńska & Paśko, 2010). Factors motivating students developed by Obrębska (2011) are presented in Tab. 1.

Table. 1 Factors of motivating students (Obrębska, 2011).

FACTORS OF MOTIVATING STUDENTS:	
JUNGER	OLDER
• Using interesting didactic means; • Diversity conducted of classes; • The quality of knowledge transfer; • Direct contact with the concept or phenomenon known to others; • Involvement of students the specific problems during lessons; • Experimentation	• Linking the acquired knowledge with practical skills; • The connection of knowledge with the problems of everyday life; • Expanding the Knowledge already possessed;; • Giving the knowledge of which will play a role in later life, young man.

Learning through playing

It seems that one way to motivate students may be learning by activity in the play. The concept of learning through activities (including entertainment) is known and has been propagated since the turn of the 20th century. Its initiator was J. Dewey with his "work school". Other experimental schools were created by:

- W. H. Kilpatrick (project method)
- C. Freinet (child's free expression)
- E. Claparède (school made to measure)
- O. Decroly (school for life through life)
- H. Parkhurst (Dalton plan)
- H. Rowid (Creative school)
- G. Kerschensteiner (work school).

At present, it can be said that the idea of learning through play has become widely available. Typing the query "learning through play" into Google search box, approximately 2,250,000 results are received. "Learning through play" involves mostly lesson ideas for younger children (preschool and primary school age), such as various types of educational games, computer software, popular science books, or educational activities (eg. swimming lessons through play or learning English through play). However, there are also ideas for older students; these are mostly courses, science festivals, museum lessons or educational trips. Their substantial part comprise suggested teaching textbooks describing the practical application of different kinds of educational games and activities.

Learning through play is not only the various activities proposed to students but also proposed literature. Using the tool Ngram Viewer, one can see how the number of published books on the given topic has changed over time.

Figure 1. Graf Ngram Viewer showing how over the years, changing the number of publications on learning through play (Keyword searching „lerning throught play").

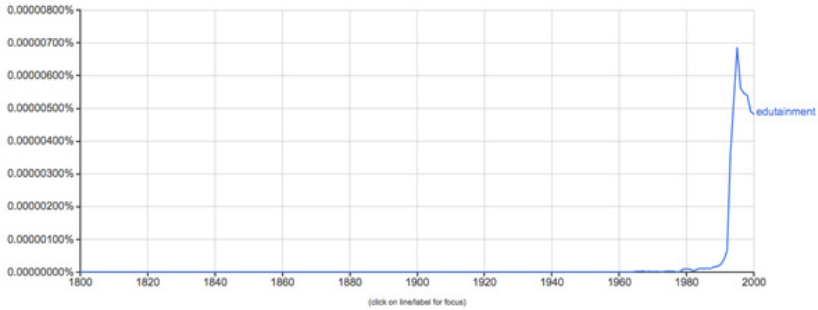


Figure 2. Graf Ngram Viewer showing how over the years, changing the number of publications on learning through play (Keyword searching „edutaitment").

The definition of chemistry

With such great interest in the use of play in education as one of the teaching methods, it seems appropriate to define the concept of play.

The concept of Homo Ludens (Man the Player) has been known for a long time, but in the contemporary humanities, it was popularized by J. Huizinga (2007), a Dutch historian and philosopher. He objected to the views of representatives of biological sciences, who thought that play is a physiological function, a strategy created by nature to teach humans to resolve various problems which they face in their lives. He even believed that "play is older than culture," and that, during play, we deal with experiences of a spiritual kind. Huizinga believed that every man is 'playful' just because they are human beings, and fun is embedded in the very nature of humanity and also constitutes the basis of culture.

In the popular belief, play is the opposite of seriousness. Seriousness is something fundamental, solemn, grave. Seriousness is contrary to the lightness of being, which, in common understanding, is accompanied by fun. But this statement is not entirely true – play is a serious activity and, in fact, it incredibly absorbs the player's attention (eg. observing children during play, we can see the seriousness with which they approach it).

According to Huizinga, play has a number of significant features which characterize it. The first feature is the fact that play is always associated with activity. Another feature of play is the fact that only a free man is a player as it is difficult to play at somebody's behest (although children are encouraged to play for the purposes of teaching, the child plays best when no one tells them to). Another distinctive element of play refers to its superfluous character, it is not a necessary action. It is needed only when it is associated with pleasure. It can, therefore, be stated that play is a free action flowing from freedom that differs from the current rhythm of life. Another characteristic feature of play is its selflessness. Our daily

activities always aim to achieve some goals. Play is an advantage in itself because the purpose of play lies in the play itself. Therefore, it can be said that play is autotelic (having a purpose in itself). Another condition for play to be considered real play is that it should have a specific order and rules (Nodzyńska, 2009).

Let us attempt to formulate a definition of play on the basis of Huizinga's considerations: Play is a voluntary activity executed within certain fixed limits of time and place, according to rules freely accepted but absolutely binding, having its aim in itself and accompanied by a feeling of tension, joy, and the consciousness that it is different from ordinary life.

Taking Huizinga's concept as a starting point for our discussion about teaching through fun and games, let us analyze further characteristics of play in the context of teaching (Tab. 2).

Table 2. Comparison of features of fun and learning

Fun / Play	Science
Associated with the activity	It should be associated with activities
It is voluntary	Is forced
Is something superfluous	It is something necessary
Diverges from the current rhythm of life	It is part of everyday student life
It has a certain order and rules	it has a creatin order and rules

Educational games / Fun

In the light of the foregoing, it appears that games can be an important factor in motivating students to learn. This is due to the fact that they provide pleasure and entertainment and, at the same time, shape reflex, orientation, agility and features such as: justice, honesty, and solidarity. Games stimulate, not only in children, creative thinking and imagination, which is why students prefer to take the effort of learning when it is accompanied by games (Goźlińska, 2004). Play is also accompanied by satisfaction from solving a given problem and excitement about the unpredictability of its outcome (Majewska). The primary objective of didactic games, as opposed to other types of games, is education. Nevertheless,

they are also a form of entertainment and evoke positive emotions. This situation brings additional value because positive emotions activate the limbic system and stimulate the brain to work. It is a natural mechanism for human survival and adaptation: pleasure teaches us to distinguish between what is good and beneficial for us and what is bad and harmful. As a result, the use of didactic games stimulates learning processes (Marcus, 2009).

A characteristic feature of didactic games is a reversal of the traditional course of lessons, which involves the transition from acquiring theoretical knowledge to the ability to apply it in practice. In didactic games, the situation is reversed – first, by acting (playing), the student performs a specific action, and on this basis, they gain/construct new knowledge.

Definition of the term 'educational games' / 'fun'

In the literature of teaching, there are many definitions of didactic games as methods of supporting the learning process. According to Okoń (1992), game is carried out according to strict rules, that is procedures enabling its process. If we add to the game the accomplishment of the intended educational aim, we can talk about a didactic game. In turn, Piskiewicz (1983) defines the didactic game as "a deliberately organized situation in which learners compete with each other within certain rules". Players are accompanied by emotions, which are vitally important in the process of learning (Łazarska, 2014) and better and longer retention of necessary knowledge. Students remember important information while having fun, and thus, the acquired knowledge is the effect resulting from the game. Kruszewski (1984) adds that the didactic game is one of the types of teaching methods, forming a group of activating and problem-solving methods. A student has the ability to bring the cognitive process closer to direct cognition.

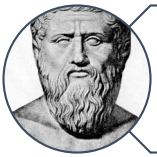
The game can turn into a simulation. Then, it is called a simulation game, which is a simplified real situation, in which individual roles are assigned to students according to the previously presented scenario (Goźlińska, 2004). Simulation is treated as a simplified representation of a part of the real or imaginary world (van Ments, 1983), and therefore it is applied more and more often in the teaching process. Using it, as an example of problem-solving methods, organizes educational content in the patterns of real situations or phenomena and processes (Kruszewski, 1992).

History teaching with the use of educational games

In the history of teaching chemistry, games had been used for educational purposes before school was established in its very concept. At the time when teaching was not so universal and compulsory, games were the equivalent of schooling. The games taught their participants some useful skills they could use

later in their life. Play is accompanied by the satisfaction from solving a given problem and excitement about the unpredictability of its outcome. These features of the game were very appreciated and used by educators of different eras (Siek-Piskozub, 1995).

Figure 3. The approach to fun / didactic games over the years, (described on the basis of publications Peter'a Vankúš (2005): „History and Present of Didactical Games as a Method of Mathematics' teaching'").



Plato (427 BC – 347 BC)

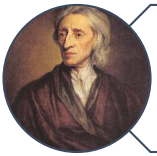
Be the first to implement an educational game for children (3-7 years), the aim of which was to prepare them for later work.

Aristotle (384 BC – 322 BC)

He thought that the game is the most appropriate form of education for children. The first games that have been applied mainly to the physical development of the students.

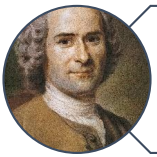
J. A. Comenius (1592–1670)

He accepted that the game is a very important means of upbringing and education of the child should be fun and joyful for students whose interest increases learning game. Children's activities, therefore, associated with pleasure, joy, teamwork in a particular action. J. A. Comenius used the group games and individual, which influenced the intellectual development (senses, memory, speech) and physical. As predecessors combined game with the future of the child and adulthood with the exercise by him of a particular profession. He also introduced educational game based on the rules, which were homing guidance for students.



J. Lock (1632–1704)

Persisted the idea that teaching must be natural and without coercion. He used therefore educational games including letters and pictures that were used to teach reading and writing.



J. J. Rousseau (1712–1778)

J. J. Rousseau as predecessors argued that education should take place in a natural way, taking into account the age and personality of the students. The basic unit of education should be your own observations, conclusions and experiences that throughout the process, students will gain. Games educational presented as a natural activating that best meets the needs of students while learning.

J. H. Pestalozzi (1746–1827)

Rousseau continued to work over the educational game. The main emphasis placed on the active activities of student. He claimed that it stimulates a spontaneous and internal motives children to work. Pestalozzi was considered to be the person who correctly put the game as a teaching method for the activation of students in the educational process and stated the need to use it in order to realize, for educational purposes.

F. W. Fröbel (1782/52).

He was a student Pestalozi, who also believed in the vital importance of teaching the game in the educational process of students. Playing for him was the development of young people. He created szerg games that later introduced in the educational process, eg .: puzzles, wooden geometric figures, which aimed to develop imagination and logical thinking of students.

F. Schiller (1759-1832)

Schiller had found in the game educational the ideas of freedom and happiness, consisting of release of the true personality of a student by taking part in the game. He said that it improves mood so make people happy.

H. Spencer (1820–1903)

Persisted for education that prepares students for life. He turned on to the principles of education, the need for a happy and active learning process, was based on the experience of the student. He postulated the introduction of an appropriate number of games in the educational process.

K. Groos (1861–1946)

He created the scientific concepts about the causes and significance of fun in the learning process. He claimed as predecessors that by playing educational students preparing for future life. Will present the game as a kind of instinctive behavior, which is the basis for the intellectual development of man.

M. Montessori (1870–1952)

He created his theory about the game as a educational center for the development of adolescents, based on the theories and actions W. F. Fröbel, Pestalozzi H. J. and J. J. Rousseau. A particular role addressed on the support of the environment to the child's learning, and the educational games as a way of motivation.

J. Piaget (1896–1980)

He dealt with exactly the functions of the game in the everyday life each man. Presented classifications game at 4 different levels of the game: practices, symbolic, constructive which scrupulously describes examples from everyday life of each of us. The main result of the study said unanimously that the game is a necessary and important part of the education process.

L. S. Vygotsky (1896–1934)

During a research on teaching the game, put on the cognitive development of the student, which he was not an inborn trait but acquired trait on the appropriate way of education. As he was particularly focused over the link, the thinking and language, so it was a game for learning about the world and the development of logical thinking. It also emphasizes the large role play in the socialization of young people.

J. S. Bruner (1915)

In his work, he based on a theory Pigeta and very much contributed to the development of cognitive psychology. Looking for effective methods of education and the proper curriculum development in schools. Your search based on the theory of constructivism. Used by him was the idea of an active process of education adequately motivated by the teacher, so that the student independently develops new concepts, koncepsję, based on their own experience or acquired knowledge. Learning game by Bruner'a, is the center of the development of logical thinking of students.

J. Dewey (1859–1952)

J. Dewey was the originator of pragmatism. In his studies emphasized the natural and cognitive functions of the game., Which for him was a very important method of education. He claimed that the game teaches children of the world in which they live and the skills and activities that they will need later in life. He introduced the concept of "learning by doing" or learning through the concrete action.

R. Steiner (1861–1925)

He created the basis for teaching in schools Waldrof's. The main idea was the development of the whole personality of the student. Determined the manner of education, dividing them into physical, mental and emotional. In his theory of the game was the comprehensive development of the human personality.

Randel, Morris, Wetzel and Whitehill (1992)

They illustrate teaching the game as a means to motivate students during lessons and increases productivity conducted by the teacher lesson. They found that with active participation of students in educational games shapes the process of reasoning and memory.

Pulos and Sneider (1994)

They introduced the concept of educational game as an aid for Mathematics. They found that with the emotions accompanying the students during the game better and more durable remember a certain messages.

G. Booker (2000)

G. Booker in his research shows the educational games as a fun activity the students, which increases their interest and engagement in the classroom. It also draws attention to the fact that games make students proud to therefore very process of learning becomes a pleasure. According Booker'a game improves students' ability to solve problems and learn social interaction.

In Poland, an "educational function of didactic games was first stressed by military teachers. Specific mention should be made of the Knights' School opened by Prince Adam Czartoryski, where tactical and strategic educational games were used almost every day, so that the future military commanders could deepen their knowledge on the art of the behavior of soldiers in various conflict and strategic situations. (...) From there, games have been moved to schools" (Goźlińska, 2004, p. 7). The history of didactic games in life sciences education in Poland is not very long (slightly over 20 years). In other countries, especially highly developed, they have been used very frequently on different levels of education since the 60s of the last century (Piskorz, 1997).

Functions and significance of educational games

In teaching, educational games can fulfill a variety of functions. For instance, in the article by Anna Iskra and Małgorzata Drop (2011), the following features of games are presented:

- Transfer of relevant information, knowledge and concepts
- Revision of newly acquired material
- Knowledge consolidation
- Developing practical skills
- Developing autonomy
- Involvement of students in their own learning process and thus teaching them responsibility for their own knowledge.

Didactic games have also a lot of advantages discussed by Gulińska (2008) in the article "Educational Games in Teaching Chemistry". According to her, the advantages of the use of didactic games include, among others:

- Making learning more attractive
- Enriching the teachers' skills with new methods
- Preparing students for teamwork
- Practical mastering of the rules of conduct in a particular problem situation
- Learning based on students' own mistakes through analyzing the results and outcomes of the game
- Gaining experience in decision-making in stressful situations
- Gaining experience in the active selection and analysis of information.

Games also allow for the formation of transferable skills that are useful and very important in everyday life and learning. By playing with children and using different kinds of games, we instill in them not only patience, selecting appropriate life strategies and following certain rules but also the ways of dealing with defeats and victories (Goźlińska, 2004).

It seems, therefore, that the application of such valuable teaching methods and, at the same time, very good educational methods, which involve many desirable

features on the future job market, on life sciences classes, in particular chemistry, is legitimate.

Systematics of educational games

In everyday life, the most popular division of games which can be encountered is the subsequent one:

- board games,
- puzzles,
- crosswords,
- domino,
- jigsaw puzzles,
- jumbled sentences,
- gap-filling.

However, in life sciences didactics, when it comes to the division of games, they are divided depending on their role in the educational process. Systematics of didactic games is not clear-cut; educators and teachers divide the games according to various criteria.

For example, Taylor classified the games into:

• problem games (case study), which provide a detailed description of deliberately selected problem situations. They constitute a set of knowledge necessary for the participants.

• problem-discussion (incidental) games, which involve the exchange of views among students.

• discussion games, thanks to which students can confront their strategies verbally, at the same time, playing hypothetical roles given to them.

• simulation games, involving the interaction of students with the alternative (model) world according to strictly described game key. In these games, we deal with a random factor, which plays an important role in the whole game.

• checking games, involving the creation of appropriate opportunities to undertake specific tasks and decisions. They are designed in such a way that we can examine the participants' reactions.

• computer games, which are one of the varieties of simulation games. Alternative (model) world, however, is created with the help of digital and graphic programmes (Goźlińska, 2004).

The above division can be used in teaching life sciences. For example, problem games can be applied when conducting experiments with the students and reinforcing drawing proper conclusions from observations. An interesting use of "case study" is providing the problem situation, which the students together

with the teacher may analyze. An example of the combination of funny and useful material is the program "Anatomy of stupidity by Richard Hammond" (http://www.dailymotion.com/video/), which explains certain life situations through the laws of physics, thus combining fun with learning, or "MythBusters" (http://www.filmweb.pl/serial/Pogromcy+mit%C3%B3w-2003-10037). If the students begin to share their views with each other, from which the discussion arises, then this may be defined as the problem-discussion or discusion game. The use of such games is very well suited to the project method. An example of simulation games can be, for instance, online chemical laboratories. The teacher can also create the game themselves or involve in this action their students, thanks to which they will check their knowledge of the given field, for example, on:

- https://learningapps.org/
- Hot Potatoes
- scholaris.pl

Many examples of games and applications that support the process of consolidating the knowledge by students can be found.

Another example of the division of games is the one presented by Kupisiewicz (1980), who divides them into:

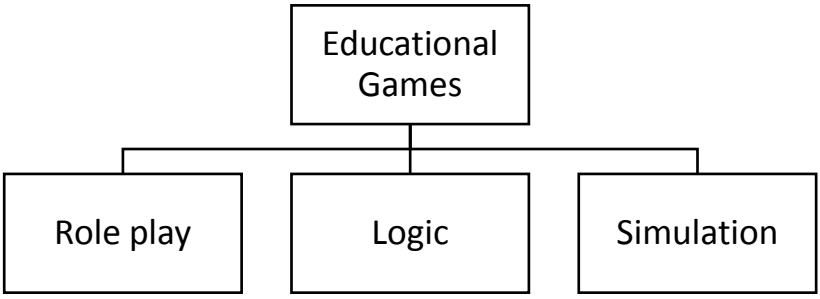
• Simulation – basing on playing the roles by the students, in which the analysis of various created problems that are reflected in reality is demonstrated.

• Situation – involving the creation of fictitious situations that can happen in the future, where students practice and learn to behave in difficult situations.

• Role play – basing on recreating a specific scenario or improvised discussion.

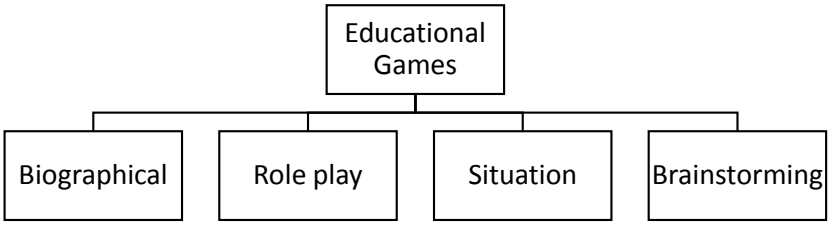
• Exchange of ideas – involving stimulating creative thinking based on the students' personal intuition and then drawing conclusions.

Another classification of didactic games was proposed by Okoń (1987):



The above divisions can also be applied to life sciences. Situation and simulation games, involving role playing can be applied using drama, in which students find themselves in a particular situation. Topics within chemistry and biology concerning the environment or the effects of its pollution are adequate in this regard. Role play can be prepared for a given subject, such as: physics, chemistry, biology or geography. To create an appropriate script, just a little imagination is needed, which the students are not short of. An exemplary theater script as a didactic game is "Light Mystery" (Carpineti, Giliberti, Ludwig 2016), which represents staging of lessons in school on a specific topic. In a similar way, "micro-detective story" can be used for solving chemistry puzzles in the role of Sherlock Holmes (Musilova E. 2003).

In quite a similar way, games were divided by Kruszewski (1984).



Gabriela Kupka cites another possible division of didactic games according to Grzesiak (www 1), being an example of classification of mathematical games; these are:

- Agility
- Structural
- Strategic.

A similar division can be used in the life sciences, and thus in chemistry, where agility games will refer to the shaping of the skills of solving and balancing chemical equations or performing specific chemical experiments. Then the teachers enable the students to practice these skills, master the knowledge of chemical reagents, and improve the efficiency of performing experiments, drawing conclusions and writing the adequate observations. Thanks to structural games, students can get familiarized with the model construction of not only atoms but also molecules or crystal structure. In turn, strategic games strongly affect the development of creative thinking in students through the search for better and newer strategies when performing specific chemical experiments.

Entertainment-education

Entertainment-education is one of the ways to transfer knowledge since it contains an element of amusement/entertainment that promotes cognitive development of students. Its use is widespread, as evidenced by both Polish and foreign teaching aids. Examples of these teaching aids are quoted in the article of Kopek-Putała & M. Bilek "The use of Entertainment-Education in teaching chemistry, taking into account pupils with special educational needs":

- educational site Ciufcia (www.ciufcia.pl)
- educational platform for children (www.squla.pl)
- educational site Poisson Rouge (www.poissonrouge.com)
- TV channel Mini Mini (www.miniminiplus.pl)
- TV educational program for children Sesame Street,
- Children's University (http://uniwersytetdzieci.pl/uniwersytet)
- educational games, for example, LearningApps (https://learningapps.org/)
- Kahoot platform (https://kahoot.it/#/)
- Phet Interactive Simulations (https://phet.colorado.edu/)

Currently, learning through play/games often goes beyond the school walls, constituting a rich package of extracurricular education. Universities, museums, and other organizations and entities join this action. Such activities are promoted by, among others: Children's Universities, Museum Education Center, Science Festivals, University Open Days, Scientists' Night, or Science Theater.

Universitet Children

Children's Universities involve extracurricular activities for children. The original idea of their creation was inspired by the natural curiosity of the child and the belief that today's parent is aware of the importance of good education. It is an idea to combine learning with fun and organize joint meetings between university professors and children.

The history of Children's University is less than 14 years long! The first children's university was established on the initiative of local journalists in Tübingen, Germany in 2002. On 4 June 2002, Professor Gregor Merkel delivered the first lecture for children titled "Why do volcanoes breathe fire?". The lecture as well as the subsequent ones proved to be an unprecedented success – the attendance exceeded all the initiators' expectations. 900 students aged 7 – 12 years completed the first year. Lectures were related to various fields of science, such as:

- issues in the field of biology (Why do people die?),
- economics (Why are some people poor and others rich?),
- paleontology (Why did dinosaurs become extinct?),
- psychology (Why do we laugh at jokes?),

- geology (Why do volcanoes breathe fire?)

(www. http://www.uni-tuebingen.de/uni/qvo/kinderuni-2005/kinderuni.html)

Another University was established a year later (in 2003) in Vienna (http://www.kinderuni.at/).

On the initiative of both Universities and with the support of other universities (of Bratislava http://www.duk.sk/, Basel http://www.zuv.unibas.ch/kinder-uni/index.html and Strasbourg http://science-ouverte.u-strasbg.fr/KUSweb/) a web portal was launched, which is available in 6 European languages (including Polish). It can be used by "little students", their parents, and members of the organization EUCUNET, uniting all Children's Universities in the world (www.eucu.net).

The idea started by two German-speaking universities was successful – the number of Children's Universities began to rapidly increase in other countries. For instance, in Slovakia, Children's Universities are already found in every Slovak university. Their precursor became Comenius University in Bratislava, offering a range of activities for Slovak and Austrian children in both languages.

Polish public and private universities as well as foundations and foreign language schools joined this initiative. In Poland, the first children's university was established in Cracow in 2007. It was organized by the Paideia Foundation (http://www.ud.edu.pl/kr/). The subsequent children's universities have been rapidly established and now there are more than 50 of them in Poland – the figure below shows the cities in Poland where there are children's universities.

Figure 4. Cities in Poland in which universities operate for children. Source: http://uniwersytetydziecieceе.lud-rekrutacja.p.lodz.pl/03_mapa/03_mapa_wejdz.html

Lectures, workshops and laboratory classes at Children's Universities are held in the lecture halls of the universities and are led by academic teachers from renowned national and foreign universities. In an accessible manner, the classes cover the issues of science and nature. The main objective of the classes is to awaken scientific passion in the students by showing that science is a fascinating adventure.

Despite the extensive network of Children's Universities in Poland, only a few publications relate to research on the effectiveness of this form of learning (Moskal & Nodzyńska, 2014). Most of the publications constitute the so-called descriptions of good practice (Krzyśko & Bartoszewicz, 2015).

Figure 5. Chemical classes for children at the University Children And Parents - Pedagogical University

Figure 6. Lecture for parents at the University Children And Parents - Pedagogical University Fri. When reading tales naturalist (Nodzyńska, 2004a,b)

Museums

Knowledge of natural and technical sciences, at all levels of education, should be acquired by students through independent and practical action. This approach to education through action and fun is also consistent with museum education. During the workshops held in museums, educational centers, open-air museums or educational parks, botanical gardens and zoos, educational paths or the so-called "living museums", students not only have the opportunity to get familiar with the actual objects but they can also very often "touch the exhibits", for example, by performing independent experiments.

More and more often we can come across virtual museums, which are digital representations of real exhibits. Students follow their designated or concrete paths using an interactive camera. It is also planned to present the most interesting exhibits in 3D (Ludwik, 2011).

Literature concerning teaching in modern multimedia education centers/ museums is quite rich, however, as in the case of Children's University, descriptions of good practices prevail (Daszkiewicz & Tarkowski 2013; Kreiner 2001; Kudła, 2002; Ludwik 2011; Moszkowicz, 2009; Nęcka, 2010; Nodzyńska, 2009; Nodzyńska & Bílek 2009; Nodzyńska & Paśko 2010; Ogonowska, 2010; Potyrała, 2011; Urbanek & Wideł, 2007; Ziółkowska-Weispp, 2013, Karwasz!); rarely articles describing the results of research on the effectiveness of this type of learning can be found (ed. Szeląg, 2012)

Days of open Universities, Scientists Night's, Festivals of Science, Theaters Science

An example of fun activities can be "science theater", which not only checks the broad substantive knowledge of young teachers but also the skills of its simple and clear transfer. Theatrical performances based on the presentation of experiments bring much into the process of learning of hard and soft skills. It plays a big role in mastering cooperation, delivering presentations/speeches (stress resistance), communicativeness, creativeness, dynamic action and above all emotional interaction with the recipients of art.

Figure 6. Theatre science - students Gymnasium. rtm W. Pilecki Zakrzowie, prepared a presentation containing chemical screenings for younger children. The project is described in Chemistry Experiment Show as a Topic for Project-based Education (Kobylańska E. 2016)

Sometimes the line between showing an experiment in class and theater show is thin – the following photos present the activities blending science theater and a classical lesson or lecture.

Figure 7. The teacher of chemistry - the boundary between the show and the experience of a theater show is fragile [http://filing.pl/wp-content/uploads/2015/03/filing_images_ea061f009f99.jpg - access 07/12/2015]

Figure 8. shows science - chemistry [http://www.ted.com/talks/ramsey_musallam_3_rules_to_spark_learning - access 07/12/2015]

As a typical example of this type of action, a biology lesson by Debby Heerkens may be mentioned. The teacher became famous on the Internet after the publication of the film from her class. She showed her students the construction of the human body using her own body. She did not appear naked in front of the students, as suggested by the headings on the Internet, but in costume depicting muscles, skeletal structure and veins. This unusual teaching technique drew the attention of not only the media from around the world but also the students, who will probably remember this event for a lifetime.

Figure 9. Photos of biology lessons Debby Heerkens [http://i.iplsc.com/foto-groene-hart-scholen/0004QHQZNS1SUX4Q-C122-F4.jpg - access 7.12.2015]

There is no doubt that such teaching shown in the above examples has more to do with theater and role playing than the traditionally understood role of the teacher.

Figure 10. Definition of the term 'alcohol' in the project Singing Wikipedia [https://www.youtube.com/watch?v=XsVJjxmnMwA - access 07/12/2015]

A similar combination of theater and science (in this case, encyclopaedia) is reflected in the Copernicus Science Center and its project of singing wiki. In this project, famous actors and journalists sing the definitions of the concepts using the entries from Wikipedia: https://www.youtube.com/playlist?list=PL938BB67F93980477.

Children's Universities or broadly understood museum education is a permanent offer, which, despite the use of fun and games to educate beneficiaries, places the main emphasis on learning. The remaining events (University Open Days, Scientists' Night, Science Festival) are rather occasional (although they are cyclical), and the main organizers' focus is placed on the beauty of science and spectacular results obtained through science (the so-called WOW effect!, that is something that can not be easily measured or described, but can be felt; it is a special state of mind, a unique combination of what we see and what we feel; it is a surprise of the event participant, thanks to which the event remains in their memory for a long time). Many of such activities have something in common with theatrical activities and base, among others, on shifting the boundary of events from the stage to the audience

Examples of good practices, the use of games in teaching science

Research and statistics show that the use of experiments and games in chemistry class is a very good idea, but rarely used by teachers who explain this fact by the time restriction or lack of time.

On the Slovak website: http://www.skolahrou.sk/, there are some examples of interesting educational games, songs, quizzes as well as tests. They have interdisciplinary significance, which is extremely important in life sciences education. The website also contains educational materials for teachers.

Agarwali Saha (2011) shows in his article an example of a logical game, through which students learn basic concepts related to the construction of molecules and chemical bonds. It creates the idea of the concepts of atoms and molecules in the mind of the young man.

A similar game is described in the article by Antunes, Pacheco and Giovanela (2012); it is based on showing the molecular geometry, polarization and intermolecular forces

Bayir (2014) presents activities and research that took place at the two-day event: Chemistry Games Days. 250 students and teachers were subject to the research then. Games enjoyed popularity and provided a pleasant way to facilitate the learning process. The topics of the games were related to: the elements of the periodic table, symbols and names of chemical elements, the distribution of elements in the periodic table and their characteristic properties.

Particular attention should be drawn to the educational game, described by Chee (2011), titled "Legends of Alkhimia". He points out that the game is an extended learning process, allowing students for a real visualization. It is designed for 13 and 14 year olds. It is possible to play in the multiplayer mode, which supports up to four players simultaneously. Each player uses a separate computer and they are connected to each other through the local network. The game makes students solve the problem concerning the use of chemistry in real life, but also engages them to work independently in the laboratory, through the use of its virtual representation. The game includes a narrative that provides extraordinary experiences and emotions.

Another example can be interactive simulations PhET, which are widely available on the Internet, so every student has the opportunity to take advantage of them. They are designed in such a way that they can serve as a virtual laboratory or demonstration. A simulation type of game constitutes a learning environment for youth and supports the process of consolidation of already acquired knowledge through play.

Czech Republic

It seems that, among the countries of Central Europe, the Czech Republic is the place where much attention is devoted to teaching through games.

The examples of publications that not only describe dozens of chemistry games and activities but also attempt to classify the games is: "Skola hrou" (www.2) and "Poznavame taje chemie" (Musilova E. 2003). In "Poznavame taje chemie", the following specific criteria for the division of games were adopted and described:

- program,
- type of task
- difficulty level
- time to solve the task,
- interdisciplinarity.

They are described in detail in "Poznajeme chemie" E. Musilova and L. Jancar.

The 'program' contains substances needed for pre-planned task groups. The types of tasks, in addition to examples of open and closed tasks, involve interesting examples of games that can be used in chemistry class and are certainly interesting for the students. These include:

- chemistry gap-filling – consisting in filling the gaps in specific words on a chosen topic. It can also be used as an example of crossword.
- chemistry word web – based on learning associations of individual characteristics, reactions or words in any selected topic.
- chemistry puzzles – involving guessing the secret word through drawings and the guiding words.

• chemistry texts – involving solving different kinds of tasks based on the information given earlier in the form of table or text.

• chemistry question marks – consisting in providing answers to specific questions by students. The questions concern interesting texts describing, for example, "The mythical element", or "The mysterious cave", in which there is hidden information. The game refers to the knowledge already acquired by students. It can be applied on lessons devoted to revision or consolidation.

• chemistry magic – describing chemical demonstrations that students can perform, perfect and present in front of a selected audience.

• chemistry zebra – involving providing a few descriptions, on the basis of which the students guess which substance is mentioned or perform a given task. This task is very often used in chemistry competitions.

• chemistry "micro-detective story" – involving adopting the role of Sherlock Homles by the student and guessing puzzles related to chemical reactions or phenomena that is very good for practicing the use of theoretical knowledge in practice. (Jančar & Musilova, 2003).

As an example of the use of games in practice, a Czech project "Hrajeme si v chemie", which involved the preparation of special playing cards, can be mentioned (Lomovcivova, Jančar, Sibor & Cidlova, 2004). The cards contained information on:

• chemical substances that students can encounter in their daily life,
• laboratory safety rules and first aid,
• chemical processes in daily life,
• recognition of glass and laboratory equipment,
• mineralogy,
• ecological topics (eg. the ozone hole, the greenhouse effect).

All the above games have a set of questions for which the players receive a certain number of points. For the students, the game was not only a revision and consolidation of knowledge, but also pleasure, therefore, it enjoyed a lot of interest (Lomovcivova, Jančar, Sibor & Cidlova, 2004).

The subject of teaching with the use of games is also raised in the Czech Republic by Renata Šulcová (Šulcová, 2009; Šulcová, R. at all., 2007; Šulcová & Zákostelná, 2008; 2010; Šulcová, Zákostelná & Reslová, 2014).

Another book dedicated to learning through play is the publication of "Hry se svíčkou = Games with a candle" by Sedláček, Holý, and Richter (2003).

Poland

In Poland, despite the large market of commercial educational games, basically, research on the effectiveness of teaching through games is not conducted.

Research on students' interest in activities in the form of game and durability of knowledge acquired in this way depending on the students' age and their early interest in the subject is described by Nodzyńska (2009). In turn, the influence of chemistry educational games on the effectiveness of chemistry education in the teaching of chemistry to dyslexic students was raised by Kamińska-Ostęp (Kamińska-Ostęp 1998; Kamińska-Ostęp & Gulińska 2004, 2005, 2006), nevertheless, these studies, due to the imprecise inclusion of students into study groups, can not be considered reliable. Teaching supported by elements of fun can be found in the work of Kopek-Putała (2014, 2016; 2017), who also conducted a survey with students with learning dysfunctions (2016), for whom entertainment was a method of correction, and later elimination of problems in learning. In these works, it can be seen that the game is a method of adjustment and adaption to the capabilities of the student and provides them with adequate motivation for further development.

Conclusions

As shown above, educational games play an increasingly important role in education. It can be noticed how wide is the range of their applications and how great the possibilities of their use are not only in the chemistry class but also in interests clubs or trips. Through the use of games in the learning process, students not only gain greater self-confidence but also broaden their perspective during solving problems, which is the main pillar of simulation (Miłosz & Miłosz, 1995). Students are not only more motivated to work independently but also strive to develop themselves. Learning is pleasure for them, and games and applications constitute a source of information, through which young people consolidate the earlier acquired knowledge. It can therefore be concluded that games should be an inherent element of teaching.

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What and why – non-formal education of children in Poland – possibilities and experiences

Introduction

Non-formal education in Poland

Poland is a fast and developing well learner, but in need of change in the approach to human society and the economy. A citizen should be surrounded by care and attention. Do not interpret this type of change through the prism of social assistance, since the same funds do not solve problems. We need new ideas, the involvement of local communities, increasing access to education, increasing knowledge, acquisition of new skills on the level of lifelong learning with the use of new teaching methods. This requires long-term and well-planned investments and orientation changes the perception of society with centralized hierarchical society based on cooperation (Stalończyk, 2014).

Today, non-formal education begins with us to share several major types. The first one represents the traditional activities of foundations and educational associations - often they are led by school or scientific institution or such institutions as lounges and clubs. Nova here are actions as having a specific time programs. These organizations operate generally based on the principle of subsidiarity, complementing the formal education system. In this way also a number of youth organizations operate. The advantages and disadvantages of this solution are as follows; the biggest advantage is that at all here, "doing something", while the disadvantage that it is more likely to model action charity than self-help. Non-formal education as it were through the back door to enter the official system primarily as a method of working with students or pupils. This type of work requires passion, a sense of mission and specific vocation - otherwise institutionalized environment is rapidly distorted.

Non-formal education also deals with agencies and national and international institutions based on many observations, bodes ill for the same idea. This is because these institutions always felt the temptation to what is informal, carefully and thoroughly formalized. Another type is spontaneous activity of self-education of by far the informal nature which often has the form of peer education or is supported by the adult animators, working in conditions of absolute minimum of institutionalization (Fatyga, 2005).

Development of non–formal education in Poland

During 6th Civic Congress (Jaki rozwój, jaka edukacja w XXI w – wielkie przewartościowanie) in Warsaw (2011) it was demonstrated, that changes in education are compulsory, and these changes are enforced by our life. We are drowning in the news. Young people most often learn through experience, see the general utility of acquired knowledge to solve real problems. Thus, in the knowledge society, education becomes a strategic factor in social and economic development, where the realization of this goal is seen in formal and informal education. In Poland, a huge emphasis is placed on formal education and non-formal education is still underestimated. It was rightly pointed out by S. Drzażdżewski, that future of education is the symbiosis of formal and informal education. And it becomes obvious that the combination of these two types of education allows much more interesting to teach. Another example is the 2nd National Congress of non-formal education, which took place on June 23, 2016 in Łodź. In conclusion, 7 directions of development were presented. Among them they were: the creation of attractive learning situations based on neurodidactic and practical education.

Non-formal education is a frequent topic of various seminars and conferences e.g. DidSci 2016. Examples of specific activities have become the subject of numerous articles (Kluza & Maciejowska, 2016) and books (Karwasz & Kruk, 2012).

Enthusiasts of non-formal education in Poland

Polish schools are more often supported by non-formal education during natural science lectures. This results in the improvement of dealing with scientific thinking, which include inter alia: identifying of scientific issues, explaining natural phenomena in a scientific manner, the interpretation and use of the results and scientific evidence. Intensifying these skills translates into higher scores of teenagers.

Non-formal education also fulfills another important function - promotes the principle of lifelong learning among students, which is carried out in Poland insufficiently. Non-formal education centers, open to everyone from school children to adults of all ages can change these statistics unfavorable to Poland.

Some interesting proposals in Poland include:

a) University of the Third Age
b) Copernicus Science Centre in Warsaw
c) Gdynia Aquarium
d) Hewelianum Centre in Gdańsk
e) Seal Sanctuary in Hel
f) Knowledge Mill Modernity Centre in Toruń
g) Museum of Municipal Engineering in Kraków

h) Stanislaw Lem Garden of Experiments
i) Botanic Garden of the Jagiellonian University
j) Archaeological Museum of Kraków
k) The Collegium Maius Museum
l) Zoological Museum of the Jagiellonian University
m) Science Education Centre of the Jagiellonian University

Own experience in non-formal education

Definition of the problem

As shown by Mareschal and Quinn (2001) children's thinking is based on perceptive impressions, but they are also capable of abstract thinking, and a lot of researchers additionally postulate children's ability to draw unusually complex causal relationships. In order not to destroy this natural curiosity in the world, a wish to ask questions and make use of children's pursuit to independent cognition of the surrounding world, an idea appeared of natural science workshops for children at the age of six. Gopnik (2010) wrote of the existence of so called naive theories shaped by child's own activity, direct experience, environment where they live, we - as the ones who run classes - are aware of the responsibility for the contents, associations and applied analogies we introduce during the classes. It is obvious that improper activities of teachers, unsuitable words uttered, generalizations created by children, simplifications may contribute to the formation of erroneous convictions, particularly difficult to eliminate.

Children university examples – school year 2015/2016

We have been cooperating with the Foundation for Children's University preparing and conducting different type of classes: workshops and lectures. In the school year 2015/2016 there were two lectures and workshop. Short characteristic of children, meetings is presented in the Table 1. This description appeared on the website of the foundation.

Table 1. Short characteristic of children, meetings.

Lecture: Can we turn kitchen into lab?
Would we be mistaken saying that cook and chemist have something in common? During the lecture pupils will find out why the kitchen might be turned into a lab and what remarkable things might be expected in sweet tea. There is something distinctive in the way in which a chemist looks at the nature of things, which actually are termed by him/her as substances, solid bodies, liquids… Would a chemist find something interesting among all the sweets, treats and other kitchen products? Is it possible to smell freshly baked bread because of chemical processes? Or is it a physical change? Recipes and processes involved in cooking are of interest to chemist, who also has secret means to prepare mixtures. Moreover, kitchen equipment resembles tools and glassware that one might find in the lab. During the lecture pupils will learn about substances: different kinds and things that happen when two substances meet… When they meet, does each encounter result in the same way? Maybe nothing will happen, because each substance being too busy with itself, will not react with the other. On the other hand, may we expect an explosion, steam and smoke? Feel invited to explore the kitchen lab during the lecture!

Workshop: May the invisible become visible?
Not always information is available and easy to read, not by everyone. The workshop targets familiarization with chemical means to convey messages in a secret way. All that encompasses human beings might be termed as substances. It is worth inspecting the differences between substances. The workshop participants will find out what characteristics the substances may have. Moreover, they will have a chance to inspect whether colourless and scentless substances might be detected in other ways than using those senses. During the workshop pupils will find out what tools might be used to detect invisible message or what kind of substance should we look for if we would like to convey a secret message. Methods of secret message elicitation and concealment will be of interest. Pupils will use substances not only found in the lab but readily available in their households.

Lecture: Why the lemon juice changes the colour of tea? (Figure 1).

Some substances, although colourless and transparent, may significantly change the colour of other substances. It is difficult to explain this phenomenon without knowledge on chemical processes.

We obtain orange colour of the mixture when red paint is mixed with yellow one. This is known as colour combination – completely natural phenomenon – primary colours (red, yellow, blue) mixed together result in a range of new useful colours.

The children are involved in testing of this phenomenon by painting: combination of red and blue yields violet, mixing blue and yellow gives green. Mixing two different colours results in new colour. What happens when we add lemon juice to tea? Can a transparent and colourless substance change the colour of other substances? How to change a red substance into a green substance? May white turn red when exposed to invisible fumes?

During the lecture pupils will find out how the character of a substance influences the way in which the colour of another liquid change. Pupils will witness a few chemical tricks and will see that remarkable phenomena might be explained when specialist knowledge is available.

Figure 1. M. Krzeczkowska as a lecturer (photo: K. Mrozowska)

The workshop „May the invisible become visible?" was held in October 2015. It was designed to introduce the students with the concept of substances in the context of conveying secret messages. Each workshop had 20-25 participants (ages 7-8), who initially were divided into 4-5 groups. Each workshop took around 50-60 minutes. This section briefly presents how the workshop was designed and what tools were used in order to meet the goals established beforehand.

As an introduction, the students were presented with an excerpt of Pilipiuk's book entitled "Kroniki Jakuba Wędrowycza":

The priest came back to his room and with a reflection started to browse a notebook with finance related entries. A dozen or so of last pages were empty. All of a sudden he spotted that those pages a marked in the corner with a little character resembling 2 with its base crossed out. A code. Something, that has been concealed. He smelled the notebook. Light, almost scentless aroma of onion in the old paper smell was present. He smiled a bit. Onion juice. The simplest invisible ink. He went to a housekeeper and borrowed a flat-iron. He carefully ironed the sheet of paper. Lines painted with the onion juice darkened quickly. He returned the flat-iron and he devoted himself to the reading. The entry was labelled with a date. From last week. The person, who left this entry, was destined to live only for two more days.

The text above was translated from an excerpt of the book available at http://www.literatura.gildia.pl/tworcy/andrzej_pilipiuk/kroniki-jakuba-wedrowycza-w3/fragment2.

This fragment was used as the basis for heuristic chat between students and the workshop leader. Bolded passages served as the anchors for questions: How did the priest find out that the notebook contains a secret message?, What sense did he use? (How he indicated the substance used?), What term did he use to term this kind of substance? How did he manage to read the secret message? The answers for those questions were inducing the follow-up question intended for the familiarisation within the scope of the workshop, e.g. What other substances might be used to conceal a message? In order to decode such messages do we have to use a flat-iron? What other tools may we use? Is it possible to detect invisible substance with another substance? Those questions (and answers to them) clarified the definition of a substance, physical and chemical changes as well as managed to refer to the act of communication itself. Based on Jakobson's functions of language the students were to identify the elements of message concealment process. They were asked to name other methods of communication apart from the written ways. The students did a wonderful job naming electronic devices and even smoking signals among others as ways of alternative communication means. They did fine in enumerating the methods of hiding messages in those alternative ways of communication.

The short (lasting around 5 minutes) introduction was followed up by a demonstration. The workshop leader had prepared a message on a piece of paper with the use of salicylic acid (information not revealed to the participants). He asked the students if they could state whether this piece of paper has or does not have any message embedded. The students were touching the piece of paper, smelling, looking at it under the direct light. Some of the students were convinced that there is no message, some were sure that there indeed is a message. The leader said that we have at our disposal a substance (iron (III) chloride, information not revealed to the participants) and asked the children to state its characteristics (state of matter, colour, smell). Then, a question was asked: If I bedaub the piece of paper with this substance what would indicate that there is a concealed message? The message probably would have some distinct colour. What colour? Students were surprised that the message (the title of the workshop) was of different colour than the developer ($FeCl_3$).

After short summary of what was presented so far (definition of invisible ink, chemical and physical developers, substances, senses, messages, kinds of developers, ways of communication) students were invited to their own work under the supervision of a group leader. At each working stations a bunch of materials was present, including: a group of substances meant to serve as ink, group of substances/tools meant to serve as developers, flashcards with symbols and names of elements, tools for using the substances and additional resources (like paper-towel, glows, plastic cups etc.).

The main focus of the group work was oscillating around the worksheet (Fig. 2) which summarized all ink and developers the children could use to hide the names of elements.

		DEVLEOPERS				
		Iodine tincture	Potassium iodide	Phenolphthalein	UV lamp	Temperature
INKS	Citric acid					
	Lead(II) acetate					
	Sodium bicarbonate					
	UV marker					
	Milk					

Figure 2. The worksheet for invisible ink investigations

Most experiments designed for the investigation of invisible ink (in classroom conditions) are based only on one or two tests concerned with a limited number of ink and developers. Those experiments are aligned on the diagonal of work sheet. The expected outcome the experiments on the diagonal starting from upper-left corner is: white character string (violet piece of paper, reference to starch or antiseptic properties of the tincture of iodine), yellow character strong (precipitated lead(II) iodide, reference to precipitation reactions), violet or pink character string (reference to pH and acid-base equilibriums), glistering effect (reference to interaction between light and matter), brown or black character string (reference to the decomposition of organic substances). As may be noted, each experiment on a diagonal might serve as an exemplary design for different teaching purposes. Nevertheless, one of the advantages of the use of matrix-like form of the worksheet is the possibility of making sound scientific judgements. After all, the workshop is based on the idea of using invisible ink. Thus, it would be of interest to find pairs of ink and developers that are fit for purpose. This was part of one of the hypothesis put forward to the students. Based on the results in the worksheet is the given pair a good or a bad combination to hide and read the message? And most importantly: Why do you think so? Students frequently noted that some developers are more universal than others and that some ink is useless or its application should be carried carefully. The leaders were more than happy when witnessed the students proposing their own hypothesis and testing them with subsequent statements of conclusion.

The most time-consuming part was the ink development stage with the use of physical tools. Several hairdryers were at disposal to dry worksheets as well as flat-irons and tea candles used for developing stage. Those activities were done under group leader supervision, thus the involvement of students was slightly restricted. Nevertheless, the leader was prepared to handle such situations and instructed to ask stimulating questions related to the coded elements, for instance: Do you know which vegetable is most abundant in that element? Which element (or elements) is necessary for human to live? Could you name the element that is the main element of the air? Maybe you could identify this element in the room? Where one could find a list of all the elements?

The main goal of the workshop was to familiarize students with chemical ways of concealing and developing written messages. The workshop was designed to present the concept of invisible ink and developer, show substances or tolls that might be found in the households and serve as ink/developers, to present the difference between physical and chemical processes (after being asked whether given developer acts as physical or chemical agent, student was queried to name other, known to him/her physical/chemical processes). Furthermore, students were familiarized with symbols and names of elements (in the recapitulation stage the workshop leader asked children to name some elements and to state their use or place where one could find them). Finally, the workshop enabled judging the results of the experiments by relating to the scientific hypothesis.

When designing the workshop, the take-home experiment (redo this at home using substances that were discussed during the workshop as being available in households) was planned to be presented to students. There was no need of explicitly stating this task because the students actively informed that they would write or paint something with the invisible ink and ask a friend or one of the parents to try and read it. Students should remember some ink (developers) might be used (and easily found) by them, for instance lemon juice (temperature) and baking soda (red cabbage stock or hibiscus tea). Nevertheless, the question May the invisible become visible? was answered.

The book passage presented to the students at the beginning was explained using scientific arguments. Not directly, but after one of the workshops a student approached the leader and asked about the name of the book as he intended to find other chemistry related fragments. The passion for science might find its origins in various aspects of day-to-day activities. Even short book excerpt may awaken the curiosity.

RESEARCH – METHODS AND TOOLS

In order to collect views on non-formal education relevant questionnaire was prepared. The study involved a group of children parents, from Krakow and nearby small towns (e.g. Wieliczka, Skawina, Zabierzów). The survey (N = 319) was carried out among the parents of the children participating in lecture in 21st May 2016. In used questionnaire some questions appeared as follow:

a) Why do you invest in your child's growth? What motivates you?

b) How do you assess the change of progress and mind-set of your child after one year of participation in this curriculum?

c) Have you tried other ways of investing in your child's growth? What were the ways?

d) Do you have any suggestions as to the kinds of development forms that could benefit your child's growth?

Figure 3 and figure 4 present age and gender of children participated in lecture.

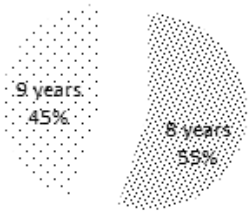

Figure 3. Age of children

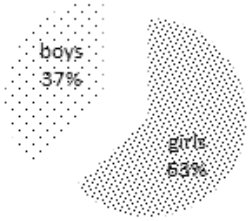

Figure 4. Gender of children

RESULTS AND DISCUSSION

Collected data allow concluding that among six most frequent indications of parents' motivation (question a) developing children's' interest in the natural world played an important role. This indicator and five other with their relative frequencies counted and expressed in percentage are presented in figure 5.

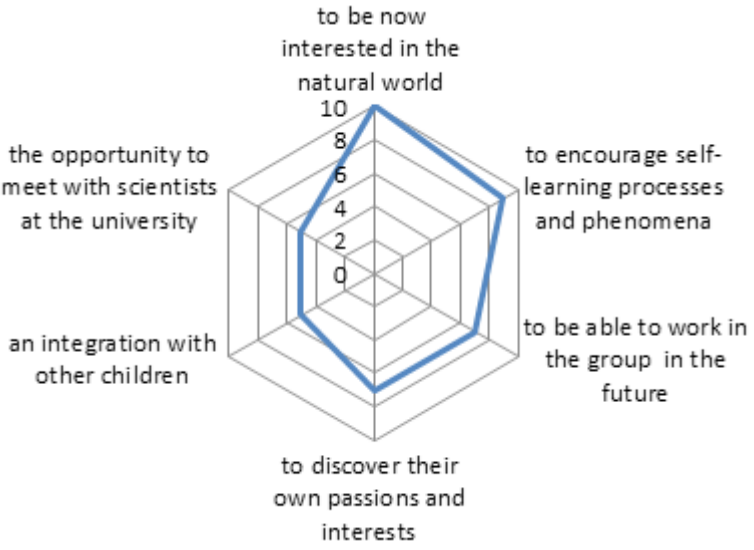

Figure 5. The most common indicators in question a

Great majority of teachers (83%) pointed some observed positive changes in the child's behaviour and their attitudes. The positive changes include, i.e. eagerness to play in a group, more spontaneous cognitive behavior, increasing the curiosity in the surrounding world. Five most often indicators with their relative frequencies counted and expressed in percentage are presented in figure 6.

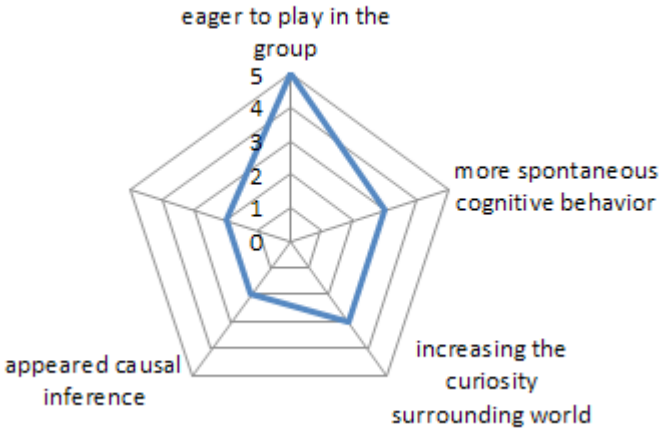

Figure 6. The most common indicators in question b

Most of the parents (69%) indicated that children participate in other activities e.g. night of scientists, night of museums, science festivals, some activities prepared by shopping centres. Less than 20% of parents did not gave an answer of question c. In parents' opinion (question d) the most valuable activities are those which gave the children the possibilities of creation of active and open-minded attitude in recognition different phenomena in everyday life.

In many cases, this type of workshop is the first step to get to know nature on one's own but under the watchful eye of a teacher. This type of classes is a challenge to a cognitive system of pre-school age children but also for those already participating in early school education, particularly when school classes do not arouse natural science interests and do not motivate to gain knowledge. The workshop can engender in children the willingness for further search and broadening knowledge via independent execution of simple experiments at home in parents' presence. The idea of such classes also boils down to making children aware that not always the adults will respond to all their questions or they do not know exactly everything and will not always tell them how to solve a given problem. The workshop is a source of positive emotions, which enable effective and efficient learning of the surroundings.

We believe that learning should be spontaneous, take place in everyday life and non-formal education is planned and thought through facilitator, trainer or youth worker who also supports the young man during the entire learning process.

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Is Cola healthy? Theoretical and lab classes for students of different age groups (preschool to junior high school)

Part I: Theoretical classes, general information about drinks such as Cola

Described considerations comprise a block of classes connected with the subject of chemical substances in our surroundings. The full cycle of classes involves, apart from a broad theoretical introduction, which can be freely modified depending on the students' age group, practical classes (lesson plans and research results are described in the article).

According to the last European Health Report of 2012 drawn up by World Health Organization (WHO), the life expectancy of Europe's population is expanding, but at the same time, patterns of disease burden are changing, and health inequalities as well as the impact of factors affecting health are increasing. The number of young people with overweight or obesity is growing. Obesity and diabetes, being diseases of the 21st century, are a serious problem in the field of public health in Europe. This is due to their direct and indirect effects, ranging from microvascular complications (kidney diseases, nerve damage, eye diseases) to vascular complications of a different course (limb, brain, and heart diseases). The world filled with fast foods, sweetened drinks and lack of physical activity or time to cook traditional healthy meals is one of the main causes of the growing problem of obesity and diabetes, among others. These problems cause significant health risks. The reasons for this phenomenon should be sought, among others, in the change in people's lifestyles, having bad eating habits and insufficient physical activity of school-age children (Nodzyńska, 2013). Cola-type drinks are one of the most frequently bought non-alcoholic beverages in the world.

Tab 1. Average consumption of Coca-Cola in liters per capita around in the world

Country	**Average consumption of Coca-Cola in liters per capita around**
Poland	7
Czech Republic	8
Great Britain	17
France	18
Germany	23
USA	36
Mexico	81

This is despite the rather negative opinions on the impact of this type of beverage on various forums about healthy lifestyles (Kazeem) and conducted scientific studies (compare the results of studies on the adverse health effects of drinks such as Cola, being one of the reasons of obesity epidemic, e.g. Malik et al., 2010a; b; Keast et al., 2011).

The main reason of obesity caused by cola-type drinks is the high sugar content: 100 ml of Coca-Cola contains 10.6 grams of sugar (Coca-Cola information site). Because the minimum intake of consumable carbohydrates is set at the level of 130 g/d, and the amount of energy supplied in the diet through sucrose should not exceed 10% (13g) (Ostrowska), 100 ml of Cola is as much as 81.5% of the daily requirement of an adult for sucrose. Excess sugar is converted by the body into fat and stored. Caffeine included in Cola makes us perceive it as a non-sweet drink. In addition, many people do not see a drink as a source of calories, and it includes as many calories as a meal (the average can has about 150 kcal)! Sucrose, apart from energy, does not contain essential nutrients, but it increases the synthesis of lipoproteins in the liver, being the source of atherogenic LDL cholesterol (Ostrowska).

The excess of sweeteners in Cola also causes damage to the tooth enamel and promotes the development of caries (Kruszyńska-Rosada, Borysewicz-Lewicka, 2000; Horowitz, 1998; Bowen, 1998).

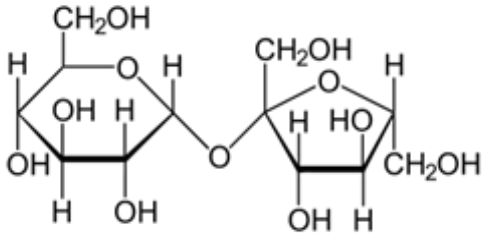


Figure 1. Saccharose ($C_{12}H_{22}O_{11}$) common disaccharide, composing of one molecule of glucose and one molecule of fructose. The application is primarily in the food industry where it is used as a sweetener

Another ingredient which is not indifferent to health is caffeine. The effect of caffeine is multi-faceted and still not fully understood. Although it also has a positive impact on the functioning of some human organs (for example, consumed in moderate amounts, it reduces fatigue, improves mood and concentration, increases the physical capacity of the body, sharpens attention by improving cognitive functions, for instance, working memory), its other activities have a negative impact on the body. Caffeine is a psychoactive substance, a stimulant. It increases feelings of anxiety and fear (Bruce et al., 1992; Bhattacharya et al., 1997). At a dose of 100 mg/day, it causes physical dependence (Garrett et al.,

1998) or psychological one (Strain et al., 1994). The withdrawal syndrome is manifested by fatigue, deterioration of mood and attention span, and very often headache (Ozsungur et al., 2009).

The caffeine content in 250 ml of a Cola-type drink is an average of 25 mg, whereas it is 20% more in Cola Light. (For comparison, a cup of strong black tea has 30 mg caffeine, a cup of roasted coffee (150 ml) – approximately 85 mg, a cup of soluble coffee – approximately 60 mg). Pregnant women (Fisone et al., 2004; Jarogniew et al., 2006; Han et al., 2007; Wentz et al., 2009), children, the elderly and people with heart diseases are more sensitive to caffeine and they should greatly reduce its consumption. Diabetics and people with a family history of diabetes should not consume it at all, because caffeine increases insulin resistance (Acheson, 2005).

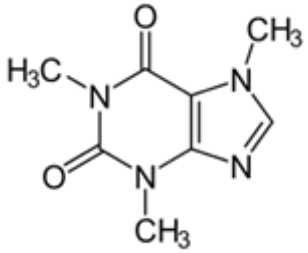


Figure 2. Caffeine is an alkaloid that stimulates the central nervous system and heart activity

Another ingredient of Cola is phosphoric(V) acid, a food additive E338. Drinking a can of Coke (0.25 l) means consuming approximately 0.2 g of pure phosphoric(V) acid. Since this acid creates chemical compounds with calcium, its excess can damage teeth and cause loss of calcium from bones. For this reason, people suffering from osteoporosis, menopausal women and children during growth should avoid it. In adolescents drinking too much Cola, the risk of bone fracture increases 3-4 times (Murray, Pizzorno, 1997; Nestle, 2003).

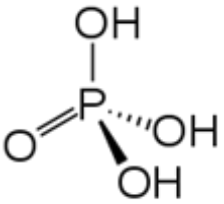


Figure 3. Phosphoric acid H_3PO_4 is a source of phosphorus, it stabilizes in foodstuffs and in the digestive system of some antioxidants

The low pH of Cola (Cola pH is about 2.2) is associated not only with

phosphoric(V) acid but also citric acid (E330, 2-hydroxy-1,2,3-propanetricarboxylic acid). Citric acid is present in small quantities in the majority of living organisms as it plays a vital role in their metabolism – it is an important intermediate of the Krebs cycle. Even consumption of 100 g of citric acid at once is safe (a typical bag of citric acid used in the kitchen contains 50 g of the product). In turn, the consumption of larger amounts can lead to severe abdominal pain caused by hyperacidity.

The latest research published in the Journal of General Dentistry of the Academy of General Dentistry (AGD) informs that the consumption of drinks containing citric acid can cause significant loss of enamel, and toothache (Lloyd, 2007). The influence of acids contained in Cola on the teeth is shown, for example, in the video on YouTube: What happens to a tooth if you leave it in Soft Drink for 24 hours?

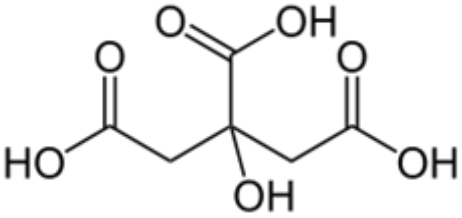


Figure 4. Citric acid – structural formula

Another controversial ingredient is aspartame (E951, methyl ester of the dipeptide composed of two amino acid residues – phenylalanine and aspartic acid). This compound has sweetness of 200 times the level of sucrose sweetness, clear and free of metallic aftertaste (Krygier, 1992). It is considered to be a noncaloric sweetener, although its energy value is 4 kcal/g (Zdziennicka, Jasińska, 1995). Safety of using aspartame has been the subject of many scientific studies (Food Additive Approval Process Followed for Aspartame, 1987) and numerous social controversies (Goerss et al., 2000, Olney et al. 1997). It was found that after the consumption of aspartame, different reactions may occur in the human body on the part of the nervous system, such as headaches, seizures, impaired perception, states of excitement, frustration, depression, and overall system disorders (American Dietetic Association, 2004). The impact of this sweetener on the development of brain tumor in rats was also shown (Ishii, 1981; Olney et al. 1997). Waszkiewicz-Robak and Świderski (2000) point out that the average content of aspartame in beverages ranges from 400 to 800 mg/l. According to Krygier (1992), in cola-type drinks, the average aspartame content is 550-680 mg/l. Since the acceptable level of aspartame in soft drinks is 600 mg/l (Sękalska, 2007), it can be seen that the upper value of these levels far exceed the acceptable content in these products.

In the human body, aspartame breaks down into its component amino acids; that is way initially it was thought that its consumption does not involve any risk, except for people with phenylketonuria, who do not metabolize phenylalanine. In these people, high concentrations of phenylalanine and its metabolites in the blood is toxic and can lead to irreversible brain damage and premature death (Wilska-Jeszka, 2002).

According to research, it is believed that aspartame in doses up to 0.4 g/kg of body weight per day is harmless (EFSA Panel on Food Additives and Food Nutrient Sources added to Food, 2013). However exceeding this dose may result in side effects. Consumer organizations and some researchers (Hert et al., 2011; Simontacchi, 2007) claim that aspartame causes as many as 92 side effects, including brain tumors, epilepsy, emotional sensitivity and diabetes (...), and that its excess in diet causes: depression, irritability, fatigue, heart palpitations, nausea, respiratory problems, etc.

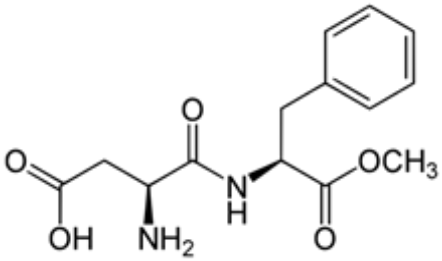
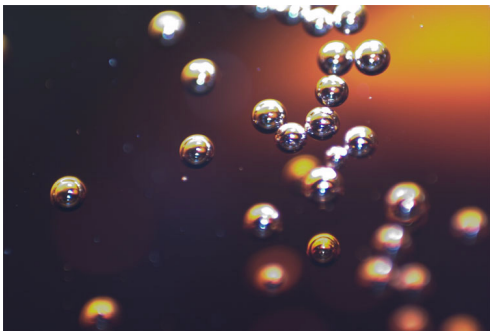


Figure 5. Aspartame – structural formula

Carbon dioxide is another component of all carbonated soft drinks causing bloating.



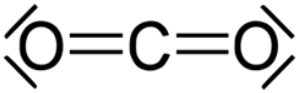


Figure 6. The bubbles of carbon dioxide in Cola. The structural formula of carbon dioxide. https://commons.wikimedia.org/wiki/File:Soda_bubbles_macro.jpg (author: Spiff)

Sodium benzoate (E211, C_6H_5COONa), food preservative, has bacteriostatic and fungistatic properties, inhibits the growth of yeasts, molds as well as butyric, acetic and, to a lesser degree, lactic bacteria. It irritates the gastrointestinal mucosa, thereby increasing the solubility of some compounds (eg. caffeine). It irritates, both directly and automatically, bronchial mucosa. In the study titled The International Programme on Chemical Safety, no adverse effect of daily doses of 647-825 mg of sodium benzoate/kg body weight were found (Nair, 2001). This substance does not accumulate in the body and is easily excreted from it with urine (Nawrot).

Large doses of sodium benzoate irritate the stomach lining (Chruściel & Gibiński, 1991; Nawrot), thus the consumption of products containing it can cause pain in sensitive individuals (eg. in patients with peptic ulcer disease). In combination with vitamin C (E300), it can become carcinogenic benzene (Data on Benzene in Soft Drinks and Other Beverages. Food and Drug Administration). Temperature and light exposure are factors accelerating the formation of benzene.

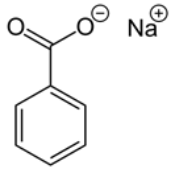


Figure 7. Sodium benzoate – structural formula

Sulphite ammonia caramel (E150d) is a synthetic, brown food dye. Acceptable daily intake is 200 mg/kg body weight (Food-Info.net: E150: Caramel).

It can cause hyperactivity, as well as diarrhea and the intensification of vermicular movements. It is toxic to rats. In rabbits, it inhibits the metabolism of vitamin B6 (Statham, 2006). In animals, it causes excessive muscle contractions and changes in the blood.

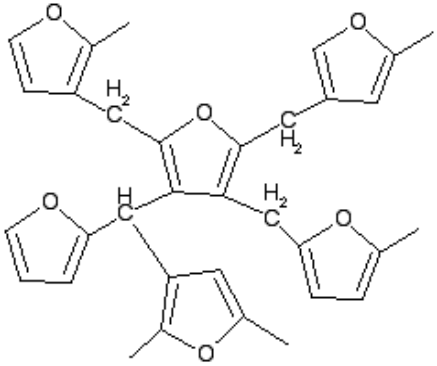


Figure 8. Caramel – structural formula

Other compounds present in Cola are sodium cyclamate and calcium cyclamate, which are used as artificial sweeteners in food and are denoted by E number E952.

In a small dilution, the sweet taste of cyclamates is about 30-35 times more intense than the sweetness of sucrose (Martindale, 1936; Gert-Wolfhard, Lipinski, s. 3). However, the sweetness decreases with the increasing concentration of cyclamates. At a concentration of about 0.5%, it can be felt as a bitter taste (Gert-Wolfhard, Lipinski, p. 5).

In the early 70s of the 20th century, cyclamates were suspected of carcinogenic properties. For this reason, their use in food has been banned in many countries (including Canada, Poland, the United States and the United Kingdom (Świderski, 2003). However, the reassessment of the toxicological data pointed to the lack of such properties. Doubts arise only in the case of cyclohexylamine – toxic metabolite of cyclamates produced by some intestinal bacteria in the human body (Martindale, 1936; Bopp et al. 1986, Cyt. za: Gert-Wolfhard, Lipinski, s. 12). The current value of the acceptable daily intake established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the European Commission's Scientific Committee on Food (SCF) is 0-11 mg/kg body weight and is based on the toxicological data on cyclohexylamine (Gert-Wolfhard, Lipinski, p. 12; Lück et. al., p. 3). JECFA also recommends that the purity of cyclamates added to food should be not less than 98% (Compendium of Food Additive Specifications. 1992, p. 283–285, 473–474, 1333–1334. Cited after: Gert-Wolfhard, Lipinski: p. 12). Cyclamates may also interact with certain medications (Martindale, 1936).

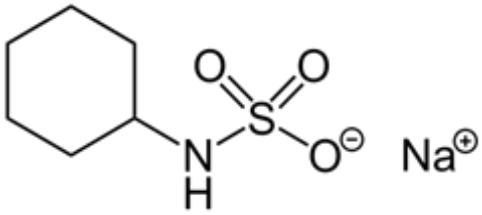


Figure 9. Sodium cyclamate – structural formula

An interesting result of the experiments is the fact that Cola is able to destroy the ability of white blood cells to search and destroy bacteria, and this state persists even for 8 hours! (Howenstine, 2002). Thus, in this time the body is virtually defenseless against bacteria. Large consumption of Cola also results in the lower and more difficult assimilability of iron. The functioning of kidneys is also impaired, and they are not able to excrete toxins, and thus, toxins are accumulated in our body, which leads to many serious diseases.

Cola-type (and other sweetened) drinks are undoubtedly tasty and popular especially among the youngest children. However, as can be seen from the above, they are not indifferent to the health of young and adolescent children. Due to

the aggressive advertising of companies selling and promoting these drinks, the children should be made aware that the frequent consumption of large quantities of Coke can lead to all sorts of disorders in the functioning of their body and, as a result, to diseases. One way of making children aware of the Cola properties is to compare its properties with another food product, which is available in the kitchen – vinegar.

Part II practical classes, laboratory experiments based on Cola and vinegar

Research

For 5 years, at the Pedagogical University in Kraków, laboratory classes for children have been conducted, whose aim is to educate children about the dangers of drinking large amounts of Cola-type drinks. Classes have been conducted in the framework of various types of events popularizing, for instance, the University of Children and Parents at the Pedagogical University, Wadowice Children's University, Open Days of the Pedagogical University, Science Festival in Kraków, etc. Classes were held in two age groups: preschool (5-6 year olds) and junior high school (12-13 year olds). In total, about 200 children took part in the classes. In the framework of the classes, the students independently performed 5 experiments in which they investigated and compared the properties of vinegar and Coke.

As part of the introduction to the laboratory classes, the students were presented with a very brief multimedia presentation that defines the topic of the laboratory classes (together with the aim) and basic information about acids.

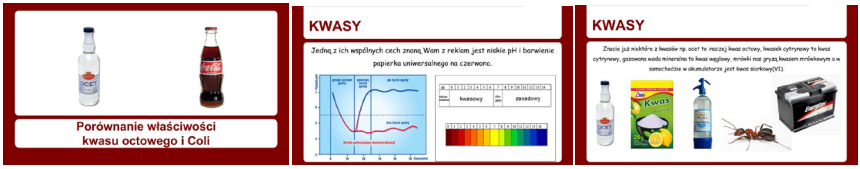


Figure 10. Introductory slides to classes

Then students were given worksheets with information on how to perform the individual experiments, and at the same time, the presentation showing the steps that must be taken to investigate and compare the properties of vinegar and Coke was displayed. In the preschool age group, there was one teacher for every 2-3 children to support the performance of the experiment and ensure the safety of children, and in the junior high school group, one teacher took care of 5-8 students. Teachers watched over the correctness of the written/drawn observations, and they assisted in drawing the correct conclusions from the experiment.

Students examined themselves:

- pH of vinegar and Cola using universal indicator paper
- reaction of the acids (vinegar and Cola) with metal (e.g. iron)
- action of the acids (vinegar and Cola) on natural substances containing carbonates (eg. teeth, bones, egg shells)
- reactions of vinegar and Cola with egg white,
- derusting properties of the acids (vinegar and Cola).

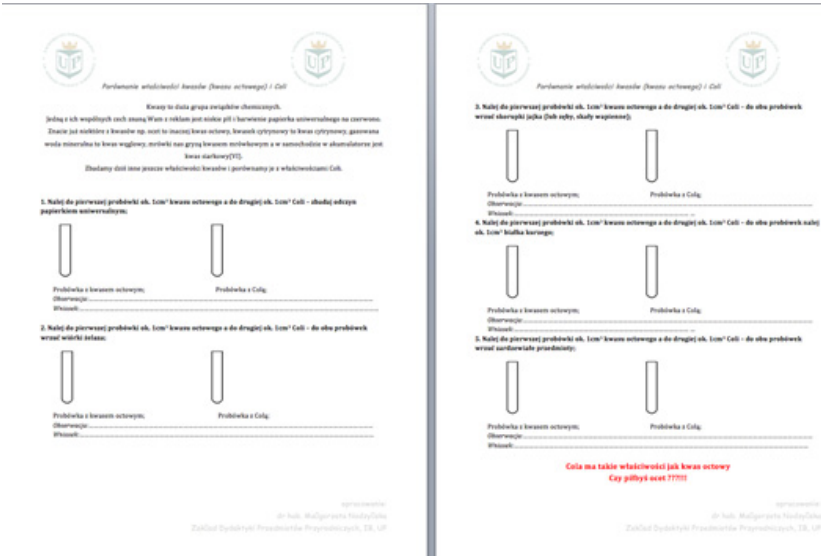


Figure 11. Student's worksheet

In order to check whether the students remember the experiment course and conclusions drawn during the experiment, at the end of the classes, the students filled in a questionnaire. The test contained 8 questions: 4 closed-ended and 4 open-ended.

Check what you remember

1. Acids have a low / high pH. (cross out the wrong answer)
2. Name acids you know…
3. Universal indicator paper stained with acid changes color to…
4. What happens after throwing iron filings into acid?…
5. What happens after pouring egg white into acid?...
6. Does Cola contain acid? YES / NO
7. Will you drink Cola after today's class? YES / SOMETIMES / NO
8. Did you like the class:

Figure 12. Student questionnaire

Research results

The conducted classes are always highly appreciated by the students (88% of preschoolers and 100% of junior high school students mark "a smiley face" in question 8), but the question is which information is remembered by the students and whether the primary aim of the classes, that is discouraging students from drinking large amounts of Cola-type drinks, is achieved.

Information that acids have a low pH was given on the introductory slide (it is known by students also from commercials, for example, Orbit gum commercials), and then the students studied the pH in the first experiment. The results show that this information was remembered slightly better by preschoolers (82%) compared to junior high school students (71%).

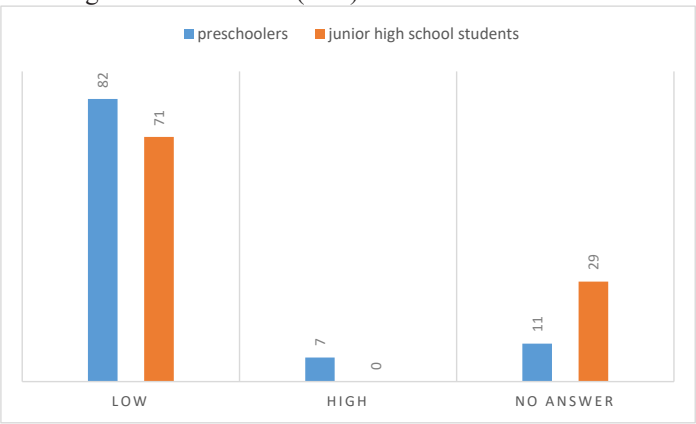


Figure 13. Answer to question 1

In the second question, the students were supposed to name acids they know. It was expected that all respondents would name acids they had examined, that is acetic acid (vinegar) and phosphoric(V) acid – an ingredient of Cola. Since the introductory presentation also mentioned: citric acid, formic acid, sulfuric acid and carbonic acid, the names of these acids were expected to appear in the questionnaire. Therefore, the students were supposed to name a minimum of two acids and a maximum of six. Difference in the number of acids named by the preschoolers and junior high school students is shown in the following Figure.

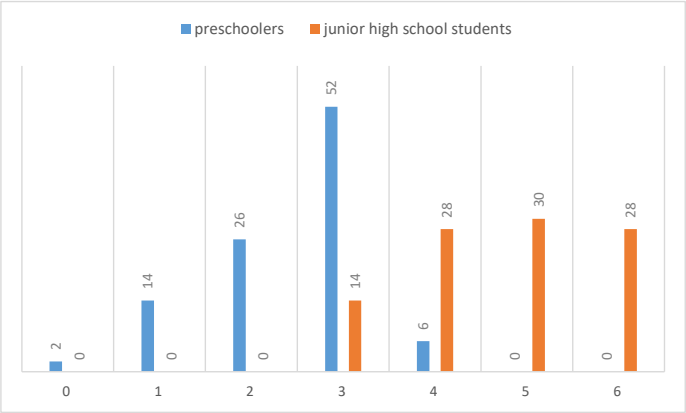


Figure 14. Difference in the number of acids named by the preschoolers and junior high school students

Half of the surveyed preschoolers named three acids, and junior high school students gave the names of three acids or more. Although the students had studied acetic acid (vinegar), 13% of preschoolers and 14% of junior high school students did not mention it among the acids they know.

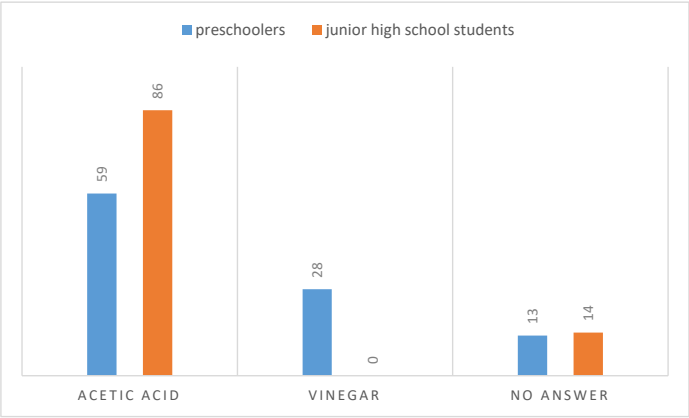


Figure 15. Percentage of students giving the name of acetic acid in question 3

Even fewer students remembered the information that Cola-type drinks contain acid (specifically, phosphoric(V) acid); as many as 50% of preschoolers and 43% of junior high school students did not mention this acid in response to question 3.

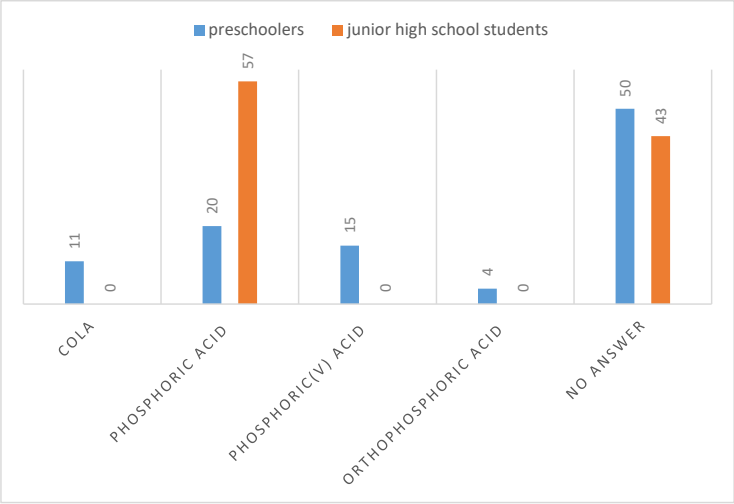


Figure 16. Percentage of students giving the name of phosphoric acid (...)

In total, the students gave names of 9 different acids. In addition to the acids mentioned in the presentation, older students also gave the names of acids that they had found on the labels of laboratory reagents.

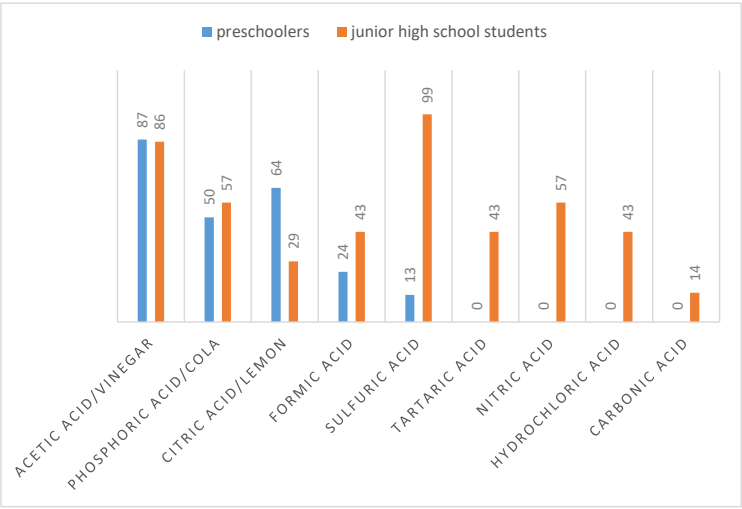


Figure 17. Percentage of individual acids (grouped)

The next question still concerned the first experiment performed by the students. The task of the surveyed students was to finish the sentence: Universal indicator paper stained with acid changes color to… It could be noticed that the answers of preschoolers were more spontaneous and actually corresponded to what they had observed (preschoolers mentioned the color red, but also orange and cream); whereas the answers of junior high school students were more "learned" – all of them mentioned the correct color – red.

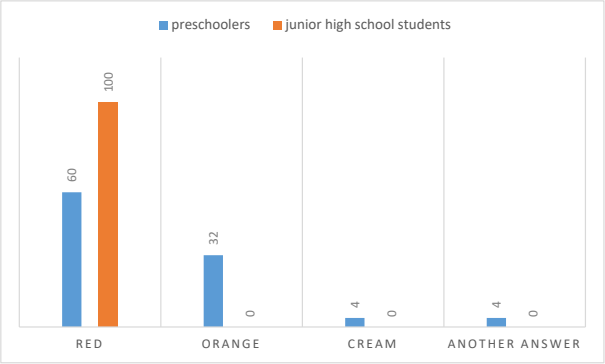


Figure 18. Students' answers to question 3: Universal indicator paper stained with acid changes color to...

The next question referred to the experiment: What happens after throwing iron filings into acid? The responses showed that sometimes an excess of knowledge has an adverse effect. Junior high school students confused iron filings from the second experiment with rusted iron nails from the fifth experiment. For preschoolers, these were two completely different experiments because they did not know that the nails are also made of iron.

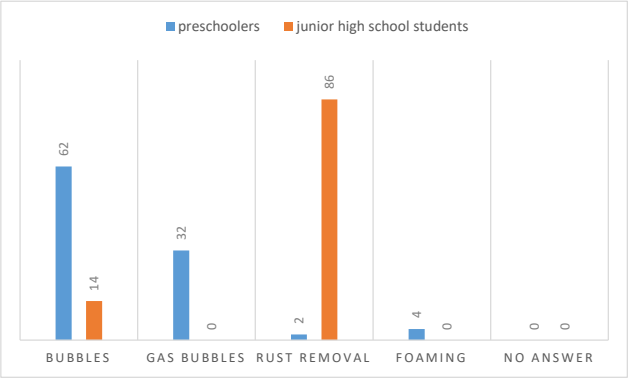


Figure 19. Students' answers to question 4

The difference in the responses to question 5 is very interesting. Only 7% of preschoolers did not answer this question, but the diversity of their responses is staggering. Preschoolers gave as many as 11 different descriptions relating to protein coagulation, as opposed to junior high school students, all of whom gave the expected response. This fact clearly shows "schematic" teaching and so-called learning to match the answers to the expected ones on the final exam, and thus killing the creativity of students.

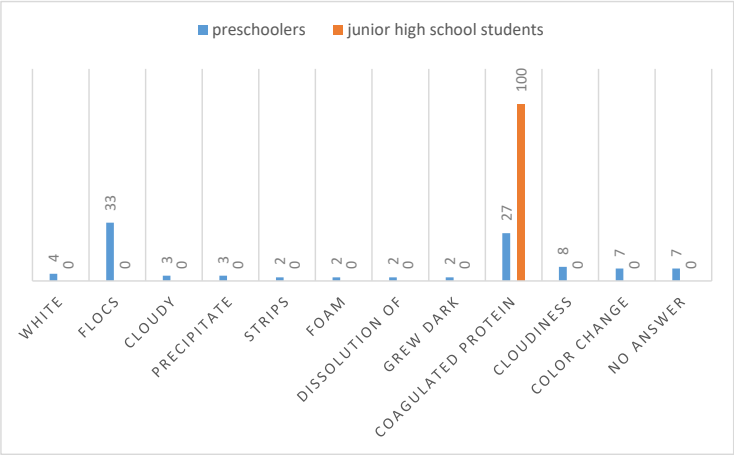


Figure 20. Students' answers to question 5

Quite surprising results were obtained for question 6 Does Cola contain acid? YES / NO

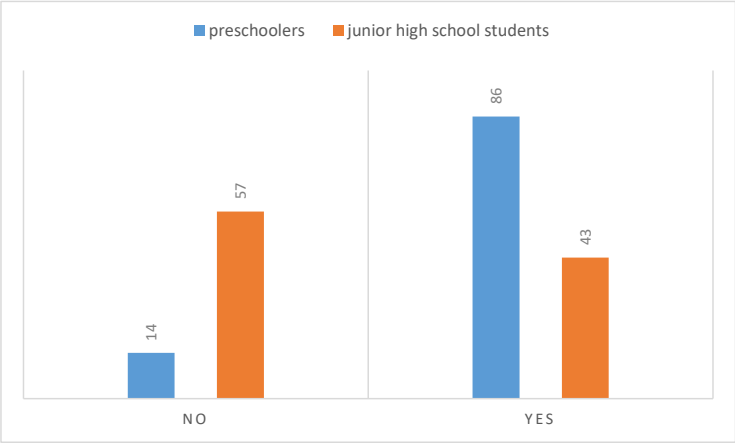


Figure 21. Students' answers to question 6

It can be clearly seen that preschoolers are open to new information and knowledge, while junior high school students, in spite of performing experiments 4 and 5 comparing a Cola-type drink with vinegar, still did not see the relationship between these substances.

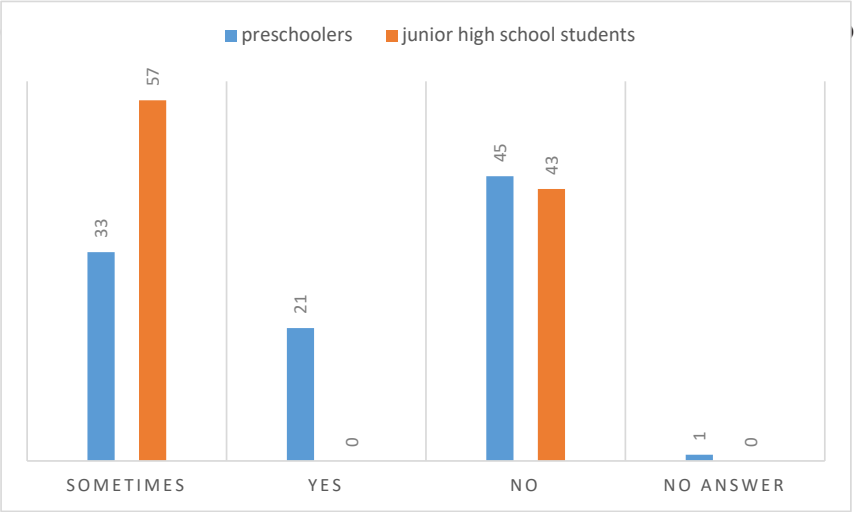


Figure 22. Students' answers to question 7

The presented results show that nearly half of the preschoolers and junior high school students after the conducted classes declare that they are able to give up drinking Cola, and 33% of preschoolers and 57% of junior high school students are willing to partly give it up. 21% of preschoolers believe that they will continue to drink it.

Comparing the students' answers to questions 5 and 6, it can be noticed that, in junior high school students, the effect of the information 'whether Cola contains acid' on their declared behavior (drinking Cola) is hardly seen.

Tab 2.

Answer to question 5	Answer to question 6	Preschoolers	Junior high school students
no	no	0	13
no	sometimes	7	29
no	yes	9	0
yes	no	45	29
yes	sometimes	27	29
yes	yes	12	0

Discussion

More than 40% of the students declared that they would not drink Cola (in research groups with which contact was maintained after class, the effect of complete cessation of drinking Cola was maintained for 3 months). ⅓ of preschoolers and over ½ of junior high school students declared that they would only sometimes drink Cola. No change of attitude was observed in only ⅕ preschoolers. It can therefore be said that persuading students to reduce the consumption of Cola-type drinks partly succeeded. Nonetheless, a healthy lifestyle should be broadly promoted not only among children but also among parents.

Moreover, what was noticed was a very big difference in memorizing the information that Cola contains acid. This information was remembered by almost twice as many preschoolers as junior high school students. In terms of observations, it can be noticed that preschoolers are more spontaneous in comparison with junior high school students, who are more focused.

Conclusions

Lessons conducted with the participation of students are safe because they are based on food products available at home. Their unquestionable advantage is that they can be held anywhere using unsophisticated laboratory equipment, and even on the trip. Although more people are needed for preschoolers to take care of them during the lessons, these classes should be carried out due to better effect compared to junior high school students.

Shaping proper eating habits from an early age may be an opportunity for children to lead a healthier lifestyle in the future. Attention should be paid not only to meals consumed but also beverages which should be as natural as possible. If we are not sure whether the drink is natural, it is best to read the composition indicated on the package label before we buy it in the store. In particular, attention should be paid to the ingredients listed in the first place, which are found in the greatest quantity in the product.

Acknowledgments:

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Effectiveness of Excursion to Water Treatment Plant in Prague Podolí

Introduction

Out of classroom education brings a lot of opportunities to improve students' attitudes towards science (Lindner, 2015; Şentürk & Özdemir, 2014). Different educators' approaches and new learning environment are strong incentives to attract and to arouse curiosity of students in science (Carson et al., 2001; Phaf & Wolters, 1993). Options of out of classroom education are wide open. It includes for example outdoor education as a field trips (excursions) or learning on schoolyards, or visits of educational centres such as museums or science centres. These informal environments have a proved impact on students' positive attitudes towards science (Şentürk & Özdemir, 2014; Watermeyer, 2015). It seems that it has a strong potential to increase positive perception of natural aspects of world around. One of the main reasons for this is the possibility for the students to connect information obtained by learning during the school year with their real life experience (Watermeyer, 2012a, 2012b). The study by Broman and Simon (2015) shows, that field trips and museum visits were one of the students' ideas how to make chemistry lessons more interesting. Thus, the mentioned study point to another positive aspect of out of classroom education – motivation.

Museum exhibitions give huge opportunity to compare and connect (mostly theoretical) information gained by students in their science class with practical perspective of scholarly content (Doğan, 2010). In this research, environment of water treatment plant in Prague, Podolí, concretely Museum of water treatment in Prague, was chosen. Exhibition shows the history of water treatment of Prague from principals of water treatment point of view as well as its industrial aspects (piping, pumps, etc.).

The topic of water is included by 4 separated subjects – geography, biology, physics and chemistry in the Czech curriculum. All of these fields' points of view are taught separately, despite of being inter-or trans-disciplinary. Therefore, school projects on this topic are quite popular (see Řádková, 2005; Šulcová & Kolková, 2003a, 2003b). Also, the museum of water treatment in Prague has a potential to be a place, where all information could be connected and turned into practical use in real life. Moreover, it offers opportunity for interdisciplinary education, which would help students perceive science topics as complex tasks (Dilli, 2016). Depending on it the museum offers educational material for schools.

The choice of methods and guidance has a big influence on effectiveness of education during the museum excursion as showed numbers of research (Bamberger & Tal, 2007; Griffin & Symington, 1997; Piqueras et al., 2008).

For example, Bedir's (2015) research shows, the constructivist approach and programs based on student-centred activities are successful. Based on these models the proposal of excursion was made. The authors of this volume prepared alternative guidance inspired by problem-based education model accompanied by discussions and dialogues. Chosen topics were presented with the use of the approaches described above. The students' ideas and conceptions were gradually put into a more accurate frame. Moreover, the alternative guidance gives opportunity to show contexts of wide spread spectre of subjects. Not only the connection between scientific school subjects but also the context with history which can have impact on the students' perception of science as indispensable part of development of human civilization. This can be also a very important motivational element (Marcus, 2007).

Effectiveness of the excursion could be improved by a well prepared teaching plan by teachers in cooperation with museum guides. Teachers have a possibility to make pre- and post- activities for the museum visits. This was identified as a factor of increasing effectiveness of excursions and museum guides, which have wide spread information about chosen problematic (Tran, 2007).

Alternative excursion plan

The original guidance in the museum was tutored mostly in monologue way. During the one-hour-long excursion about 6 stands were made. Before the entrance into the "water supply part" of the museum the students had an opportunity to see pictures of Czech famous artist – Josef Lada which were painted for the museum on theme Water. Then the students continued to the "water supply part" of the museum. At the first stop the guide talked about the history of water transport from antiquity until present. As the main mechanism of water transport, gravitation was concisely mentioned. At this stop materials of conduits used in history were named. The following theme was about water supply of Prague, where the mechanisms of water towers was explained and the water-industries used in history were shown. The next stop was by the board of the architect of the water treatment plant in Podolí. After that, the mechanisms of water filtration – mostly the mechanical part of it and the history of the invention of the mechanism followed. In the end of the excursion, the guide took the students to educational boards with information about actual water supply of Prague and briefly talked about them. Then she let the students free time to read the information boards. During the excursion, the students were not encouraged to make any activity and were only taken through the exhibition and were supposed to listen to the guide.

Compared to that, an alternative guidance based on different approaches was proposed. It was designed for the same exhibition and the same time duration. Different order of (the same) information and exhibits was chosen as well. The authors' conception of the excursion was designed to build the construction of

information starting with the already known students' knowledge– what they know from their everyday life and what they can see as a product of water treatment process. The first stop in the museum started with a short discussion about how water gets into the taps in their home.

The students were divided into two groups. Each group was given one of the two water sources to describe. With help of a thematic educational board and their smartphones they were looking for information about the chosen water source. The gained information was filled into prepared worksheets containing 4 question about the chosen water source (what it is, where it is, how far it is, which part of Prague it supplies). After that, each group shared the information about particular source to the other groups. Next, a related theme – transport of water from the source was brought upon through a dialogue with the students. This theme includes not only information about transport conduits and pipes, the students were also led to find out the basic mechanism of water transport for long distances. The students were encouraged to share their ideas aloud and were indirectly led to the basic theme of physics – gravitation. This topic was followed by the historical aspects of water transport in Prague, where they had an opportunity to touch the old wooden conduit and other historical transporting systems. Here the museum guide was asked to show the old photography and illustrations of old Prague water towers to make the connection of known buildings of the city where the students live with their technical function. The following part was found by questioning the students if it is already the water that pours from their tap at home. The answer was of course not because the water still contains microscopic contaminants which needed to be filtrated – another big topic of the excursion. Students were taken in front of the graph of disease and mortality by typhus in Prague from the turn of the 19th and 20th century. They were encouraged to describe and explain what they can read from the graph. By the description of the significant decreasing trend in one part of the graph, the time of invention of water filtration in Czechia was found. The story of inventing the mechanism of filtration inspired by geological process water purification was told here. Depend on this information the students were encouraged to explain the context of the geological subsoil with the process of filtration. The mechanism of current mechanical water filtration could be seen through a big window to sand filtration tanks installed in the water plant. The students were led to described the analogy of the mechanism in nature and in the tank in the water plant. The following theme of chemical purification of water was brought about via a discussion about diseases and safety of the water transport through conduit from water plant to our homes. As a conclusion of the excursion, a task which was solved in small groups (3 students in one group) was prepared. The task was made based on the mentioned information about the water transport and history of water treatment the students could reach by the excursion – "Why were the water towers needed to transport water to parts of Prague in the past, and why is it not needed nowadays?". After the time given to each group the students

described and explained their ideas to other groups. The groups responded to each other and discussed the possibilities of the theories to find the solution they all would agree on. After the discussion about the right solution the excursion was ended.

Methodology

Goal of the research

The goal of the study was to verify the above mentioned alternative approach to excursion in the water treatment plant in Prague Podolí. The research was driven by these research questions:

To what extent is the contemporary conception of the exposition in Water treatment plant in Prague Podolí effective?

Would problem-based approach improve the efficiency of the exhibition for elementary school excursions?

The visit of the water treatment plant takes usually an hour. The effectiveness is regarded as increase of the students results to the test compiled by the authors of this contribution. The improvement consists in proposing alternative methods, order of particular exhibits as well as emphasis on particular information within the same museum (water treatment plant) and the same amount of time for an excursion (see the chapter above). Effectiveness of the excursion will be examined with the use of a didactical test.

Based on the research questions it is possible to formulate the following hypothesis:

H: After the excursion, the students in the experimental group score better in the didactical test than the students in the control group.

The hypothesis may be tested only on the premises that both the groups achieve comparable score in the pre-test, i.e. may be considered equal.

Research sample

The research sample was represented by two classes of grade 9 students (ISCED 2) from Elementary school of prof. Otokar Chlup, a school by Pedagocical faculty of Charles University in Prague. For the testing classes 9.A and 9.B were selected. The group 9.A was appointed a control group, 9.B an experimental group. Further details are listed in Tab. 1.

The numbers of respondents differ, as there were some students who did not participate in the pre-test present at the excursion.

Table 1. Number of respondents in the pre-test

Control group				Experimental group			
pre-test		post-test		pre-test		post-test	
M	F	M	F	M	F	M	F
2	12	5	14	9	11	9	13
∑ 14		∑ 19		∑ 20		∑ 22	

Rem. M=male, F=female

Research design, tool and its administration

This study follows a design of pedagogical experiment. In order to test the two groups of students, a didactical test was constructed. The test included 9 questions (7 open-ended, 1 semi-closed-ended and 1 closed-ended multiple choice question). They were based on: the authors visit of the museum excursion – ordinary content of the excursion (i.e. guide's teaching efficacy) as well as expected students' knowledge – further, based on content of chemistry classes and the framework educational programme (i.e. potential/expected excursion outcome).

The students filled the didactical test in the Chemistry lesson before the excursion (pre-test) and immediately after the excursion (post-test). That is why the number of students differ in pre- and post-test for both groups.

Data analysis

The test results were evaluated as 2 – correct, 1 – partly correct and 0 – false. Some statistical require only two values, therefore were the results simplified to 1 – correct, 0 – false. For the data administration MS Excel 2016 was used. Statistical analysis was computed with the STATISTICA 12 software. Statistical values used in this text are in accordance with modern statistical literature e.g. Hendl (2016).

First of all, reliability of the testing was examined with the use of Crombach alpha. The value $\alpha=0,64$ is rather low, however with respect to the number of test items and the number of respondents is satisfactory.

In order to test whether pedagogical experiment is feasible, i.e. the crucial presumption of the two groups being equal is met, the students' results in the pre-test were analysed. It is possible to rely on the presumption that in case of samples of low count ($n<30$) it is not important to employ tests for data normality and the t-test may be used. Nevertheless, in order to test normality of the data, Shapiro-Wilk test of normality was used (Shapiro & Wilk, 1965).

The hypothesis about the difference of the student' results in the didactical tests corresponds with the zero hypothesis which says that the two values are independent. It was tested with the use of the Pearson's χ^2– test for 2x2 contingent tables. This zero hypothesis was observed separately for each of the didactical test items.

The Pearson's test requires the array of cells to contain corresponding expected counts higher than 5 in more than 80%[1] cells and no zero in any of the cells. This condition has been broken by the 3rd, 8th and 9th question. Therefore, the Pearson's χ^2– test was exchanged for the Fisher's exact test in case of the 3rd and 9th question. The 8th question did not fit the test requirements. Its values are therefore only orientation.

The practical significance was calculated with the use of the Cramer's φ for 2x2 tables and using the $\eta 2$[3] for continental tables.

Evaluation of the pre-test-post-test deals with related variables, therefore Pearson's test (for independent variables) cannot be used. In case of 2x2 tables (questions 3, 7 for the experimental and 6, 9 for the control group) McNemmar's test was used (McNemar, 1947). In case of continental tables MxM, Bowker's test (Bowker, 1948) was used, for the rest of the questions the Cochran's test (Cochran, 1950).

Results and discussion

The results are presented as the analysis of the overall test results, i.e. pre-test – comparison of the two groups' results and post-test – comparison of the two groups' results. The comparison of the tests filled in by the students in a particular group – pre-test-post-test – is further completed with question results analysis. This offers more in-depth interpretation of the results leading to alterations in the alternative excursion scheme as well as in the didactical test.

Pre-test

The test is conducted against the zero hypothesis that the analysed data have normal distribution. The p-values are listed in the Tab 2.

Tabele 2. P-values for pre- and post-test

	pre-test	post-test
Experimental group	**p=0,02**	p=0,39
Control group	p=0,13	p=0,41

1 This examination has been done for every measurement separately.

2 0,1-0,29 (small effect); 0,30-0,49 (middle-size effect); 0,50 and more (large effect)

3 0,01-0,059 (small effect); 0,06-0,139 (middle-size effect); 0,14 and more (large effect)

On the 1% significance level, it is not possible to reject the zero hypothesis about the data normality. The data have normal distribution. In case of parametrical tests is the zero hypothesis formulated for consistent means, in case of non-parametrical tests for consistent medians .

T-test as well as Mann-Whitney tests were used to compare the two student groups' test results. The p-values are listed in Tab. 3. The data are also completed with the value of the Hays' coefficient of determination. The zero hypothesis saying that there is no difference between the means/medians of the didactical test values of the control and experimental group.

Tabele 3. Comparison of the students' results in pre-test

	p-level t-test	p-level (Mann-Whitney test)	Hays' coefficient
Experimental vs control group	p=0,21	p=0,36	p=1,70 %

Based on the values in the table, it is obvious, the zero hypothesis cannot be rejected. Therefore, it is possible to consider the groups equal. This is also confirmed by the value of the Hays' coefficient of determination (Hays, 1963) ω^2=1,70% .

The zero hypothesis about the independence of the two variables was also tested separately for each of the test questions. The p-level values as well as the values of the practical significance are displayed in the Tab. 4. The values were calculated at 5% significance level (on 1% significance level no difference would be found).

Tabele 4. Test values for particular questions of the didactical test (inter-groups)

Question	1	2	3	4	5	6	7	8	9
p-level	p=0,924	**p=0,047**	p=0,193	p=0,237	p=0,437	p=0,666	p=0,052	p=0,612	p=0,22
Effect size	0,10%	4,11%	19,73%	1,95%	1,12%	7,17%	2,55%	0,03%	20,60%
χ^2– test	0,15	**6,09**	1,44	2,88	1,66	0,19	3,78	0,04	1,57

Only in case of the second question a significant difference between the answers of the students in each group was found. The effect size value marks a small effect. The question focuses on daily consumption of water by a person living Prague. The students in the experiment group seem either to be a little more informed or have a better estimation.

Post-test

Despite it has been already suggested in the previous section, the comparison of the test results between the two groups has been done with the use of t-test for independent samples and Mann-Whitney test. The values were again completed

with the calculation of practical significance with the use of the Hays' coefficient. As it is displayed in the Tab. 5, there are both statistically as well as practically significant difference between the post-test of the two groups.

Tabele 5. Comparison of the students' results in post-test

	p-level t-test	p-level (Mann-Whitney test)	Hays' coefficient
Experimental vs control group	*p*=0,000	*p*=0,00	*p*=50,46 %

The value of the Hays' coefficient suggests that the final result of the students in each of the groups is influenced by their belonging to the group by 51%. It may be considered a good example of effectiveness of the alternative excursion approach.

Pre-test-post-test

In order to examine the hypothesis, the very same didactical tests were given to the students after they participated in the excursion with either the museum guide (control group) or with a member of the research team (alternative excursion conception, experimental group).

As two related samples are being compared, t-test is used as a parametric and Wilcoxon test as a non-parametric method. The statistical significance value is again completed with the values of Hays' coefficient of determination. The results for the both groups are listed in Tab. 6.

Tabele 6.

	p-level (t-test)	p-level (Wilcoxon)	Hays' coefficient
Control group	*p*=0,021	*p*=0,031	12,43 %
Experimental group	*p*=0,000	*p*=0,000	64,56 %

As it is obvious from the Tab. 4, the excursion in both conceptions had a positive effect on the students' knowledge of the topic. The zero hypothesis about the same results in pre-and post-test for both the groups may be rejected based on the p-level at 5% significance level for both the groups, whereas on 1% significance level only for the experimental group. The values of Hays' coefficient suggest the testing is affected by 12% in the control group, whereas by 65% in the experimental group. The quartile graphs (Fig. 1) display the differences.

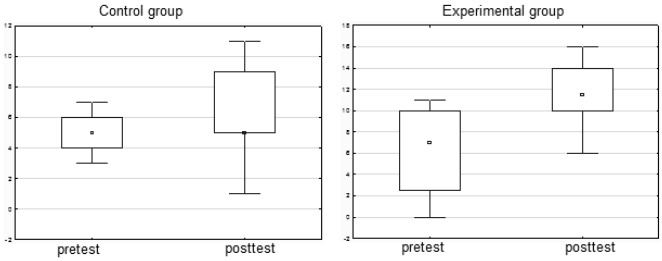

Figure 1. Boxplots of pre-test-post-test differences for the control and the experimental groups

The values of the control group shifted for the respondents between the bottom and top quartile. The values of the experimental group, however, shifted on the vertical for the entire group. On the 1% significance level, it is possible to conclude the students in experimental group improved significantly in the post-test whereas the students in the control group did not. The values of the Hay's coefficient suggest a minor (12%) improvement of the control group students' results after the excursion. This may be affected by the difference of the guide's conception to the information required in the didactical test. Nevertheless, the information required in the test included general knowledge of the topic. Possible change of the original guidance style may also be in adding more information the general public should know about the topic.

Examining particular answers for the test questions with the use of above mentioned McNemar's, Bowker's and Cochran's tests brings several complications as the answers were coded 2, 1 and 0. With retaining the quality of information (a shift from a false answer to partially correct answer is still considered a success) the STATISTICA software could not count some of the values for in same cases the formulas used dividing by zero. For this reason, the values were computed manually and are, with respect to the number of items, only orientation. Therefore, the Tab. 7 contains only verbal information about the statistically significant differences found in particular questions.

As it is obvious from the table, only the students in the experimental group improved their answers after taking part in the excursions. The questions they improved in were concerning: 2. the average consumption of water by a person in Prague in litres, 3. units the consumption of water is measured in, 6. principle of water flocculation, 7. suitability of mechanically purified water for drinking, 8. principle of chemical water purification.

In order to get more accurate (numerical) answers only two possible answers were taken into account – correct and false . In this case the data create 2x2 tables, therefore McNemar's test was used. The results of the rest are listed in the Tab. 8.

As obvious from the table, there are more cases where the p-values enable to refuse the zero hypothesis about the consistent test result. Effect sizes were impossible to be calculated for these results. Therefore, the quality of improvement (worsening) will be assessed based on the arithmetic mean. The results are also displayed in the Fig. 2 and 3.

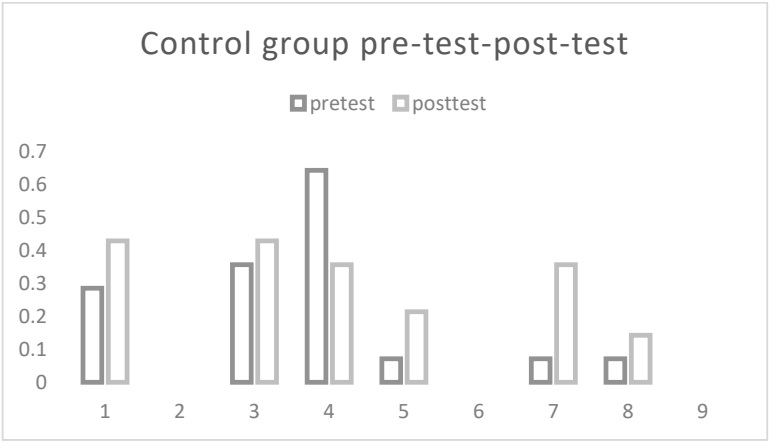

Figure 2. The pre-test-post-test results of the control group (arithmetic means)

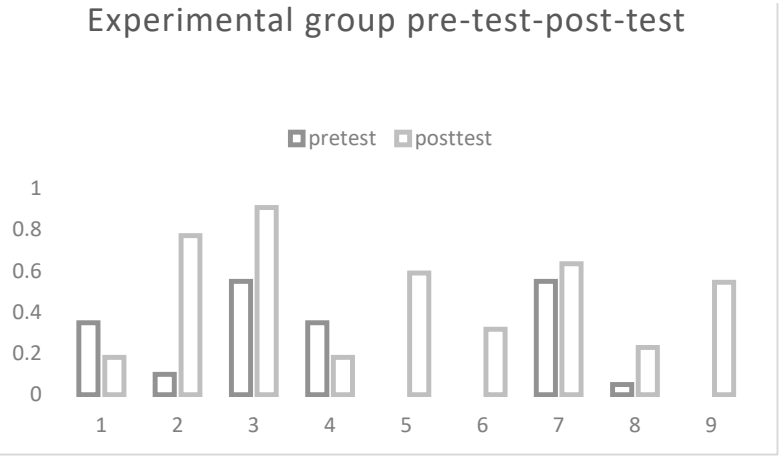

Figure 3. The pre-test-post-test results of the experimental group (arithmetic means)

For the first question (the schema of water purification and denomination of particular stages), statistically significant difference was found only for the experimental group. Although in the original scoring (2, 1, 0) there was an 0,05 increase, in the simplified scoring the average answer worsened by 0,2. It seems that the alternative conception of the excursion confused the students and needs to be improved.

Once partly correct answer is omitted for the second question, it is necessary to conclude the excursion in any conception does not convey the message. The authors of the study consider this information vital for the reason of environment-protection. Therefore, the excursion scheme will be altered in order this information to be more to the fore.

The units the consumption of water, asked in the third question, is measured in, is a mere information. Its importance is, however, associated with financial literacy. The students encounter this topic within home economics. Again only the students in the experimental group improved (by 0,36). It is therefore possible to conclude that the alternative excursion approach is more effective in this respect.

The fourth question was focused on the particles which cause impotability of water. Surprisingly, a decline has been recorded for both the groups. A statistically significant difference was found in the experimental group. The absolute decline as well as the decline in the simplified scoring was by 0,2. It is possible the information the students received about water quality indicators, water particles or sampling confused the students. This aspect of the excursion must therefore be improved.

In the question five, the students were supposed to name at least four materials people have been using to make water piping. As it was an opened question, the scoring which makes provision for the partly correct question is reasonable. In this case, the students in the control group improved by 0,14, the students in the experimental group by 0,95. In the simplified scoring, both the groups of students improved significantly. The control group students by 0,14, the experimental group students by 0,59. It is obvious, the exhibition (the museum offers several real exhibits of old water pipes) gives the students only general information. Further work with the materials is needed. Mere note of the pipe and material seems not to help. On the contrary, the students in the experimental group tried to move a wooden pipe, played with an auger or inspected the amount of mineral deposit on an iron pipe.

The sixth question focused on water flocculation principle (and the chemistry behind it) represents a topic which, despite of the museum guide mentions the cisterns, none of the students in the control group answered correctly. On the contrary, students in the experimental group improved by 0,32. Further change needs to be done in this respect, however, the general idea of the alternative excursion plan seems to be effective.

The fact if the mechanically purified water is drinkable – the topic of the seventh question – was remembered by roughly a half of the students in each of the groups. In this question, only the students in the control group improved significantly (by 0,29). In order to interpret this result, further analysis of the original guidance would be needed. However, the students in the experimental group reached better results that their peers in the control group in overall score.

The eight question was focused on the principle of chemical water purification. Statistically significant change has been found in the results of the both groups (0,07 for the control and 0,18 for the experimental group). The results, however, are quite poor. Majority of the students cannot explain the principle even after the excursion. On one hand it is a topic for in-school chemistry and the students should have known it from their in-school Chemistry lessons, on the other hand, the exhibition offers several exhibits which may help explain the process in the museum too. Improvement with the use of multimedia may be used for example via a QR code linked with a video which shows a water purifying exhibit in action.

The last (ninth) question was included in order to test how effective is the last section of the original exhibition. The museum guide shows a map of Prague with the two water supplies and a set of information panels on this topic. No one of the students was aware of the water supplies for Prague before going to the excursion. Only the students in the experimental group (50%) answered correctly. When partly correct answers are taken into account, only one student from the control group answered partly correctly after the excursion, whereas 50% of the experimental group answered correctly and 50% partly correctly. This was due to the initial activity where the students were supposed to name the source of water they use at home. Then they worked with a map. This approach proved effective.

Conclusion

Water represents a wide, interdisciplinary topic which bonds not only scientific school subjects. It also offers out-of-classroom approach, namely excursions, as there are many museums, water treatment plants, water power stations, sewage plants etc. which offer programs for visitors. The water treatment plant in Prague Podolí is one of such places. The guidance in this water treatment plant is attractive, although it does not fully use the potential of the exhibition. From this reason the authors of this volume decided to plan their own program of the exhibition.

It has been tested on the two student groups (grade 9 students from one elementary school in Prague). Results of the pre-test enable to use the pedagogical experiment use of pedagogical experiment as both the groups scored the same in a didactical (pre)test. The results of the post-test suggest the students in the experimental group who undergone the excursion designed by the authors of this volume reached significantly better results than their schoolmates. The first research question: To what extent is the contemporary conception of the exposition in Water treatment plant in Prague Podolí effective? is resolved based on several statistical tests results. Also the second research question Would problem-based approach improve the efficiency of the exhibition for elementary school excursions? was answered, however there are some aspects (as measured by the

didactical test) which need to be changed. The original guidance as provided by the museum of water is effective only in a few aspects, majority of the changes in the students' knowledge on the topic were statistically (and also practically) insignificant. An alternative approach built on the problem-based pedagogy, however, proved effective in overall test score as well as in the majority of the question. Nevertheless, several necessary changes have been identified by the testing.

Naturally, the results would be different if another diagnostic tool – didactical test of different construction, interviews or word problems were used. In further work the authors plan to conduct a retention test in order to measure effectiveness of the approach proposed by them. Also the diagnostic tool will be changed in order to be more neutral. The testing will be repeated in the similar manner with only some changes which were proved necessary by this study.

The management of the water treatment plant seeks cooperation and is very open to new ideas. This pilot study might therefore be a beginning of a fruitful cooperation with this facility often visited by schools.

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Multimedia in science education

Introduction

Nowadays, there is no effective education without new technologies. The introduction of new media on a wide scale to the education is a must, which is also enforced by the technological development and globalization. You cannot longer effectively teach young people accustomed to the digital world (that is, by Mark Prensky - „digital natives") by means of conventional methods of teaching. Young people who are brought up using audiovisual media, who are accustomed to writing e-mails and SMS, show no interest in a traditional book, solving difficult tasks, collecting statistical data. Students choose unlimited surfing on the Internet, which they believe is „a treasure trove of knowledge". They spend their time surfing the net, watching YouTube video, Tweeting or posting on social media and instant messaging. Instead of devoting their time on studying sciences, they spend many hours on surfing the net without even being aware of the time flow.

A characteristic feature of modern educational systems is the search for more and more attractive and more efficient methods and forms of work with the student. This feature applies to all stages and levels of education. The use of computers in teaching can reduce the students' formation process of thinking. Too easy an access to knowledge prevents them from thinking independently, and hence they does not develop enough deductive thinking. Therefore it is important that we use in the teaching process various available teaching aids, which especially are complementary and comprehensively develop learners skills. An attractive aspect of teaching - learning science is presented in an interactive way. Forget about the fact that the teaching should be close to what the student knows from daily life and from the media. Science is the knowledge of the world and should not be limited only to describing experiments at the school laboratory, it must definitely go beyond the school building.

According to the theory of multimedia learning by Richard Mayer the information received by us is processed separately in two channels: the visual one and the audible one. The first is responsible for what we see (pictures, graphics, videos, graphs) and the other for what we hear (sound, comments). A person can receive and process signals that come to him from two independent sources at the same time (Mayer, 2009). Appropriate action in multimedia education is the awakening of activity and cognitive processes through a prepared or selected educational materials, including Internet sources (Skibińska, Kwiatkowska & Majewska, 2014). Work in a network of active search, and not just passive viewing pages, supports the mental processes. This is due to the development of students' skills in critical and analytical thinking (Tapscott, 2010). Multimedia

presentations, videos and quizzes are the resources stimulating students' activity and interactions in the emotional and motivation sphere. High efficiency of teaching can be achieved by mastering a few basic skills, which include: searching, collecting, selecting, comparing and analyzing the information. Well developed multimedia materials not only enliven and add variety to the learning process, but also make it easier to understand and remember the content posted. Particular attention should be paid to the aesthetics of the site or a program and applied the colors. Several studies indicate that too many colors makes it difficult to read the message, and also understand the message (Lindsay, 1991). Tasks requiring the use of reflection and the ability to formulate meaningful questions and answers provides a lot of good results in the science education. Educational materials should be adapted to an appropriate level of teaching and the preferred learning style and the overall learning process. Educational portals provoke to people of all ages to cognitive activity and self-learning.

Methods

Research questions

Dr. A. Kamińska has prepared a questionnaire and conducted a study in 2010 on a group of about 150 secondary school students. The results obtained show that they have worked with the computer on average four hours per day (outside the school), including they surfing the net approximately 3.5 hours. The surveys were carried out again in 2016 on a group of students from the same schools. It has been observed that the students spend less time in front of the computer, on average 1.7 hours per day. However, they spend more time surfing the Internet much more time - about 7 hours daily. It turned out that students do not use so often computers, but they prefer variety of different smartphones and tablets. They only devote 45 minutes a day using the media for learning. Being asked the question: „what purpose do you use the computer for?", we received the following answers from the students: for entertainment and games (76 %), for social media (60 %), for learning (32 %), for listening to (or download) music (15 %) (Fig. 1).

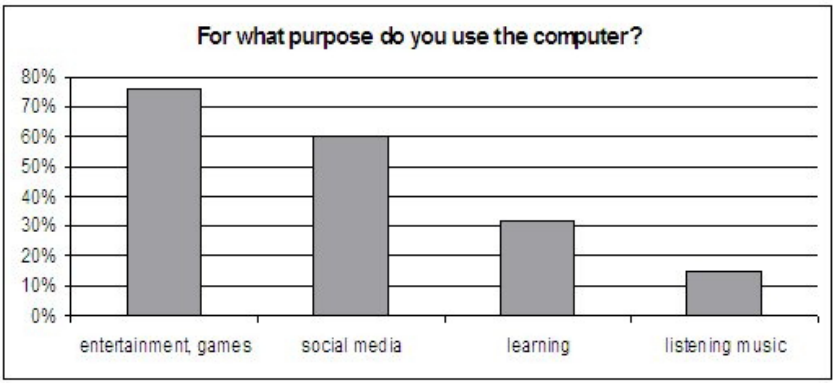

Figure 1. The results of a questionnaire conducted in the school year 2015/16 among secondary school students

Among the answers to the question of what multimedia programs you use - 80% of the interviewees do not know any educational programs, the others responded in the following way: Wikipedia (10%) and there were some single responses which included: Wirtualna Polska, Google, bryk.pl, ściaga.pl.

The question of how computer programs can help in learning, the students responded that you can find ready solution of the tasks, essays, etc. (as much as 90% of the respondents). Therefore, to provide a positive educational outcome of the use of mass media, care should be taken to properly guide its application. Teachers and educators should, on one hand, conduct properly thought-out and planned media education and, on the other hand, point to the dangers associated with it. We should not be afraid of new technologies. Instead we should use them as a modern resource to achieve our goals. The use of new technologies along with the increasing level of education will change the attitude to science. Its reception will be more active, thoughtful and focused on choosing the right content. The same survey of high school students shows that they are aware of the benefits offered by the new technologies. The question of how computer educational programs help them in their learning process, the high school students surveyed replied that they help them consolidate the part of the material previously discussed in the class (animations, tests, written reports), develop independent thinking, memorize quicker, deduct some processes, stimulate the aesthetics note keeping, teach precision and accuracy in the transfer of information, prepare charts and drawings, find certain information quicker, shape simple and communicative scientific language, adjust working time student to their own capabilities and enable them to acquire knowledge and facilitate the development of an individual learning without any stress. Despite the threats modern technologies give us unlimited possibilities of making science education more attractive. Speaking about the usefulness of new technologies in the educational process one should

be aware that they should meet certain requirements: be innovative, interactive, intuitive and have the ability to fit the individual needs of the user (Okoniewska & Meger, 2002).

Multimedia education is a broader concept which involves the use of the teaching process, a variety of teaching methods and different, specially selected materials, such as films, recordings, computer programs, as well as the traditional scientific aids. Sound effects, which hugely enrich the way of teaching, are often applied in media literacy. They should be designed and introduced into the process of teaching and learning in the form of a multimedia package, providing the learning information through different channels of communication. This way of transmitting information to start multiple types of students' activity, for example: perceptual, manual, intellectual and emotional (Strykowski, 1984).

E – books

Teachers, parents and students alone recognize the e-books possibilities that they offer the positive impact on the development and progress of students in science education. The results of a on-line survey, which was carried out by the Polish Ministry of National Education (MEN) in October and November 2012, confirms the need to introduce information and communication technologies in schools. In the survey 10 229 people responded, including 5716 teachers, 1373 parents and 3140 students and other participants. Most teachers believe that e-books will help to develop the skills of creative use of available sources of knowledge, will affect the development of creativity and will help to develop students' skills. In their opinion, the biggest advantage of e-books will be interactive exercises because it will help consolidate the material and videos and educational games (about 90%). Teachers appreciate the possibility to carry out interactive simulation experiments, using the self-checking test or filling digital workbook. They hope also to track students' progress and the ability to modify any learning content. According to parents, these elements they will would encourage their children to learn. On the basis of research results obtained by MEN up to 73% of students acknowledge that they spend more than 10 hours per week in front of the computer. Among the people surveyed 95% search for a variety of information, but the same number of people use it to maintain social contacts, or for the entertainment. Only 23 percent of respondents think that e-books will contribute to the creative use of available sources of knowledge and creative thinking. They also recognize the possibility of equalizing educational opportunities for children, to increase their participation in culture elements, development of skills in different subjects, skills development cooperation (MEN, 2013).

Research conducted by the Organization Project Tomorrow in 2009 among American students, shows that young people expects that school, above all will have greater access to mobile tools. The researchers gathered the students' ideas on how to create the perfect digital textbook. For many of them, the prospect of

using the paper guide is repulsive and archaic. Young people would like to have the ability to match the form of a manual to their individual needs, for example through the application of underscores, or adding notes. They would like to have the assistance of a specialist in the field that could answer their questions online, also after the end of the school. Both students and parents highly appreciate a career in areas such as science and life sciences. More than half of parents just to learn these areas encourages its children the most (Andrzejczak, 2009).

As the first on the Polish market appeared manuals EduROM Publishing Young Digital Poland (Ed. 2001). These included the whole package present multimedia textbooks for secondary school (Polish language, mathematics, physics, geography, biology, history, chemistry). Today, almost every textbook publisher includes a CD into the book set. Multimedia textbooks can be used by the teacher during the lesson to illustrate the experience simulation, explaining the essence of the phenomenon. It is on important functions of this type of a textbooks to enable its use at home. The student has the opportunity to carefully analyze the course of an experiment conducted in the classroom during a lesson once again, with a detailed description of the phenomenon and deepen their knowledge about the content that was not discussed on the lessons.

Multimedia textbooks to teach biology, chemistry and physics include lectures, photos, 3D animations, videos, and interactive exercises. Educational content is illustrated with numerous videos and 3D presentations that facilitate the understanding of particular issues. Videos and multimedia presentations allow you to remind students that physical phenomena occur not only in the classroom or laboratory, but in the whole world around us. Thanks to the movies and animations you can present a physical experience which is impossible to do in the classroom, for example: because of security precautions, because it requires too expensive equipment or inaccessible devices. In order to consolidate the new material, it is included in CD exercises checking that students can solve them systematic. These tests check the level of understanding of the material and allow you to prepare for tests and exams.

Due to the increasing sales of tablets along with the teachers', parents' and students' growing interest and expectations towards new teaching methods, new educational programs for mobile devices have been introduced. (Fig. 2). Mobile chemistry is a textbook created by the staff of the Adam Mickiewicz University in Poznań which is primarily dedicated to teach chemistry. It is compatible with the operating systems of Android, iOS and Windows. This is not the electronic version of printed materials, enriched only a few illustrations of enlarging the film (as a number of programs to support teaching available on the Web), but creates new opportunities for student interaction in the process of teaching - learning. It deserve special attention because it includes (Bartoszewicz & Gulińska, 2015):

- videos with tasks, animation, radio broadcast,
- rich selection of well illustrated experiments,

- proposals of different experiences that can be taken at home,
- educational games, virtual laboratory, project proposals,
- interactive task for the student.

Figure 2. Mobil chemistry to support entertainment-education in science education available on mobile devices

Interactive tasks allow you to quickly verify the acquired knowledge. However, instead of filling in the gaps, or combining the elements of drawing with pencil lines, simply drag items using your hand or stylus. This is fun learning chemistry, if you make a mistake, you can easily improve your figure.

Laboratory of Multimedia in Education and Culture

In order to achieve the effective teaching of science with the use of multimedia resources we organized in 2015 new laboratory of Multimedia in Education and Culture in the Institute of Physics at Nicolaus Copernicus University in Toruń. During the classes we observed a huge interest of students in this form of acquiring knowledge (Fig. 3). First of all, students can compare not only different contents, but also various attitudes towards presenting it – in a manner more or less effective, respecting the cognitive teaching methods. The ability to assess the suitability of available multimedia resources and their use in science education is an important competence of future teachers. The main advantage of the multimedia encyclopedia installed on computers in our new laboratory is that they are closed resource (CD-Roms on Science, Education and Culture), thus enabling students to concentrate on learning focused on a specific subject and activity which allows to go back to try and check again. Nowadays, most children and students use the Internet every day and have to deal with hyperinflation occurring here information (Karwasz, 2012). There is the problem of how to find the best information among the thousands of pages found by the search engine.

Figure 3. Students in the classroom learning in a friendly atmosphere conducive to acquiring new knowledge and skills

The important role of multimedia in science education was proposed already in the 90s of the twentieth century. Regular multimedia textbooks at high school level were already present on the Italian market and a publishing house of Dorling Kindersley published a thematic encyclopedias to teach Science subjects such as: Earth, Birds, Human Body, Animal Encyclopedia and others. At the time, educational software used in the classroom with students and pupils mainly came from abroad. In the late 90's of the twentieth century, the first multimedia encyclopedia has been published by Polish publishers and became available on the market. The first interactive exhibition of multimedia educational software was organized by us at Pomeranian Academy in Słupsk as early as in 1997. Later, with the advent of the Internet, the development of new multimedia declined.

In the present paper we discuss the variety of available multimedia resources in science education, respecting the division proposed some time ago (Karwasz, 2010): the collection of loose files, educational pathways, encyclopedia, multimedia textbooks. Among the multimedia, there are resources of communication with users: photos, pictures, diagrams, movies, animation, 3D animation, narratives, music, sounds.

In the process of teaching science the multimedia textbooks are very useful, where we meet the two essential requirements (Okoniewska & Meger, 2002):

• multimedia and interactivity - the appropriate use diagrams, animations, movies. A correct animation is the one that can be run step by step, to see its details. The film should be different from a traditional television programme even in the way that one can stop it at any point and view frame by frame in order to explain the phenomenon presented.

• multi-level structure - is a fundamental difference between the traditional textboo and computer presentation program. In case of a computer program, the teaching/learning content is properly ordered and planned either by the teacher or the student. Multimedia textbooks do organize knowledge on several levels, according to its importance and learner's predispositions.

The value in using of the program determines the external form of software, its functionality, and concluded its substantive content. Computer learning programs cannot be a simple reflection the content of a printed textbook. These programs should make full use of the technical capabilities of a computer. Educational programs need to have an attractive form, which enables colorful animations and sound. It is very important that these programs are characterized by a substantial correctness and teaching content must be consistent with the current state of science (Morbitzer, 1997). The content must also be adapted to the curriculum for the type and level of education in such a way that the program can be used in a teaching process at the right time. A very important feature of a good educational program is simplicity, which is a well-designed user interface, which allows the student to well concentrate on the substantive content provided by the program and facilitate the support for the program. The corresponding interface is usually the determining factor in the assessment of the whole program. A major role here is the language of communication with the computer, and the interface (the arrangement of the information on the screen), the system of evaluation and reward, the response and reaction of the computer on incorrect data. Computer programs should be tailored to the individual user's work rate. A special form of individualization of content is the ability to repeat selected parts of the program so that the learner can always go back to them many times. Such a feature of the educational program provides the structure and use of appropriate control mechanisms.

To the active and creative teaching physics developed educational pathways „Physics and Toys", where playing objects becomes a pretext to get interested in Science (Karwasz, 2005). The multimedia resource created at Pomeranian Academy in Słupsk in 2003-2005 had on the website of Didactics of Physics Division at Nicolaus Copernicus University in Toruń more than 200 000 views in six years, and exercised a strong influence on development of interactive Physics in Poland (Fig. 4).

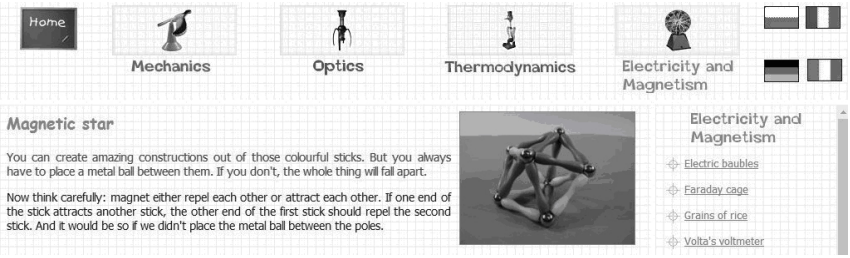

Figure 4. "Physics and Toys" educational pathways. On the screen you can find photos, videos, a brief description of the experiment and the 1.5 bit of new information for the user

In the four branches of Physics here are descriptions and videos of about 100 interesting experiments and they are available in five languages (English, French, German, Italian, Polish). The descriptions are short (5-6 sentences) to encourage the student to read carefully and take an interest in the presented experiment. The end of the description is humorous and funny in order to get a positive reception. At the end of the text here is a link more and when interested people click it and they can get a detailed description of the experiment and of the phenomenon (Fig. 5). In this part of the detailed description of the experiment there are diagrams, formulas, new scientific concepts to detailed explanation of this phenomenon. The Internet has become the main source of knowledge for the younger generation. Information technology is changing the world and our students. Teachers should improve their skills and teaching methods and offer students a wise use of Internet resources. The way of describing the experience should be very friendly for students. A short description of the causes that students can easily remember is on important piece of information and new concepts. This way of describing the experience is very effective and makes the teaching of physics and science more exciting and attractive for students.

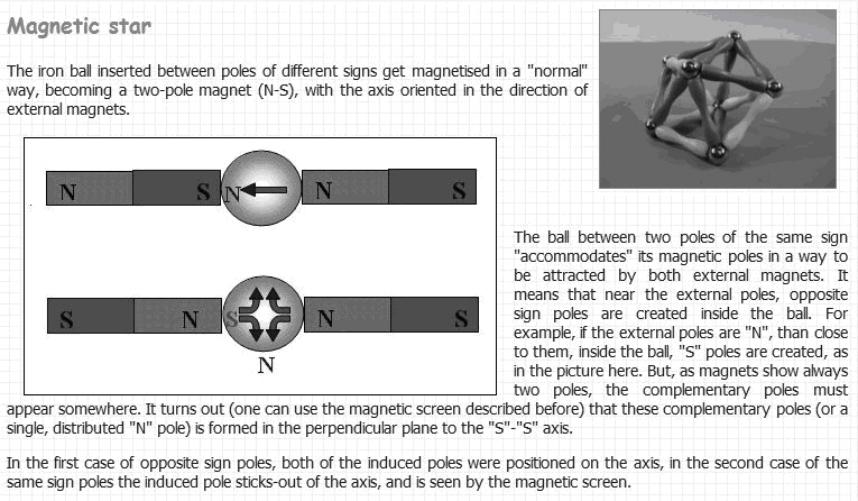

Figure 5. The detailed description with explanation of the experiment entitled "magnetic star"

„The Ultimate Human Body" published by Optimus Pascal and Dorling Kindersley Multimedia is an example of a well-prepared and developed multimedia encyclopedia in science education (Fig. 6).

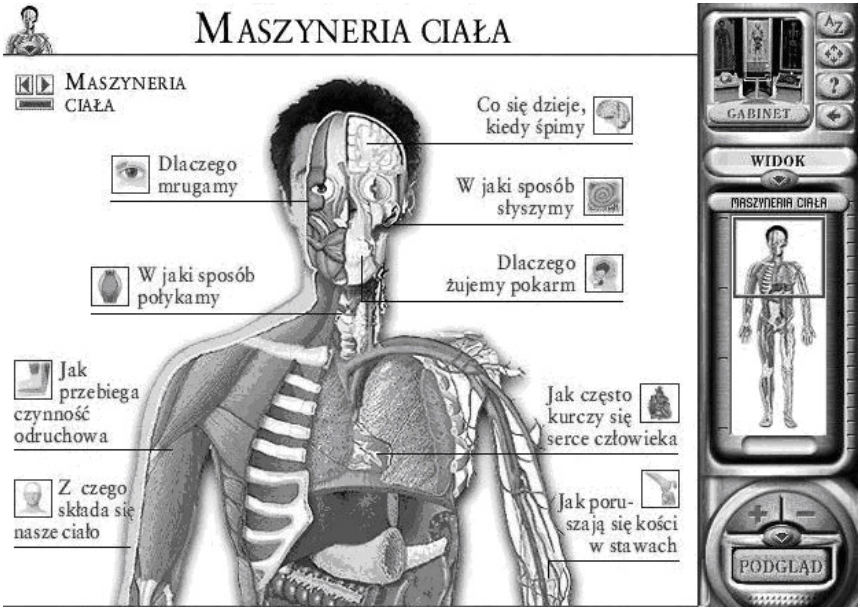

Figure 6. An example of the screen the multimedia encyclopedia with an intuitive menu and extremely interesting content on the internal structure of the human body

This is a wonderful journey into the interior of the human body illustrated with many photographs, colorful drawings, videos and texts that can be read aloud. The contents of the material is extremely interesting, focusing our attention and stimulating to discuss the issues and encouraging the learning of science in a fun way. The encyclopedia can be used during lessons at school at various levels of teaching and student can also use it at home, if they would like to know more about the structure of the human body. The CD contains extremely useful information on the functioning of our body and its various organs and systems such as circulatory system, nervous system and bones. The concept of pedagogical, social phenomenon, interpersonal relationships, experience personal take on new meaning and for the author, and the recipient if you give them the form of photos, drawings, metamorphosis, video or audio. Student is a unique experience to enrich not only their own workshop, but above all personality (Siemieniecki, 2001).

In the science education for the young the multimedia encyclopedia entitled „Cell Biology" published by Polish Editors Prószyński and Company seems to be very valuable (Fig. 7).

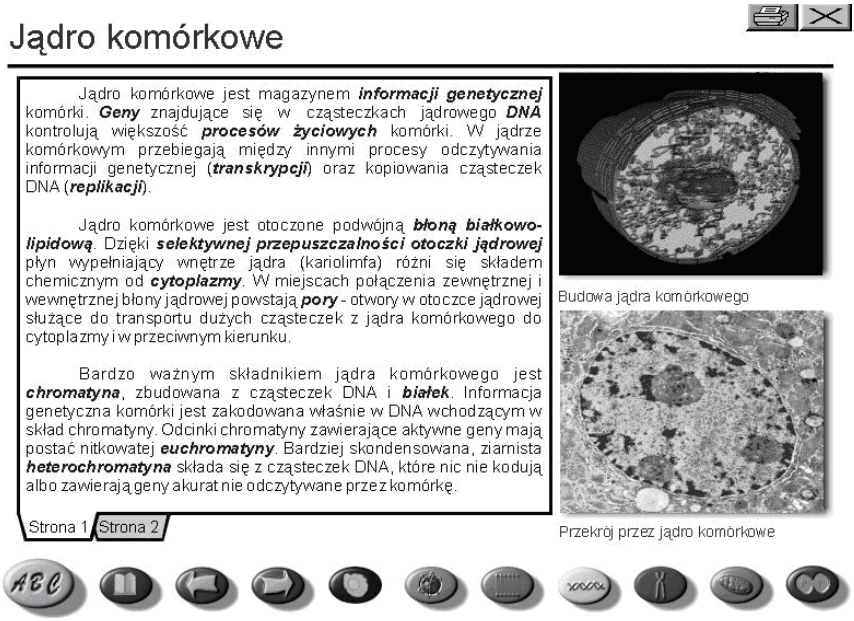

Figure 7. Description of the nucleus with photos and a cross-section of the cell nucleus

The encyclopedia contains a lot of interesting pictures (also in high magnification), videos, descriptions with links that provide easy access to the next message. On the CD, you can see the ordered structure of knowledge and concepts. This makes it easier to learn and acquire new skills in the field of science education. Another very interesting encyclopedia among the collections of the new laboratory is the encyclopedia Earth published by Polish Scientific Editors (Fig. 8).

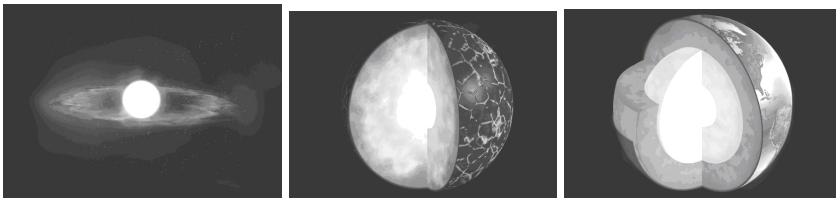

Figure 8. Sample photos from Earth encyclopedia: a) a picture of the formation of the Sun and our solar system, b) photo illustrating the formation of the Earth in the start-up period, when it was formed the nucleus, c) the Earth with oceans and continents on the surface

The encyclopedia entitled „Earth" is a rich source of knowledge about our

planet. The multimedia layer is enriched with a number of popular science films and fascinating animation. They are very attractive for the user, in comparison with the traditional printed book, as they provide a detailed construction, of the growth and functioning of the Earth. While watching movies and animations the teacher explains phenomena presented among other things, the formation and the formation of the Earth. Themes are developed in a clear, comprehensive and interdisciplinary, and the contents of the CD is a proven factually by many authors. The bibliographic sources put forth knowledge are up to date and come from the Polish Scientific Editor.

In order to teach science effectively, interdisciplinarily and in modern way we created a website „Fizyka dla każdego" (Physics for Everyone) (http://dydaktyka.fizyka.umk.pl) in the Didactics of Physics Division at Nicolaus Copernicus University in Toruń. You can find on-line multimedia on our website, such as: video recordings of lectures and lessons, short movies with experiments, animations and simulations of different phenomena, interesting photos and diagrams, descriptions of experiments, press reviews, tweets, educational funny materials for pupils, students and teachers (Fig. 9).

Figure 9. Various ways of directing the user's attention to important content on the "Physics for Everyone"

Every day we observe from 500 to 1000 different users surfing our website. Most often users use the pages on which there are videos and descriptions of

funny cheap and simple experiments. Videos implements the various learning objectives, as part of a triad of „cognitive" of G. Karwasz (Karwasz & Kruk, 2012): i) interest and fun, 2) understanding and explanation, 3) exploration and independent reasoning. A good example of such a material is film "Ball, jump up!" (Fig. 9). This is a movie about a falling ball, but played backwards. Multimedia and Internet have a very large impact on learning and a better use of time in the classroom. It is changing the role of the student in the classroom. In the constructivist classroom, students often work together, they have more opportunities to make choices and play a more active role in their own learning process (Pitler, Hubbell & Kuhn, 2015)

Conclusions

Multimedia play a very important role in science education. Students do not imagine a lesson without them, and more and more often they ask teachers about the use of multimedia in the classroom. This attractive and a little entertainment-education corresponds to the students, because they are more active, interested and process the messages and skills in a better way. Additionally, multimedia in science education allow us: to make our learning process more attractive, consolidate the knowledge, focus students on a knowledge transfer, illustrate the phenomenon hard to imagine and impossible to carry out, increase the effectiveness of teaching science, stimulate cognitive activity and creativity.

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Interactivity – how to prepare study module

Formal and informal education

According to Krieck (1922), people learn unconsciously through work, art, language and culture. All communication between human beings is educational. When we use term "education", usually it means that a teacher and learner are needed. Formal education is normally provided by trained teachers in a systematic intentional way within school. Informal education is the part of one´s development that comes about outside of formal education. It is realized in family, peer group, by mass media and by the institutions of informal education (library, museum, science center, and so on) – by subjects whose main role is not education. A new form of pedagogical thinking during the late 1920s and 1930s developed the idea of science museums: interactive models, demonstrations, and objects to be touched – "hands-on" principle, as a contradiction to the traditional "hands off" signs in museums (Salmi, 1993).

In the case of natural science, the institutions of informal education include, in particular science learning centers and discovery centers. In the Czech Republic, as well as in other countries of Europe Union, they have been established thanks to Europe Union funds. The reason for this financial support was the government´s desire to promote science, especially among the younger generation. The goal of science and discovery centers is to present science to children, students and everybody in a fun and entertaining way. They want to stimulate interest in these fields by offering opportunities to explore the laws of physics in the world around us. Interactivity is the key to this. One such institution is the Science and Technology Center in Ostrava's Lower Vítkovice Area. The science center was opened in 2014 and supporting program has been running since 2013, so we are still at the beginning, but we already have experience with more than 40.000 children.

Interactivity – can mean everything and nothing at the same time

In a general point of view (dictionary.com), interactive means acting upon or influencing each other; allowing a two-way flow of information between a device and a user, responding to the user's input, if users receive real-time feedback.

In the area of education, respectively digital technology, we usually mean by interactivity the possibility of establishing an active connection with the machine or technological device when the device is able to respond to stimulus that gives the user some connection between the human object and device that enables a two-sided flow of information, actions and reactions.

The degree and character of this communication may, however, be different. Thanks to the technological possibilities in the learning concept, interactive is understood primarily as ICT. But digital does not necessarily mean interactive in a deeper sense and interactive, as mentioned, is not always an ICT product.

An interactive learning material or tool, for example, could be a computer game that requires certain inventiveness, but also a building kit (for example in physics) or a static object that arouses the senses. It could be also an educational program, learning module or other activity without the "device" you work with.

One step and multistep interactivity

The action-reaction process can occur once or the communication can work in several steps. A one-step interactive object is, for example, an exhibit demonstrating some mechanical or optical phenomena where, by launching balls a track, the experiment is finished. Multistep interactivity can be seen in computer equipment, the student, according to a set of information, is asked for an action which, in turn moves the set of information on. Both types have their advantages and disadvantages.

In the case of one-step interactive tools a general process is presented, a phenomenon that is always the same. After realizing and understanding, the pupil does not need to repeat it. The multistep interactive device may have, due to the information "tree", more alternatives for action and reaction and it can be played repeatedly. The actions and reactions have to be at such a level that the pupil will be able to take in the entire process intellectually. If the process is complex, then it's best to break it down into bite-size chunks. It is necessary to keep in mind, however, that an adult´s attention span lasts approximately 7-19 minutes if the person is interested in the topic. After that the probability of holding the information decreases significantly. For a younger person this period is much shorter, according to age level.

Level that interactivity is working on

We can also discuss the level which the interactive element is working on – physical, intellectual or emotional. If we use some interactive element as an educational tool, we need to know what to expect. For example, in art the emotions are central, the intellectual level is necessary but usually the physical aspect is not needed. On the other hand, if we want to teach the children ride a bike properly, the physical level is key and other levels are not so necessary. But it always holds that well-designed interactive element pervades all these levels.

The physical level is usually the first step of the interactive element, it starts the communication. It can be implemented by performing certain physical activities, as often with interactive exhibits in science centers, or by controlling the interactive element using a keyboard (in computer equipment).

The intellectual level is the bearer of an educational feature. The primary target is to think about the process, establish the questions and start to find the answers. An interactive tool never gives the answers to the question without the process of thinking. This is often carried out by highlighting something that a pupil has noted during the communication. The interactive tool can help with the answers by offering the comparisons of a successful and an unsuccessful experiment. Interactive games where a learner fills out the test questions without an explanation as to why the answer is correct or incorrect offers little or no intellectual stimulus. In these types of devices weaker pupils often resort to random reactions and stop thinking analytically.

The emotional level is often neglected, although its role is no less important. The role of this level is motivation for further investigation or discovery. Emotional level may be in addition to visual performance, which strongly influences our first impression, supported by non-educative elements (graphic, topic and so on). An example is the educational computer game MinecraftEdu, based on the principle of the well-known and popular commercial games.

Professional design and homemade product

One misconception is that complicated, expensive and commercially made interactive tools are better. It is always important to reflect the age of the target group. Young learners don´t need professionally processed products, they are happy with simple tools that may be improvised at home. Professional companies, as well as owners of the exhibits, depending on the number of visitors, tend to design interactive tools in the form of "black boxes", where the only form of communication is pushing the buttons. This product is practically indestructible, because mechanic or electronic parts are not visible and are not hands-on. Often, if an exhibit is digital, it is possible to repair software remotely. But this type of exhibit is not as interactive as it could be.

The self-made interactive tools can often incorporate multiple cultural, social and knowledge environment for the target group. Usually they are tailor-made to the needs and abilities of the pupils. Lower quality of technical appearance need not be a problem - on the contrary, if the students see that such an device can be made from commonly available items, it may inspire them to produce something similar at home. But we must always remember: safety first!

How Science centers work

The majority of interactive exhibits in science centers are professional products on very high level of design and quality. There is a brief instruction of what you have to do with the exhibit and a short explanation of the phenomena (often QR code for the further information). But that is only the start. In the Science and

Technology Center in Ostrava we use an interactive idea in our supporting program for schools which mainly consists of three parts: study modules, Your idea – Kids and Science program and we use the LARP game as an educational tool.

Your Idea – Kids and Science is a unique license of the Netherlands Kids and Science Foundation and "Inventor class" is a week-long program aimed at the whole class with exact time planning and fixed goals – to make inventors out of the students in 7 days. More about our experience with Kids and Science can be seen in (Václavíkova, 2015) and general information in on www.kidsandscience.org. We focus on designing the study modules and LARP games.

The schedule in science center is organized using a reservation system. The center announces available slots and schools can reserve specific day, time, activity and topic.

The education modules are linked to the exhibits and develop the phenomena the exhibits are about. The module is usually 2 or 3 hours and is based on the idea of creative science (Václavíkova, 2015), includes production of one item or one experiment which can be implemented anywhere – at home, at school, with friends or in a science center. In terms of the time, it involves motivation, device production itself and feedback (comparison of products, discussion about modification options, etc.). At the present time we offer approximately 20 active modules targeted to mathematics, physics, chemistry, biology, new technology and robotics and 20 new modules are in the preparation stage.

The LARP (Live Action Role Play) is in the form of a game where the participants represent fictitious parts (with precisely defined characters) of a prepared story and they create and perform the story themselves. It is important for the game to be performed in an authentic environment with respect to the plot itself; actors have costumes, scenery and predetermined rules. LARP is intended for players – actors and there is no audience. This type of game originated independently in several places: in Northern America, Europe and Australia at the end of the last century; nevertheless, its use has not been particularly widespread in the educational process. In fact, it is the LARP which offers a unique opportunity for students to create something independently in an entertaining way, to deal with situations and estimate the consequences of decisions, to implement their knowledge and learn where to look for information. LARP as a means of education forms a separate group in classification of games; it cannot be assigned to thematic or even dramatized play. If the LARP is to have an educational effect, it should not be created universally but always with respect to the age group of participants. However, this does not exclude LARP that interconnect more diverse age groups but their augmentation as well as implementation is more demanding. Younger children are often satisfied with a materially and spatially less demanding LARP as with a thematic play. Many tools and much of the scenery can be prepared from commonly available inexpensive materials. Characters should be simple,

unambiguous and mostly positive to be easily reproduced by students with respect to the developmental stage of cognitive functions. If we want to prepare an LARP role play for older students, it is essential to prepare a story with high quality costumes and appropriate environment so that the students can really get into the story. Older students are also able to empathize with more abstract characters. They are able to adjust their decisions during the game according to characteristic features of the part that they play.

Even though the major educational theme is generally provided, knowledge from other fields will be needed during the game as well. The LARP game is guided by animators who form part of the story, too. In order to meet the educational requirements, a perfect preparation of both the story itself and material and technical facilities during the LARP is inevitable.

At the present time we offer 2 LARPs and 2 new are in the preparation stage.

How to design the interactive activity

The first step to well-designed interactive module or game, is answer to the "Five Ws" (they are often mentioned in journalism): what, who, when, where and why. The answers to these questions are considered basic in information-gathering or problem-solving. In our case it is more or less the same but we slightly modify their meaning.

Before start, we need to know:

- What we want to teach.
- Who will visit our module.
- When we will implement it.
- Where we will teach it.
- Why the audience should visit the module.

What

What is the primary phenomenon we want to show. Especially for young pupils it is necessary to stick to one thing, one process. We can support the module by interdisciplinary links, but only by the secondary questions (to thinking about). If we supply too much information, people tend to lose track. When we ask the visitors at the end what a module was about; they must be able to answer in one word.

Who

In order to be successful it is necessary to adapt an interactive element to the visitor or user. So we need to know how old the audience will be, if they are children, only boys or only girls, what they like, and so on. When a module is run during school time for a particular target group, it is very easy to fit it to

children. It is not so much a matter of the topic, but mainly the language to be used for communication with the target group. They probably won´t know a lot of scientific terms and sometimes is difficult to explain the phenomena to children using "their language".

When

During term time we expect the majority of visitors to be the school children or students. We can take advantage of the fact that the pupils come in the morning, so they are ready to learn and explore. The situation is different at the weekend, with mostly families – the children are with parents or grandparents. The activities have to be entertaining for all of them, young and old alike. They could incorporate some cooperation between the children and parents. Festive events are very popular– for example during Christmas, Easter, or Earth Day we can tailor the modules to fit in with the traditions of these days.

Where

The interactive module or other activity can be set up in the science center, at school or anywhere. In all these places we can use all the things the environment offers. In a science centre there are usually exhibits or whole expositions that are linked to the module and children do not have a chance to see them anywhere else. When we design a game like LARP, which is meant to be played in the countryside or in old factory, the topic should be played out in this surrounding. The area does not play the primary role, but very strongly influences our spirit, senses and our immersion to the game. At school, we often do not have many possibilities for experiments, but we can use a touring exhibition or choose some interesting place at school outside of the classroom - like changing room, gym, etc.

Why

The majority of visitors are school children, so primarily we have to cater for them. But there are many other events they go to – like concerts, exhibitions in galleries or sports events. Before designing we need to know why the visitors should choose our module. What will be our benefit? What we can offer them? There are two things which are interesting to schools. The first one is that we offer some "standard" topic what is included in the syllabus, and we give a different angle on it – popular, funny and interesting. Or we offer exhibits or experiments which cannot be seen or carried out anywhere else. In this case the school plans the visit during the time they have this topic in their timetable.

The second thing is that we can offer something very "cutting edge" – the latest technology or topic which the non-specialist teacher is not able to teach. This case is usually more interesting for the students but more difficult for preparation because we have to start at a child's knowledge and skills level.

But in our experience schools reserve this kind of module more often than the one that offers a "standard" topic.

Our experience with designing the study modules

Having answered these questions, one still remains – how will it be done?

Being a part of informal education, our activities can afford to respect all these rules:

- offer an individual approach to each student with a strong emphasis on collaboration,
- bring a real experience in interactive form,
- encourage the student to apply their knowledge, skills and abilities from other fields, not just natural science,
- be playful and entertaining.

From our experience with designing modules and games, we have found that it is good to do it in several steps. The first is the brainstorming of ideas – what there will be, for whom, and where. We collect these ideas into a database all year round and working group (mentors, tutors and guarantors of partial areas) discusses them. If someone likes an idea, the person is asked to describe the idea in more detail – to expand it into a whole module minute by minute. Then we let a pilot run only for members of working group (there are tutors for different age groups and areas). A module or game is discussed – its classification for the given age group, concept, level of fun, continuity of each partial activity in the module, and so on.

We also invite school teachers for the piloting and we engage their experience. They help us with the assessment of understanding the module for the target group of children, with the timing of the module, and with the language.

If the module does not work as we want, or if there are many unanswered questions or unsolved problems with the partial activities in module, we usually decide not to go ahead with it.

If the module works, the piloting run for children is the next step. We invite our cooperating classes for the module and the children (as well as the class teacher) evaluate the module. In this step we try to sort out any last hitches.

The next stage is to find the best lecturer (or lecturers) for teaching the module. Not everybody can teach everything not matter how much of an expert they may be in their field, because it is totally different to teach pre-school children, young pupils or teenagers. For informal education it is necessary to be tuned to the same wavelength as the visitors. The lecturer must like the module, because if he is not interested in the topic, the children will feel it. Still, we have to keep in mind that we offer not only the experience and knowledge but also the emotions.

Once a lecturer has been chosen, the creator of the study module starts to train him for teaching. Sometimes they make changes if the lecturer wants to teach some parts in another way and the author agrees. After that there is more piloting inside the working group and with the cooperating class. It may happen that the module presented by the lecturer is not as good as it was from the author – an idea was not understood. But also it may happen that it is much better! Then the module is ready for our offer.

Guarantee of quality

Science and Technology Center Ostrava cooperates with the University of Ostrava, with the experts of the university making sure the modules and LARPs are of the highest quality (for further information about activities of University of Ostrava in popularization of mathematics see (Konečná, 2015) or (Konečná & Kričfaluši, 2012)). There is at least one professor of each science subject area - mathematics, physics, chemistry, biology, new technology and robotics and these people make up the working group. The creators of activities have to communicate with this person during the preparation stage and have to consult the idea as well as how the topic will be presented to children. Sometimes it is almost impossible to present a complex science problem using elementary language. But if you make a mistake and the children get the wrong idea, it is very difficult to change it. So every word that we use, every notion, every concept has to be correct from a scientific point of view.

Traveling module

In Czech Republic, there is a law that the class can leave the school and visit some institution of informal education a maximum of 5 times per year. If they leave the school more times, they have to compensate the lessons at another time.

So there is not as much room for cooperation with schools as the science centers would like. That is the reason for designing the traveling module and traveling LARPs. The animators and lecturers go to the school and implement the activity there. In fact, it is not the same as in science center. The module cannot be linked to exhibits and you work with different surroundings, each classroom is specific. The animators travel by car and all the things they will need have to be able to fit into it. The module must be designed for traveling. This is the first year that we have worked with travelling modules and LARPs and we hope they are successful.

The examples of interactive module

As an example the modules “Symmetry” and “Motion pictures” will be described. The original idea of the module “Symmetry” was to introduce

symmetry as a phenomenon that appears throughout the world and is best explained and understood through the language of mathematics. The target group was children aged 10. An everyday example of symmetry is our body – the left half is the same as the right one. Or a butterfly – if we imagine folding it wing to wing, both halves of it will be the same. At this point children do various physical activities – seeking symmetry on our body, on a friend's body and on the things around them. But symmetry is not only on living creatures´ bodies. We can find it in words – palindromes are words that can be read backwards the same as forwards – eye, level, noon. The similar symmetry we can find in the world of numbers – some of the prime numbers are palindromes – for example 11, 131, 151, …. The geometric shapes are symmetric – a square, some kinds of triangles (but not all of them), a circle and many others.

The questions are put and the children should think about them and try to find an answer, the intellectual level starts. Our buildings are symmetric, our equipment (cars, televisions, computers, and so on) are symmetric – we love symmetry! But why does nature like it? Why are the bodies of animals bilaterally symmetric? Why are leaves and flowers symmetric? What are advantages of symmetry? The goal of this module was to motivate children to search for symmetries around, and to consider the advantages and disadvantages of symmetry.

Then we introduce them to symmetry from the mathematic point of view – something is symmetric if there is any mapping such that the pattern and image are the same. The easiest way is use a mirror – during the module the children produced a kaleidoscope from a toilet-paper tube, mirror-foils and beads. It is a nice toy - you look inside the three mirror sides and as you shake it, the beads make nice images thanks to the mirrors. This step was the main feature of creative science and plays the role of emotional level. We also describe to children the fractals as an example of symmetric mapping, show pictures with colorful fractals, and draw the Sierpinski triangle.

When we discussed the module during the piloting inside the working group, we had doubts whether the students would understand the principle of fractals and the general concept of symmetry. It turned out that the biggest difficulty was in producing the kaleidoscope – there was not enough time for it. Because the schools travel to the science center and need to be back at school for lunch, it was not possible to take more time for it. We changed this activity to symmetry painting. The child has a pen in both hands, body fixed, and, trying to do same moves with each hand, paints on a big sheet on the wall or on the floor. It was very funny and it was interesting to talk about the ability of left/right hand, to compare the symmetry of our body with the symmetry of our two-hand moves and the symmetry of the final picture.

Figure 1. Two-hand painting

The module "Motion picture" was created as a byproduct of temporary exhibition of historical projectors and cameras. During the exhibition the visitors could prepare the thaumatrope – the old children´s toy made of rough paper that can be turned very fast. On the one side of the paper is drawn one half of picture (for example bird) and on the second one the second part of picture (cage). As we turn the paper very fast, our eye sees both sides in one picture – we see the bird in cage. This is the inertia of our eye.

When we were thinking about the module that will be linked to the exhibit about the function of human eye, we used the idea of thaumatrope. Gradually we have designed a module in several versions depending on the age of the children – thaumatrope was replaced by the production of more complex optical toys such as phenakistoscope, zoetrope and others.

The first part of the module was about the human eye and its deficiency and how we can put the deficiency to use – in motion pictures! The second part was creative – children can build any optical toy or they can make an animation movie on the tablets and share it on YouTube.

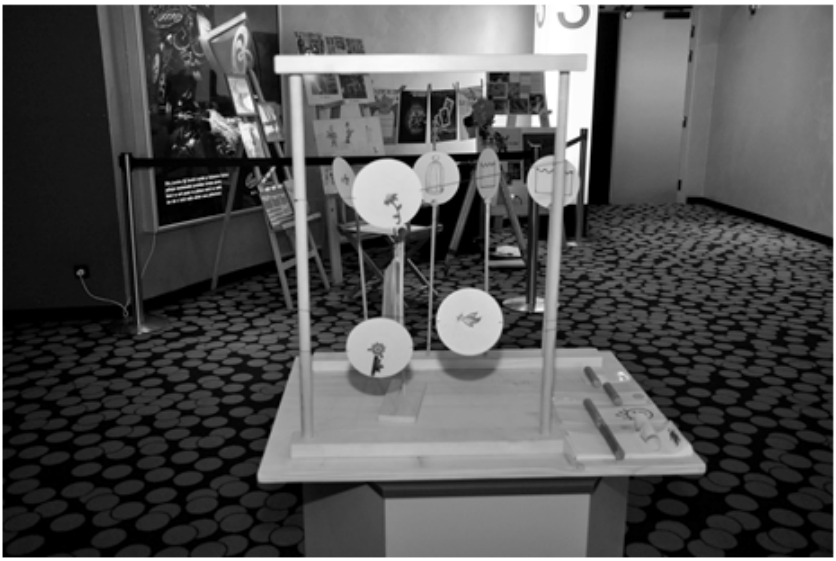

Figure 2. The thaumatropes made by children

This module had such success that we designed the whole set of modules with the title "Creating technical inventions" and these modules are still in our schedule.

We also extend the module for teenagers; they record the animated movie themselves. They have to prepare the topic, storyline, scene and the characters. Then, by using a stationary camera they make the pictures of the scene and between two pictures they move the characters a small amount. When they have a lot of pictures, it is possible to put them together to make a movie.

Evaluation of success

Science centers need visitors to come back so they need to offer a wide variety of activities to keep it interesting. The evaluation of the activities by the visitors is important in this process.

The first source of information about interest is the reservation system. If a module or game is booked up very fast, it probably means that the topic was a good choice. The visitors – in this case usually children and class teacher – give us feedback immediately after the activity. We use a simple questionnaire with emoticons. After ten runs of the module or game we evaluate its success using the feedback and availability in the schedule. If the module is popular, it is kept on and we try to work on "gaps" from the feedback.

It is really unbelievable how fast the schools share the experience from the visit and from the module. Sometimes it happens that a school contacts us for a specific module because word of mouth.

On the other hand, any module that is not bringing people in is replaced in our schedule by a new one.

Interactivity in formal education

It is hard, but not impossible, to use interactivity in formal education, too, especially in primary or secondary schools. There are subjects like painting, art or workshops in Czech education system that can be combined with science. During the creative production of some device or a toy the pupils cut, stick and draw – just like in an art lesson. The projects respect the individuality of every child and offer scope for cooperation. Some ideas are very simple and we often recycle common household materials, so it is low maintenance. Also the LARP can be used, for example, as an adaptive course at the beginning of the academic year.

Conclusions

Rapid growth of information and acceleration of time is changing education – with the danger of quality being replaced by quantity. We tend to look for the easy and safe option everywhere, not only in education, with, unfortunately, experience being the loser. This approach needs to be changed. Informal education that offers an interactive feature is the way forward. Any activity that makes children explore the world around them is to be applauded. Interactivity doesn´t bring just knowledge but also a real experience and deep emotion, and then interest follows naturally. Interest brings questions and questions beg to be answered. And finally, answering questions is nothing other than natural way of learning.

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How to Motivate Pupils to Be Interested in Maths: an Inspiration Resulting from One Mathematical Competition

Introduction

From 1995 to 2007, results of Czech students in mathematics deteriorated most of all the countries that took part in the international research of Mathematics and Science Education TIMSS. Although the results of Czech students within the research of TIMSS 2011 and PIRLS 2011 were above the average, they achieved the worst results in mathematics (Tomášek et al., 2012; Kramplová et al., 2012). One of the main reasons for the lack of success of many students in mathematics is that the student's knowledge is formalistic. Pupils minimize their focus on the required knowledge only; they reproduce the subject – matter without understanding. They are not able to apply the gained knowledge, strictly distinguish the school information from situations in the real world (Mikulčák et al., 1968). Results of our research focused on monitoring the choice and success rate when solving mathematical and chemical problems of varying difficulty from a simple reproduction up to solving problematic tasks by students at secondary schools showed that students are able, in most cases, to answer simple question aiming at reproduction. They avoid solving of unusual problems and problems requiring complex mental operations, application and creative thinking (Konečná & Solárová, 2015).

One of the reasons why we encounter these problems is no or low motivation of pupils to be interested in math. They consider mathematics to be useless topic without connection with real world, boring and very difficult subject. We try to change this negative view of pupils and show that mathematics can be useful, real, interesting and entertaining; we focus on popularization of science and mathematics for several years (Konečná & Kričfaluši, 2012), organize various activities within informal education (Václavíková, 2013), (Václavíková, 2015), make teachers and future teachers familiar with new and unconventional methods in teaching mathematics (Konečná, 2015). One of activities aimed at this objective was thematic day with a mathematical competition for secondary school students which we organized at our faculty.

Description of the competition

We organized a thematic morning for students of different types of high schools in the Moravian-Silesian region. 150 students in total aged 16 – 18 took part in this event. We have prepared 40 mathematical problems concerning eight topics, always with five problems in each of them:

Modification of algebraic expressions (in short AT),
Axial and central symmetry (in short S),
Numbers and operations (in short N),
Word problems leading to simple equations (in short WP),
Logical word problems (in short LP),
Adding a magic square (in short MS),
Solving Futoshiki puzzles (in short F),
Folding a tangram according to a template (in short T).

Problems in the first four topics are usual problems and can be found on a regular basis in mathematics education of the upper stage of basic education and at high schools. Problems focusing on modification of algebraic expressions belong to traditional problems in the field of algebra and are usually dealt with in the last year of basic schools and in the first grade of high schools. Students are able to define a definition domain of an expression with respect to the described facts. They are able to decompose a polynomial into a product using algebraic formulas, factoring out or using the properties of polynomial roots.

Axial and central symmetry are taught in the sixth grade of basic schools within the field of Plane Geometry in the part called Congruent shapes. Students manage to explain the difference between the concepts of direct and indirect consistency. They can dealt with construction problems using the same display and homothecy. Axial and central symmetry makes use of geometric imagination; however, basic knowledge of symmetry is needed as well. Students were asked, for example, to draw the axis of symmetry into a traffic sign if there is any.

Figure 1. Example of axial and central symmetry

Problems focusing on simple sequences and series were for example as follows: "Compose ten-digit numbers out of the numbers 0 – 9 that would be divisible by 2 – 5." Students make use of their knowledge in divisibility of numbers and then the combinatorics to compose the resulting number.

Word problems are already dealt with in the first grade of basic schools. The word problems we have chosen enabled us to find out connections between facts, going from abstraction to concretization and to simple equation with one unknown variable. For example, students dealt with the following problem: "Jane is 24 years old. She is twice older than Hana was when Jane was as old as Hana is today. How old is Hana?"

Remaining topics aim at unusual tasks/problems. We focused on problems that traditionally do not occur in classes; students do not practice the solution procedure in advance and yet the problem must be tempting for them.

At the beginning of solving a word problem students must analyse the problem and determine the stated objective. Then they find the correct answer using deduction or propositional logic. An example can be as follows: "Let's have an island where two types of people live: honest ones who always tell the truth, and liars who always lie. To distinguish them we will use the propositional logic: In the market there are three inhabitants A, B and C. A stranger is going around and he asks the A: "Are you a liar or an honest person?" The A answers something; however, the stranger does not understand him and therefore asks the B: "What did the A say?". The B answers: "A said he was a liar.", and the C reacts: "Do not trust him, the B is lying!" Who are the B and C then? (Pěnčík & Pěnčíková, 1995)

Magic squares come from China and the first mention appears in the book by the emperor Ju from about 2100 BC. A magic square is considered a table with the dimensions n×n which is filled with a variety of natural numbers where the sum of the digits in each row, column and diagonal must be equivalent, i.e. it is equal to the magic number which is:

$\frac{n(n^2+1)}{2}$. These squares formed the basis for the popular game of SUDOKU. Magic squares are based on a basic skill of a binary operation of addition for a limited set of natural numbers. It develops combinatorial and logical thinking.

Futoshiki is a young Japanese number logic puzzle game which can be translated into English as an inequality. There is a similar principle used for solving as for magic squares; however, there is yet a sign of inequality that must be satisfied. Futoshiki is based on the knowledge of a well-ordered set of natural numbers and this knowledge must be applied for adding the four numbers between the inequality signs.

Fill in the numbers 1, 2, 3 and 4 so that in each row and column there is just one of these numbers and that the inequality is satisfied:

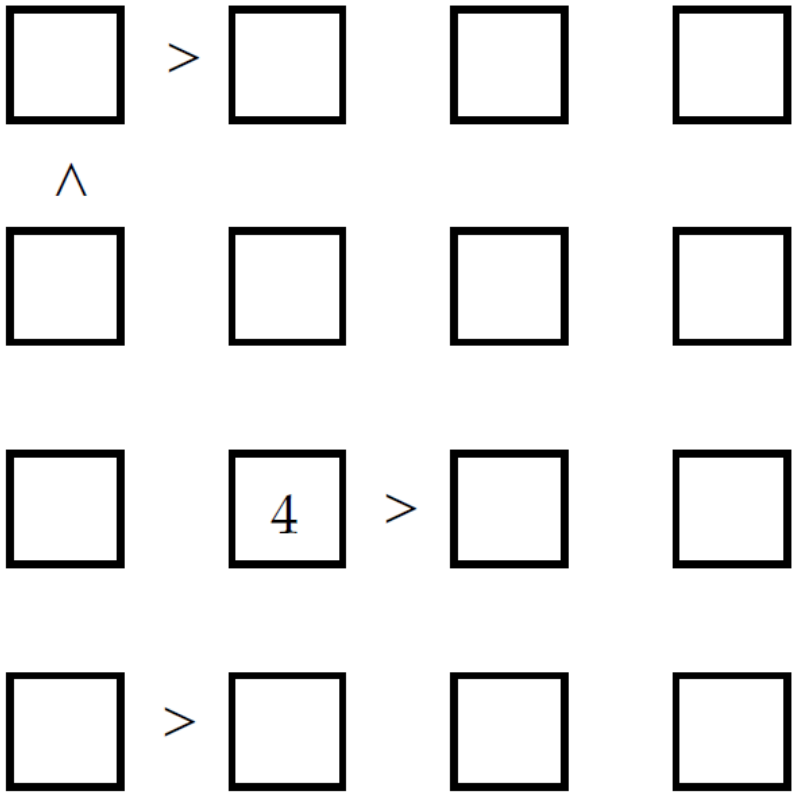

Figure 2. Futoshiki

Tangram is one of the oldest puzzle games. It comes from old China where it was called ch'i ch'iao t'u, which generally means "ingenious seven-piece plan". Tangram is a square divided into seven geometrical parts that can be used to create different geometric shapes, objects, animals and human figures so that all these seven pieces are used up and do not overlap. In this case the visual imagination, inference and combinatorial thinking are involved.

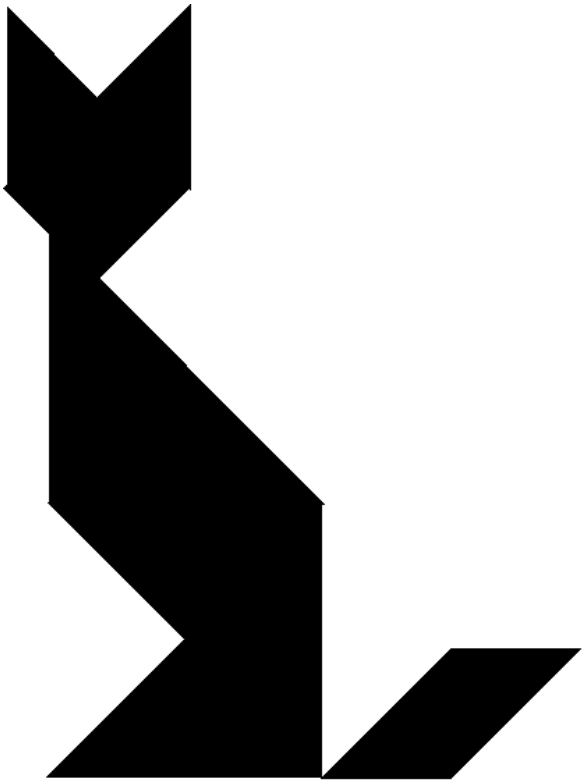

Figure 3. Tangram cat

Students formed five-member teams and they were supposed to solve the problems in 20 minutes in total; nevertheless, it was impossible to finish all problems within the time limit provided because of the time demand. Problems were mixed up and students could choose at their discretion. No matter how difficult the problem was, each team was given one point for each correctly solved problem. If they solved it incorrectly or did not solve it at all, they were given no points and were not penalized at all. The objective was to receive as many points as possible within a team, i.e. to solve as many problems as possible within the given time.

With regard to the said goal of students (to get as many points as possible) we expected that students would prefer and would succeed particularly in problems where they know procedures for solving and in problems they would find easy; then, on the basis of one quick successful solution, they could select next problems of a similar type. In fact, it was different, which made us examine results of the competition closely.

Results

In addition to the division of problems into usual and unusual ones, we divided problems into three categories: geometry problems (symmetries and tangrams), word problems (standard word problems and logic problems) and algebraic problems (other problems). We were interested, what the preference when selecting the problems is. Do the students prefer school problems which they are familiar with and should the solution processes be adopted and automated by students? Are students more successful with solving standard school problems? Are both problem selection and success influenced by the mathematical field?

The evaluation was managed by descriptive statistics and the analysis of variance (ANOVA) within which we tested whether there are statistically significant differences between the results of the monitored values with individual topics, groups and categories into which the problems were classified.

First we carried out the analysis of problem selection preference. Students preferred unusual problems more.

Table 1. Percentage of the problems selected which students started solving

LP	F	T	MS	WP	S	N	AT
59%	82%	100%	97%	24%	96%	51%	61%

As the pivot table of absolute frequencies shows, one can observe fundamental relation between the problem type and the number of attempts – it means the number of problems that the respondents selected and tried to solve.

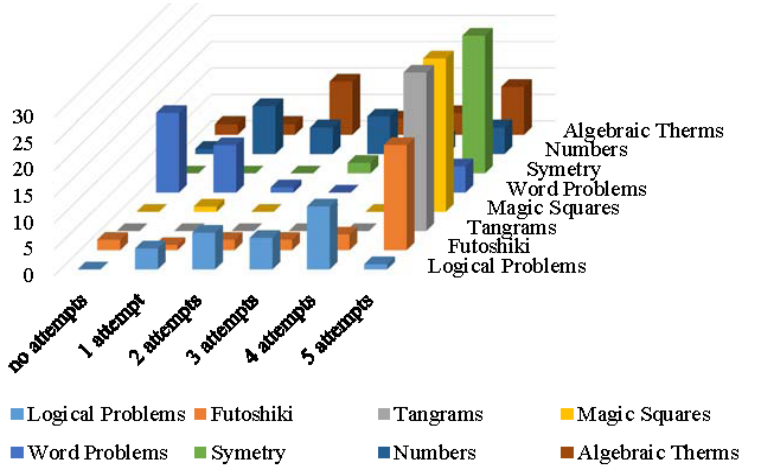

Figure 4. Absolute frequency of attempts in topics

Students showed the greatest interest in tangrams and magic squares. In terms of tangrams each team made use of all five problems offered; with magic squares it was the same with the exception of one team. There was also great interest in the topic of symmetries and futoshiki. On the contrary, the word problems experienced the lowest interest. Based on the table of frequency, one can notice that students strongly preferred nonstandard problems to standard ones. There was just one exception represented by "popular" symmetries included in standard problems.

The ANOVA results confirmed statistically significant differences between the selected types of problems. Multiple comparison test for all pairwise differences between the means was made by Bonferoni multiple comparison test and Tukey-Kramer multiple comparison test.

Table 2. Result of multiple comparison tests

Topic	LP	F	T	MS	WP	S	N	AT
Count	30	30	30	30	30	30	30	30
Mean	2,97	4,10	5,00	4,87	1,20	4,80	2,57	3,07
Different from topics	WP, F, S, T, MS	WP, N, LP, AT	WP, N, LP, AT	WP, N, LP, AT	N, LP, AT, F, S, MS, T	WP, N, LP, AT	WP, F, S, T, MS	WP, F, S, T, MS

These results can be illustrated in the following graph. Statistically significant differences were confirmed in areas that are not connected by an edge. This creates components of areas where the statistically significant differences were not confirmed. Concerning the preference of problems within the unusual problems group, the logical problems singled out; on the contrary, in terms of the usual problems group no statistically significant differences between symmetries and three remaining unusual problems were confirmed. A separate component is formed by word problems where the amount of attempts is the lowest.

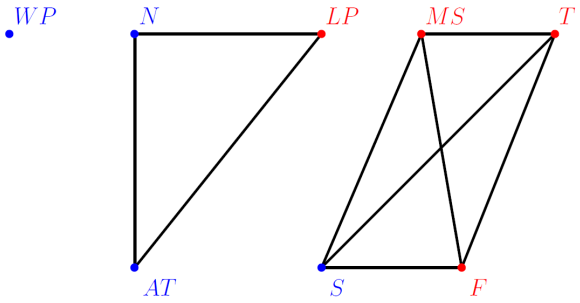

Figure 5. Result of multiple comparison tests in the graph (Group of usual problems, Group of unusual problems)

Statistically significant differences were confirmed by the same methods even between the group of usual and unusual problems. And it was the same even in case of mutual differences between all categories of problems – geometric, algebraic and word problems – which were confirmed as well.

In the second stage we analysed the relation between the number of successfully solved problems and all that.

Table 3. Percentage of successfully solved problems out of the total amount of problems

LP	F	T	MS	WP	S	N	AT
33%	70%	62%	87%	3%	75%	29%	22%

Based on the pivot table of absolute frequencies of successfully solved problems, we can notice the lowest number of the solved problems within the word problems; only 4 problems were solved out of the 150 problems in total. On the contrary, the highest figure concerning number of the solved problems was noticed within the magic squares.

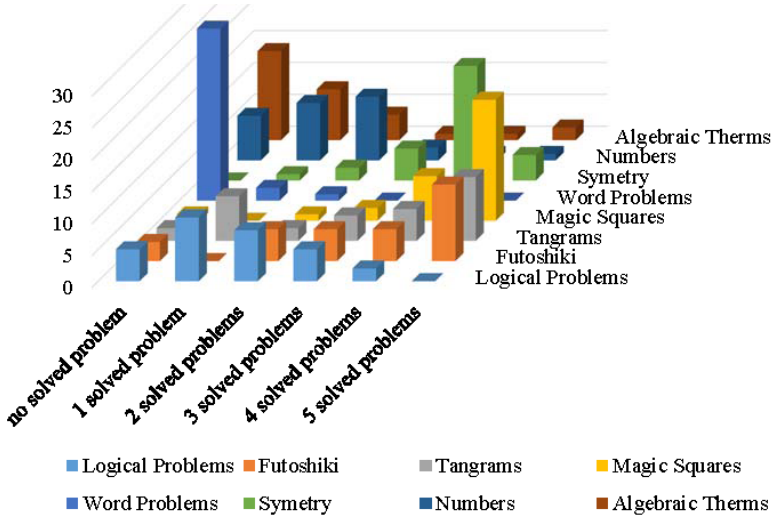

Figure 6. Absolute frequency of solved problems in topics

When applying ANOVA, we used the same tests as with analysing the results of attempts. And again the statistically significant differences in the amount of successfully solved problems between the group of usual problems and group of unusual problems were confirmed. Mutual differences between all categories of problems were confirmed as well. Multiple comparison test, however, showed different links between particular problem groups compared to the situation as it was in case of monitoring the number of attempts.

Table 4. Result of multiple comparison tests

Topic	LP	F	T	MS	WP	S	N	AT
Count	30	30	30	30	30	30	30	30
Mean	1,63	3,50	3,10	4,37	0,13	3,73	1,47	1,10
Different from topics	WP, T, F, S, MS	WP, AT, N, LP	WP, AT, N, LP, MS	WP, AT, N, LP, T	N, LP, T, F, S, MS	WP, AT, N, LP	WP, T, F, S, MS	T, F, S, MS

These differences can be better observed in a graphical representation.

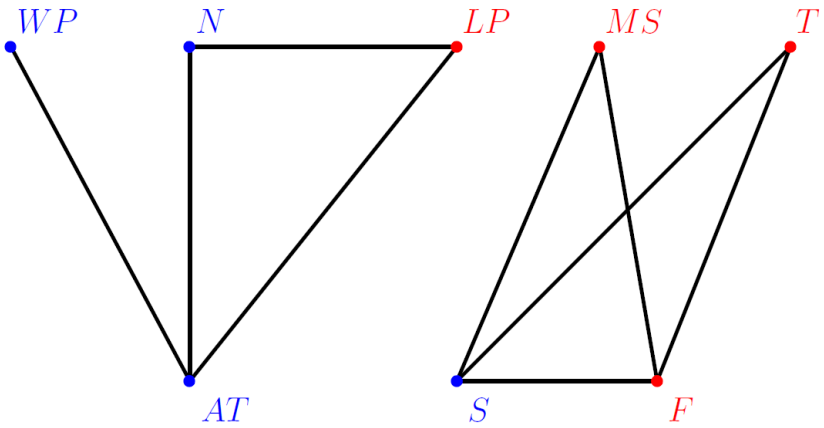

Figure 7. Result of multiple comparison tests in the graph (Group of usual problems, Group of unusual problems)

In contrast to the number of attempts, no statistically significant differences in number of the solved/completed problems regarding the topic of both word problems and solving of algebraic expressions were actually proved. On the contrary, there was proved a statistically significant difference concerning the topics focusing on magic squares and compilation of tangram puzzles.

Summary

While monitoring the problems selection preference the statistically significant differences were confirmed within all monitored categories. It was rather surprising that students preferred the category of nonstandard problems, and concerning the standard problems they greatly preferred problems focusing on symmetries. Within the categories students were selecting the geometric problems most and the least popular category included the word problems.

While monitoring the number of the solved, or let us say completed, problems the statistically significant differences were again confirmed within all monitored

categories. Nevertheless, the trends that were observed here were not as clear and unequivocal as they were with the number of the preferred problems. Rate of successfully solved unusual problems exceeded the rate of the successfully solved usual problems only in the category of word problems and algebraic problems. However, with the geometric problems you could notice the opposite trend. It even dropped below the algebraic problem category value. One of the reasons can be the proved declining level of spatial imagination ability (Molnár & Tláskal, 2012), which – in combination with less known and less practiced type of a problem – decreases the success in problem solving despite its high attractiveness.

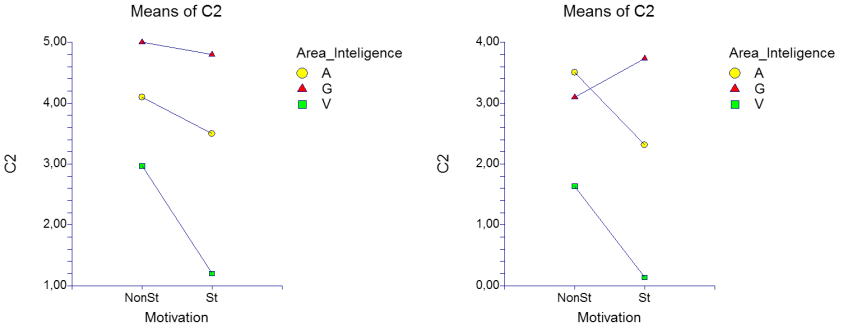

Figure 8. Results of the multi-factor analysis of variance of the monitored features with respect to groups and categories of problems

If we compare numbers of the selected problems and of successfully solved problems with respect to both factors, i.e. groups of unusual and usual problems, and categories of geometric, algebraic and word problems, we can notice that the geometric problems belonged to the most preferred ones and in spite of a lower success rate in tangram puzzles compilation, it is the category with the highest number of the successfully solved problems.

To sum it up, our results has shown that, in spite of a decreasing level of the visual-spatial intelligence, adequately selected geometric problems have a high motivational potential although solving them is not easy for students. On the contrary, word problems have the lowest success rate as well as the lowest incentives. This may be related to a low reading literacy influencing reading comprehension then. This one is also significant for mathematical education (Hejný & Kuřina, 2009), particularly for solving of the so called word problems. Research has also showed that students find unusual problems more interesting. Although they are not used for them that much and they do not practise those solving processes, their average success rate with these nonstandard problems turns out to be higher than with standard problems.

Conclusion

Presented results are based on evaluation of one competition only. Thus, conclusions cannot be generalized as well as this is not any universal manual how to motivate pupils to be interested in mathematics. Results, however, show that tasks that do not traditionally appear in course books but do unambiguously support development of mathematical thinking are highly motivational for pupils and students. Thus, their more frequent use in class might be one of ways how to motivate pupils to solve mathematical problems.

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Comparison of the Achievements of the Student with Difficulties in Learning Chemistry and Using "Entertainment-Education" and Traditional Teaching

Introduction

The idea of Entertainment-Education (also called Edutainment) settled in the forms of knowledge transfer over 60 years ago. The official beginning of Edutainment is believed to be the 50s of the 20th century, when: the first radio soap opera about the development of agriculture – The Archers (1950-1951), and a soap opera on family planning (1950) (Singhal & Rogers, 1999) were broadcast in the UK. During these 60 years, Entertainment-Education entered education for good – as examples, science centers, educational films, and educational games can be mentioned (Kopek-Putała & Bilek, 2016), and show for children at University "Children and Parents" (Kobylańska, 2016; Nodzyńska, Kopek-Putała & Hásek, 2016).

Research

Students with learning difficulties are easily discouraged, thus it was decided to take advantage of the known elements of Edutainment to teach chemistry. Due to the fact that play is an activity entailing pleasure (Grad, 2005, p. 14-26), it was decided to use this feature during classes and examine the effect of the use of elements of fun at work with the student having difficulties in learning chemistry.

Research questions

The idea of the study emerged based on the desire to deepen knowledge of the following issues:

- How does a student with diagnosed learning difficulties gain knowledge during chemistry classes?
- Do, and if so, to what extent, ways of teaching-learning impact the learning outcomes of the student with learning difficulties, for example within the subject of chemistry?
- Which ways of working should be used in chemistry classes to facilitate the learning of the student with learning difficulties?
- How attractively and effectively teach chemistry to the student with learning difficulties?

Prior to beginning the study, a general question was posed: Which way of working in chemistry classes is more effective in the case of the student diagnosed with learning difficulties:

- work with the use of Edutainment together with the use of Information and Communication Technology (hereinafter referred to as Edu-ICT), among others,

using games, or

- classes without the use of Edutainment and Information and Communication Technology (hereinafter referred to as No-Edu-ICT)?

Detailed research question on this stage of the study was: Which technique: teaching without Edutainment and ICT, or with elements of games based on Edutainment and ICT, is more appropriate in the education of the student with learning difficulties?

Research design

In 2012-2015, a comprehensive study on working with students with learning difficulties was conducted. The study was carried out by the case study method. The subject of the study was a student who has been under the care of Psychological and Pedagogical Counseling Center (also called PPP) since the early years of primary school. The student has been diagnosed multiple times and received opinions issued by Psychological and Pedagogical Counseling Center indicating generalized learning difficulties, difficulty concentrating, impaired processes of memory, attention and association and weakening of the effectiveness of memory-based learning.

Research description

The issues covered based on different ways of working were two key aspects of teaching-learning chemistry:

- chemical reaction equation,
- chemical laboratory.

Research block on "chemical reaction equations" included 7 lessons, during which the said topic was implemented and 2 lessons, during which checking knowledge was carried out (knowledge and skills of the student) (Table 1). The selected issue is important in teaching chemistry and generates numerous difficulties covered, among others, by Haduch and Paśko (1999), Cieśla and Paśko (2006), Nodzyńska and Paśko (2008, 2010).

The second research block on "chemical laboratory" included 6 lessons, during which the said topic was implemented and 2 lessons, during which checking the student's knowledge and skills was carried out (Table 2). This issue was proposed by the student themselves and defined as interesting and evoking a lot of emotions, and, at the same time, causing trouble. The difficulties that the student faces is performing and describing in a comprehensive way the experiment and, in particular, distinguishing observation from conclusions as well as the precise execution of experiments.

Traditional way of conducting experiments underwent many "modifications" described by, among others, Jenny (1990), Bílek (1997, 1999), Kričfaluši, (2004), Stratilová-Urválková, Šmejkal (2009), Bílek, Hruby (2012), Jagodziński, Wolski (2010, 2016).

Creating the study plan, the ways of working were divided into two groups: lessons without the use of Edutainment and ICT and lessons using Edutainment and ICT (Table 1, 2). In the two groups, different ways of working were contrasted, and the optimal method of explanation and acquisition of information for the studied student were sought in terms of the resulting: outcomes, attitudes, emotions and preferences of the student. All lessons were taught by the same teacher on the basis of pre-prepared lesson plans and teaching aids.

In order to determine which teaching techniques give better results, the results of tests performed before the start of the intervention, the so-called pre-tests, were compared to the achievements in the overall test after the intervention, the so-called post-test, and achievements in post-tests concerning different types of lessons.

In order to learn about the attitudes, emotions and preferences of the student, after each stage of the lesson (lessons using Edu-ICT and No-Edu-ICT), the student was asked for feedback in the form of a modified 4-point Likert scale; the neutral opinion was removed from the traditional 5 - point approach. Individual points on the scale were described as follows: 1 - uninteresting, 2 - not very interesting 3 - interesting, 4 - very interesting. At the end of the entire block of classes, the student was asked to assess how interesting each lesson was for him on the scale of school grades (1-6).

This article discusses a fragment of the results of the feedback given by the student having difficulties in acquiring the knowlege of chemistry concerning chemical reaction equations and chemical laboratory without the use of Edu-ICT and with the use of games based on Edu-ICT.

Lesson description

The issue of the chemical reaction equation was discussed in the three analyzed types of lessons:

- Working with descriptive text (way of working without the use of Edu-ICT, lesson number 1, Table 1, Figure 1)
- Working with the computer - simulation of the equation and the seesaw (the way of working with the use of Edu-ICT, lesson number 2, Table 1, Figure 2)
- Working with the interactive whiteboard - simulation of the equation and sandwiches (the way of working with the use of Edu-ICT, lesson number 3, Table 1, Figure 3)

The issue of the chemical laboratory was discussed in the two analyzed types of lessons:

- Working with the computer - application of virtual laboratory Late nite labs (the way of working with the use of Edu-ICT, lesson number 3, Table 2, Figure 4)
- Working with text - verbal and picture instruction (way of working without the use of Edu-ICT, lesson number 4, Table 2, Figure 5).

Each lesson implementing the material in question was carried out according to the following scenario:

a) Introductory activities: reminding the student the lesson aims (due to their learning dysfunction),

b) Subjecting the student to the pre-test,

c) Relevant part of the lesson, in which, through the selected method ("Edu-ICT or No-Edu-ICT"), the specific content within the range of issues of the chemical reaction equation or chemical laboratory was implemented,

d) Subjecting the student to the post-test,

e) Self-assessment, in which the student expressed their views on the various classes (Kopek-Putała, 2014).

f) Teacher's comments, correcting inaccuracies or answering the questions.

After conducting the entire cycle of 7 lessons from the first block as well as 6 lessons from the second block, on the following lesson, the student was subjected to the collective test on the content of all previous lessons within a given block, and then after about 2 months from the start of lessons within a given block, they were subjected to a delayed test.

The results of these tests will be used to assess the effectiveness of the assumed didactic solutions in terms of the durability of knowledge over time (Kopek-Putała, 2015).

Table 1. Diagram showing a fragment of the first research block

<table>
<tr><td colspan="4">I RESEARCH BLOCK ON THE CHEMICAL REACTION EQUATION</td></tr>
<tr><td colspan="2">Classes without Edutainment and ICT
No-Edu-TIK</td><td colspan="2">Classes with Edutainment and ICT
Edu-TIK</td></tr>
<tr><td>Sequence of lessons</td><td>Issue covered in the lesson</td><td>Sequence of lessons</td><td>Issue covered in the lesson</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Working with descriptive text</td><td>2</td><td>Equations and the seesaw (TIK)</td></tr>
<tr><td>3</td><td>Equations and sandwiches (TIK)</td></tr>
<tr><td>4 -7</td><td colspan="3">Subsequent lessons with different ways of working</td></tr>
<tr><td>8</td><td colspan="3">Evaluation – post-test at the end of the first block of lessons</td></tr>
<tr><td>9</td><td colspan="3">Evaluation – post-post-test 2 months after the end of the first block of lessons</td></tr>
</table>

Table 2. Diagram showing a fragment of the second research block

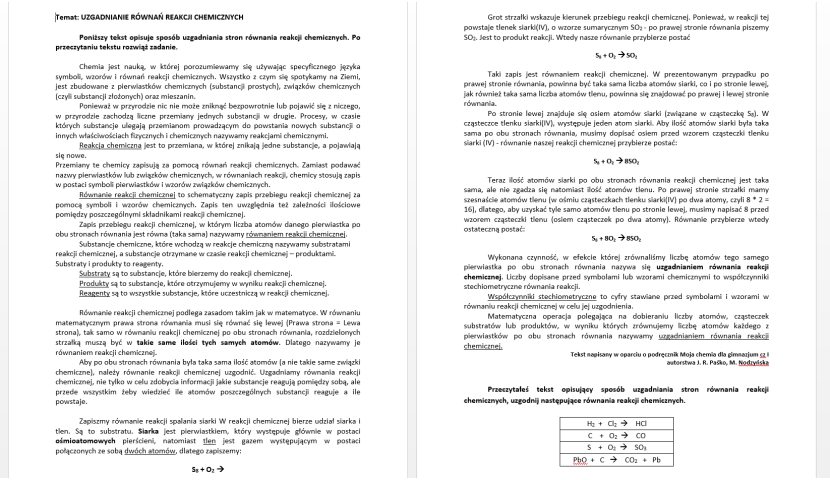
II RESEARCH BLOCK ON THE CHEMICAL LABORATORY			
Classes with Edutainment and ICT Edu-TIK		Classes without Edutainment and ICT Edu-TIK	
Sequence of lessons	Issue covered in the lesson	Sequence of lessons	Issue covered in the lesson
1-2	Lessons with different ways of working		
3	**Interactive virtual lab (TIK)**	**4**	**Working with text – picture instruction for laboratory work**
5-6	Subsequent lessons with different ways of working		
7	Evaluation – post-test at the end of the first block of lessons		
8	Evaluation – post-post-test 2 months after the end of the second block of lessons		

Characteristics of particular lessons

a) Block on the chemical reaction equation

LESSON No 1 Working with descriptive text

In the first lesson, the student worked with the text prepared by the teacher, which characterized the notions of: a chemical reaction, a chemical reaction equation, reactants, products, reagents, balancing chemical reaction equations, stoichiometric ratios and described step-by-step the way to balance both sides of the chemical reaction equation on a specific example. (The text was written based on the high school chemistry textbook Moja chemia dla gimnazjum cz. I J.R. Paśko, M. Nodzyńska).



Temat: UZGADNIANIE RÓWNAŃ REAKCJI CHEMICZNYCH

Poniższy tekst opisuje sposób uzgadniania stron równania reakcji chemicznych. Po przeczytaniu tekstu rozwiąż zadanie.

Chemia jest nauką, w której porozumiewamy się używając specyficznego języka symboli, wzorów i równań reakcji chemicznych. Wszystko z czym się spotykamy na Ziemi, jest zbudowane z pierwiastków chemicznych (substancji prostych), związków chemicznych (czyli substancji złożonych) oraz mieszanin.

Ponieważ w przyrodzie nic nie może zniknąć bezpowrotnie lub pojawić się z niczego, w przyrodzie zachodzą liczne przemiany jednych substancji w drugie. Procesy, w czasie których substancje ulegają przemianom prowadzącym do powstania nowych substancji o innych właściwościach fizycznych i chemicznych nazywamy reakcjami chemicznymi.

Reakcja chemiczna jest to przemiana, w której znikają jedne substancje, a pojawiają się nowe.

Przemiany te chemicy zapisują za pomocą równań reakcji chemicznych. Zamiast podawać nazwy pierwiastków lub związków chemicznych, w równaniach reakcji, chemicy stosują zapis w postaci symboli pierwiastków i wzorów związków chemicznych.

Równanie reakcji chemicznej to schematyczny zapis przebiegu reakcji chemicznej za pomocą symboli i wzorów chemicznych. Zapis ten uwzględnia też zależności ilościowe pomiędzy poszczególnymi składnikami reakcji chemicznej.

Zapis przebiegu reakcji chemicznej, w którym liczba atomów danego pierwiastka po obu stronach równania jest równa (taka sama) nazywamy równaniem reakcji chemicznej.

Substancje chemiczne, które wchodzą w reakcje chemiczną nazywamy substratami reakcji chemicznej, a substancje otrzymane w czasie reakcji chemicznej – produktami.

Substraty i produkty to reagenty.

Substraty są to substancje, które bierzemy do reakcji chemicznej.

Produkty są to substancje, które otrzymujemy w wyniku reakcji chemicznej.

Reagenty są to wszystkie substancje, które uczestniczą w reakcji chemicznej.

Równanie reakcji chemicznej podlega zasadom takim jak w matematyce. W równaniu matematycznym prawa strona równania musi się równać się lewej (Prawa strona = Lewa strona), tak samo w równaniu reakcji chemicznej po obu stronach równania, rozdzielonych strzałką muszą być w **takie same ilości tych samych atomów**. Dlatego nazywamy je równaniem reakcji chemicznej.

Aby po obu stronach równania była taka sama ilość atomów (a nie takie same związki chemiczne), należy równanie reakcji chemicznej uzgodnić. Uzgadniamy równania reakcji chemicznej, nie tylko w celu zdobycia informacji jakie substancje reagują pomiędzy sobą, ale przede wszystkim żeby wiedzieć ile atomów poszczególnych substancji reaguje a ile powstaje.

Zapiszmy równanie reakcji spalania siarki W reakcji chemicznej bierze udział siarka i tlen. Są to substratu. **Siarka** jest pierwiastkiem, który występuje głównie w postaci **ośmioatomowych** pierścieni, natomiast tlen jest gazem występującym w postaci połączonych ze sobą dwóch atomów, dlatego zapiszemy:

$S_8 + O_2 \rightarrow$

Grot strzałki wskazuje kierunek przebiegu reakcji chemicznej. Ponieważ, w reakcji tej powstaje tlenek siarki(IV), o wzorze sumarycznym SO_2 - po prawej stronie równania piszemy SO_2. Jest to produkt reakcji. Wtedy nasze równanie przybierze postać

$S_8 + O_2 \rightarrow SO_2$

Taki zapis jest równaniem reakcji chemicznej. W prezentowanym przypadku po prawej stronie równania, powinna być taka sama liczba atomów siarki, co i po stronie lewej, jak również taka sama liczba atomów tlenu, powinna się znajdować po prawej i lewej stronie równania.

Po stronie lewej znajduje się osiem atomów siarki (związane w cząsteczkę S_8). W cząsteczce tlenku siarki(IV), występuje jeden atom siarki. Aby ilość atomów siarki była taka sama po obu stronach równania, musimy dopisać osiem przed wzorem cząsteczki tlenku siarki (IV) - równanie naszej reakcji chemicznej przybierze postać:

$S_8 + O_2 \rightarrow 8SO_2$

Teraz ilość atomów siarki po obu stronach równania reakcji chemicznej jest taka sama, ale nie zgadza się natomiast ilość atomów tlenu. Po prawej stronie strzałki mamy szesnaście atomów tlenu (w ośmiu cząsteczkach tlenku siarki(IV) po dwa atomy, czyli 8 * 2 = 16), dlatego, aby uzyskać tyle samo atomów tlenu po stronie lewej, musimy napisać 8 przed wzorem cząsteczki tlenu (osiem cząsteczek po dwa atomy). Równanie przybierze wtedy ostateczną postać:

$S_8 + 8O_2 \rightarrow 8SO_2$

Wykonana czynność, w efekcie której zrównaliśmy liczbę atomów tego samego pierwiastka po obu stronach równania nazywa się **uzgadnianiem równania reakcji chemicznej**. Liczby dopisane przed symbolami lub wzorami chemicznymi to współczynniki stechiometryczne równania reakcji.

Współczynniki stechiometryczne to cyfry stawiane przed symbolami i wzorami w równaniu reakcji chemicznej w celu jej uzgodnienia.

Matematyczna operacja polegająca na dobieraniu liczby atomów, cząsteczek substratów lub produktów, w wyniku których zrównujemy liczbę atomów każdego z pierwiastków po obu stronach równania nazywamy uzgadnianiem równania reakcji chemicznej.

Tekst napisany w oparciu o podręcznik Moja chemia dla gimnazjum cz I autorstwa J. R. Paśko, M. Nodzyńska

Przeczytałeś tekst opisujący sposób uzgadniania stron równania reakcji chemicznych, uzgodnij następujące równania reakcji chemicznych.

$H_2 + Cl_2 \rightarrow HCl$
$C + O_2 \rightarrow CO$
$S + O_2 \rightarrow SO_3$
$PbO + C \rightarrow CO_2 + Pb$

Figure 1. Text on balancing chemical reaction equations

LESSON No 2 Working with the computer. Equations and the seesaw.

In the second lesson, the student worked using a computer simulation of the equation and the seesaw. Tasks involved balancing the chemical reaction equation using a seesaw. Each time, the ends of the seesaw visualized the types and number of particular molecules in the reactants and products. After performing the task, the student had additional one-time opportunity to play the didactic game based on the exercise of balancing the sides of the chemical reaction equation with the use of scales. The fact that after finishing the game the student asked the teacher for permission to play the game two more times is noteworthy. With each new game, they had to balance new chemical equations. The results obtained by the student during the games are as follows: first game: 4/10 points, second game: 6/10 points, third game: 7/10 points.

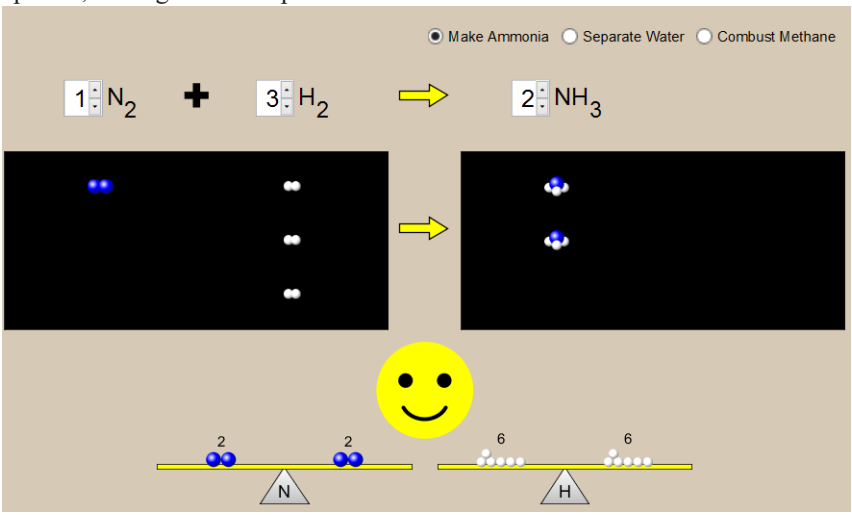


Figure 2. Simulation of the equation and the seesaw https://phet.colorado.edu/en/simulation/balancing-chemical-equations

LESSON No 3 Working with the interactive whiteboard. Equations and sandwiches.

In the third lesson, the student worked with the interactive whiteboard using a simulation of equations and sandwiches. The task to solve was to determine the quantity of products and the so-called residue based on the quantity and type of molecules selected in the reactants. After finishing the task, the student had also an opportunity to play a didactic game based on the same principle.

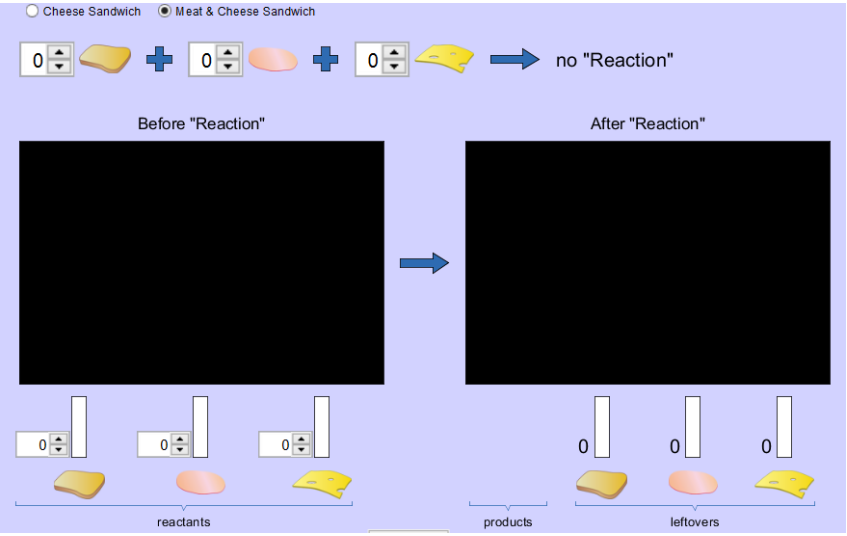


Figure 3. Simulation of the equation and sandwiches https://phet.colorado.edu/en/simulation/reactants-products-and-leftovers

b) Block on the chemical laboratory

LESSON No 3 Interactive virtual lab

In this class, the student worked with the use of the computer application, that is interactive virtual lab Late nite labs Macmillan Learning. The task was to conduct the experiment concerning the reaction of zinc with hydrochloric acid. During the class, the student worked with the interactive lab, where they designed and step-by-step performed the experiment online. In the beginning, the student adapted the lab to their preferences and then started to perform the task of a single displacement reaction.

While working with the student with learning difficulties, an undoubtful advantage of virtual labs is the fact that, among others:

- they can experiment in a safe environment,
- they can repeat the experiment as many times as they want (in the absence of sufficient perception to ensure maximum understanding of the subject of reaction/process) without generating additional costs,
- they can also zoom in or zoom out the view.

However, this does not change the fact that it is much better when the students perform experiments themselves with real reagents. On the other hand, in order to teach students the correct reasoning and drawing conclusions from experiments, interactive computer experiments should be used (Nodzyńska & Cieśla, 2016).

Virtual labs are available on the websites of many universities such as:

- http://onlinelabs.in/chemistry,
- http://www.chemcollective.org/vlab/vlab.php,
- http://www.chem.ox.ac.uk/vrchemistry/livechem/transitionmetals_content.html,
- http://www.virtlab.com/,
- http://www.onlinechemlabs.com/,
- https://latenitelabs.com/chemistry/,
- http://chemlab.byu.edu/ (Nodzyńska, 2015), so the possibility of their use should not pose major problems.

It is widely believed that nothing can replace real-life experiments in the real lab, but in the case of this student, what should be considered is their learning dysfunctions and poor manual skills. Therefore, assessing their preferences for lessons in the block, the student appreciates, among others, computer experiments and the teacher's demonstration (discussed in Kopek-Putała & Nodzyńska, 2015) because they do not reveal their learning dysfunctions. This proves that, while planning work with the students, we must also take into account their preferences and limitations.

However, the results of the conducted research in this block show that, in these lessons, the increase of knowledge was not the highest. The highest increase of knowledge was recorded in the lesson with an educational film and verbal instruction discussed by the teacher (detailed results will be discussed in other publications).

Figure 4. Simulation – interactive laboratory - Late nite labs (http://latenitelabs.com/interactive-labs/)

The discrepancy between the student's preferences and clear evidence in the form of the increase of knowledge is a challenge for the teacher: What is more important at a given time and what is the proportion of "fun" and "curiosity" that should be maintained in relation to "hard" science?

LESSON No 4 Working with text – picture instruction for laboratory work

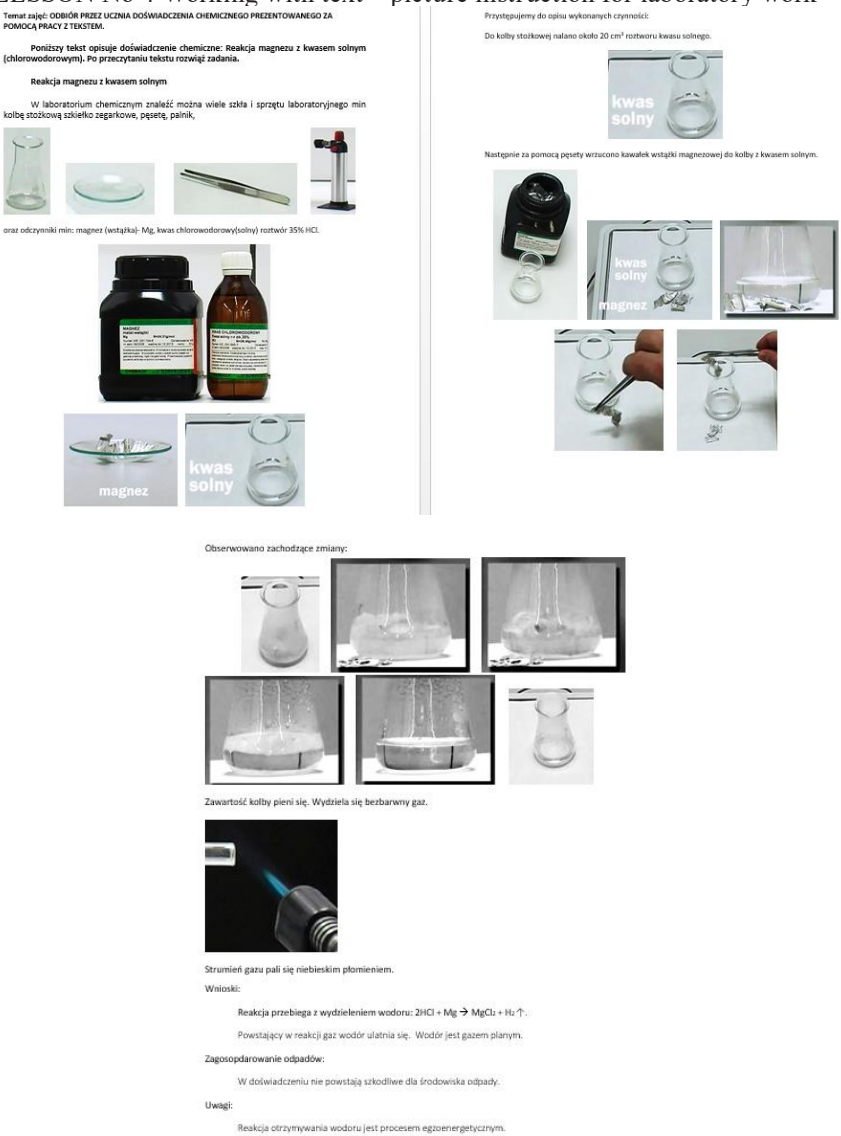


Figure 5. Written and picture instruction for laboratory work

In this class, the student worked with the picture instruction bearing a short written comment. They student could see the images of glass and the equipment needed to carry out the experiment, needed reagents, as well as the stages of performing the experiment, step by step, and read the corresponding descriptions. This instruction was prepared based on the materials of the ZamKor publishing house - Film Library of the Chemistry Teacher. Chemistry Experiments Part 2 by A. Danel, B. Jarosz, E. Kulig, A. Warchoł (https://chemia.zamkor.pl/artykul/67/422-filmowe-biblioteki-nauczyciela-chemii/).

Both classes with Edu-ICT and No-Edu-ICT were conducted by the same teacher, who declared no preferences for the use of tools.

Table 1 shows that the classes using Edu-ICT took place after classes with No-Edu-ICT. This calls into question the point of using the delayed post-test. However, in view of the entire research, the delayed post-test is necessary because, as can be seen in the later part of the research (second block, Table 2), research was started by conducting classes with Edu-ICT. In addition, one of the student's difficulties identified by the Psychological and Pedagogical Counseling Center is a "lack of durability of knowledge". The student quickly forgets what he learned in the previous lesson, and therefore such a procedure was implemented.

Table 3. Example of student evaluation

<table>
<tr><td colspan="3">STUDENT EVALUATION</td></tr>
<tr><td>Number</td><td>Question</td><td>Answer</td></tr>
<tr><td>1</td><td>In these classes, I liked the most:</td><td></td></tr>
<tr><td>2</td><td>In these classes, I liked the least:</td><td></td></tr>
<tr><td>3</td><td>I remembered best:</td><td></td></tr>
<tr><td>4</td><td>I remembered the least:</td><td></td></tr>
<tr><td>5</td><td>Is this way of learning interesting for you:</td><td>YES, I HAVE NO OPINION, NOT</td></tr>
<tr><td>6</td><td>The general assessment of the lesson:</td><td>☺ 😐 ☹</td></tr>
<tr><td>7</td><td>The assessment of my knowledge after the lesson:</td><td>5, 4+, 4, 3+, 3, 2+, 2, 1+, 1</td></tr>
<tr><td>8</td><td>The assessment of my mood before the class:</td><td>☺ 😐 ☹</td></tr>
<tr><td>9</td><td>The assessment of my mood after the class:</td><td>☺ 😐 ☹</td></tr>
<tr><td>10</td><td>Which way of learning is the most interesting for you:</td><td>a) Lesson on which I worked with the text
b) Lesson on which I worked with the computer
c) Lesson on which I worked with an interactive whiteboard</td></tr>
<tr><td>11</td><td>Rate how interesting was work within particular lessons on a scale of 1 to 4 (1 – uninteresting, 2 – not very interesting, 3 – interesting, 4 – very interesting)</td><td><table><tr><th>The way of working class</th><th>Rating</th></tr><tr><td>Working with descriptive text</td><td>1 2 3 4</td></tr><tr><td>Working with the computer</td><td>1 2 3 4</td></tr><tr><td>Working with the interactive whiteboard</td><td>1 2 3 4</td></tr></table></td></tr>
</table>

The research tool was a questionnaire, which included:

- 4 questions on knowledge (knowledge and skills) of varying structure: open-ended questions and single-choice closed-ended questions, some of them supplemented with drawings. Among all the questions, 3 were selected for the analysis, while the others were treated as supportive.

- 6 questions on the student's attitude of varying structure: open-ended questions and single-choice closed-ended questions,
- 3 closed-ended questions on the expression of feelings and emotions (Tab. 3).

Questionnaire after the class with Edu-ICT in the first block and No-Edu-ICT in the second block contained 2 additional single-choice closed-ended questions on the assessment of the student's preferences for each type of class.

In addition, functional behavior assessment observation form was implemented during the research, which will be discussed in another article.

Results

The Tables 4 and 5 show the results achieved by the student in each exercise. During the assessment of the student's knowledge, the following scoring system of the student's answers was applied: 0 – wrong answer or lack of answer, 1 – correct answer, ½ – partially correct answer.

Table 4. Results achieved by the student in the block on chemical reaction equation

Type of classes: Classes without Edutainment and ICT No-Edu-TIK					**Type of classes: Classes with Edutainment and ICT Edu-TIK**				
Name classes	**Number of points**				**Name classes**	**Number of points**			
	Pretest		**Posttest**			**Pretest**		**Posttest**	
	Number of questions	**Number of points**	**Number of questions**	**Number of points**		**Number of questions**	**Number of points**	**Number of questions**	**Number of points**
Working with descriptive text	**1**	0	**1**	½[1]	Equations and the seesaw	**1**	½	**1**	½
	3	0	**3**	0		**3**	½	**3**	1
	4	0	**4**	0		**4**	0	**4**	1
Total	0		½		Total	1		2 ½	
Increase	½ pkt				Increase	1 ½ pkt			
					Equations and sandwiches	**1**	½	**1**	½
						3	1	**3**	1
						4	1	**4**	1
					Total	2 ½ pkt		2 ½ pkt	
					Increase	0 pkt			

The results achieved by the student in the block: Chemical reaction equation (Fig. 6)

In the class devoted to working with descriptive text, in the pre-test, the student did not score any points, whereas, in the post-test, they received ½ point. It represents knowledge increase equal to ½ point. In the class on equations and the seesaw using a computer, the student scored 1 point in the pre-test, whereas, in the post-test, they received 2½ points. The increase in knowledge in this class is 1½ points. The results obtained in the class on equations and sandwiches are as follows: both in the pre-test and post-test, the student received the same number of points (2½). Therefore, there was no increase in knowledge.

Table 5. Results achieved by the student in the block on chemical laboratory

Type of classes: Classes with Edutainment and ICT Edu-TIK					**Type of classes: Classes without Edutainment and ICT No-Edu-TIK**				
Name classes	**Number of points**				**Name classes**	**Number of points**			
	Pretest		**Posttest**			**Pretest**		**Posttest**	
	Number of questions	**Number of points**	**Number of questions**	**Number of points**		**Number of questions**	**Number of points**	**Number of questions**	**Number of points**
Interactive virtual lab	**1**	½	**2**	1	Working with text – picture instruction for laboratory work	**1**	½	**2**	1
	2	1	**3**	½		**2**	0	**3**	½
	4	0	**4**	½		**4**	½	**4**	½
Total	1 ½		2		Total	1		2	
Increase	½ pkt				Increase	1 pkt			

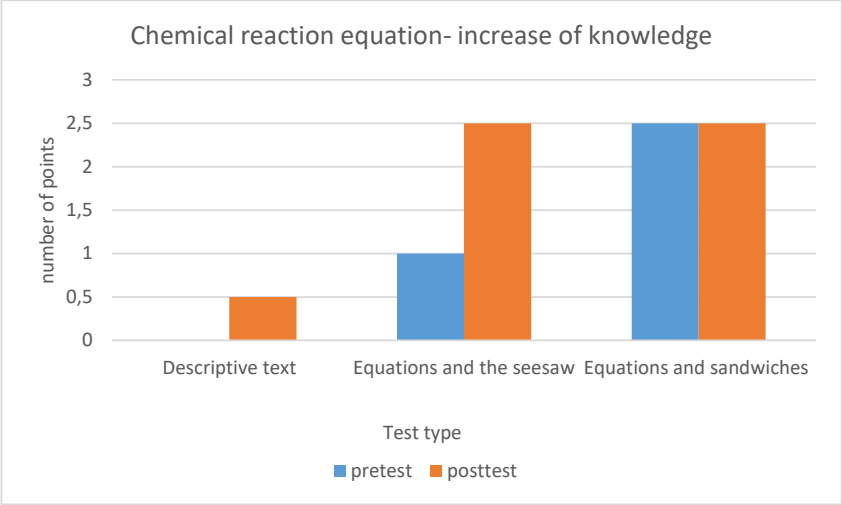


Figure 6. Increase in knowledge in the block on chemical equations

The results achieved by the student in the block: Chemical laboratory (Fig. 7)

The class in which the student worked with a virtual laboratory allowed them to achieve the following results: 1½ points in the pre-test and 2 points in the post-test. The increase in knowledge is ½ point. The results obtained in the class in which the student worked with a written and picture instruction for laboratory work are as follows: 1 point in the pre-test and 2 points in the post-test. The increase in knowledge is 1 point.

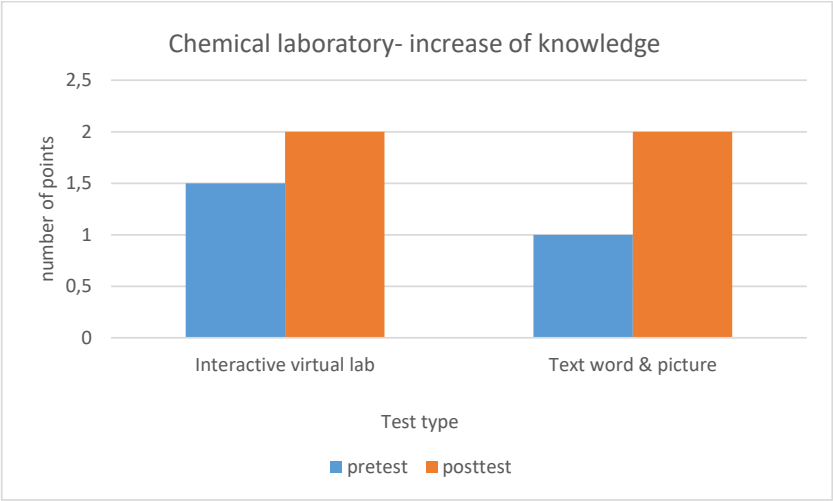


Figure 7. Increase in knowledge in the block on Chemical laboratory

Conclusions

Thanks to games, students with learning disabilities, in a friendly atmosphere, can acquire knowledge, which initially presented in the traditional way could seem complicated to them. Changing attitudes towards learning can play a key role before using traditional ways of working. However, a critical analysis of selected teaching aids should be made in order to avoid the ones whose preparation for classes is hard and time-consuming for the teacher. Some of the teaching aids are effort-intensive in terms of their preparation and give a small increase in knowledge. Regular achievement of a small knowledge increase by the student (despite high motivation to learn) in the event of a high above-average commitment of the teacher could result in teacher demotivation.

Teaching students with learning difficulties requires a comprehensive look. Attention should be paid not only to student achievement but also to a motivating factor. The motivating factor is very important in such students because sometimes the change of attitude opens the student to a desire to acquire knowledge in a given field. Methods based on games often bring weaker results in terms of an increase of knowledge in relation to teaching without the use of games. There are, however, important for the formation of proper motivation to learn. They should therefore be used to produce a proper "working atmosphere", which might promote greater achievements of students with learning difficulties.

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Value of children's literature as a source of information about biology and ecology of pollinating insects

Introduction

Biodiversity is important for the existence of life on Earth. Every living organism is an important part of the ecosystem, because it is linked to a number of dependencies with other organisms. Some interspecific interactions are so specific that the existence of one species is closely dependent on the existence of another. In the case of extinction of one of them, the other is not viable. This kind of dependence combines many of the plants and pollinating insects. In Poland 249 of the 469 species of angiosperms placed on the Polish red list needs insect to produce seeds/offspring (Zych & Jakubiec, 2008). It is estimated that the reproduction of about 78% of the Polish flora depends on the participation of animals, especially insects (Majewski, 2014).

The state of biodiversity is a determinant of the quality of human life (Rosin et al., 2011). In addition, research conducted in the UK showed that the availability of green areas such as parks, gardens or forests have long-lasting positive effect physical condition of man. People living in the city, where there are more areas to allow contact with nature, are less prone to depression and anxiety disorders. Associating people with nature reduces stress due to the fast pace of life, which makes it easier to make the right decisions and to communicate with others. This increases the level of satisfaction with everyday life and increases the psychological resistance to failure (Alcock et al. 2014).

Insects are the most numerous group of animals on Earth, which is characterized by large morphological differentiation. So far, over million species are described worldwide. In Europe, there are approximately 50 000 species of insects, while in Poland about 30 000. More than a half of the domestic entomofauna are the representatives of beetles (Coleoptera), flies (Diptera) and bees, ants and wasps (Hymenoptera). Adaptation developed over millions of years of evolution have enabled the insects to occupy different environments. Many insect species are adapted to extreme conditions of life and in most terrestrial ecosystems they play very important functions. In addition to the role of pollinators of plants, they provide a broad base of food for other organisms, regulating at the same time number of other arthropods by predation. Saprophagous insects contribute to the decomposition of dead organic matter, improving circulation of microelements and taking part in the processes of soil formation (Nowacki, 2000).

The main role in the pollination of angiosperms plays superfamily of bees (Apoidea) of about 20 000 species worldwide. European fauna includes representatives of 7 separate families: Colletidae, Halictidae, Andrenidae,

Melittidae, Megachilidae, Anthophoridae and Apidae (Banaszak et al., 2000). In Poland 450 species of insects belonging to the abovementioned families are found. Representatives of this insect family are honeybees (Apis mellifera). They are known to the public due to substances produced by them and used in the food industry, cosmetic and pharmacy. However, the value of bee products is less than the benefits of pollination by these insects (Majewski 2014).

Other pollinating insects belonging to the bee family (Apoidae) are bumblebees (Bombus sp.). This genus includes about 300 species of insects, while in Poland there is 29 species. Bumblebees unlike honeybees effectively pollinate plants grown in confined spaces, eg.: in greenhouses (Pruszyński, 2007). In addition, more efficiently than honeybees pollinate the tubular flowers of red clover. Longer proboscis in bumblebees, enables them to access the nectar contained in the bottom of the flower (Teper, 2007). Solitary bees also take very important part in the pollination. Increasingly important in the pollination of orchards gain mason bees (Osmia sp.), which are easy and inexpensive in rear (Biliński & Teper 2004).

Less important in the pollination of angiosperms are flies (Diptera), butterflies (Lepidoptera) and beetles (Coleoptera). These insects are involved in pollination of respectively: 33%, 11% and 3% of species of angiosperms placed on the Polish red list (Zych & Jakubiec 2008).

In recent decades there has been a significant reduction of biodiversity on a global scale. This process concerns also pollinating insects. In Poland the number of honeybee colonies decreased from 2.5 million in 1985 to 1,123 million in 2009 (Majewski, 2009; 2011). The greatest loss in the number of bees was recorded in the United States, where in 2006 came to the extinction 30-90% of bee colonies. However, this phenomenon affects many other European countries (Strachecka & Demetraki-Palaeologus, 2011). The phenomenon is called (CCD - Colony collapse disorder) and consists of a mass extinction of adult honeybee workers departing for the benefit, without which the survival of the colony is impossible.

The phenomenon of CCD consists of many factors. One is the use of chemicals in agriculture. As a next significant cause of bees decline is considered pathogenic organisms: viruses, bacteria, fungi, protozoa and mites, for example: Acarapis woodi, Varroa destructor (Glinski & Kostro, 2007).

It should be noted that these factors have a negative impact not only on health and life of bees, but also other pollinators. Evidence for this are the changes observed in population Bombus sp. in 11 countries of Western and Central Europe. At the beginning of the twentieth century in this area it was found 60 species and sub-species of bumblebees and cuckoo bumblebees. By the year 2000 throughout the study area, 4 species of insects have been recorded to be extinct. Authors noted that 16 bumblebee species were classified as critically endangered (CR), 22 as endangered (EN), 38 as vulnerable (VU) and 38 as Near

Threatened (NT). Kosior et al (2007) have identified as many as 21 different factors adversely affecting the populations of Bombus sp., but analysis showed that very negative effect on bumblebees have anthropogenic factors. The main risks for pollinating insect pose the fragmentation and destruction of their natural habitats, next factor is the previously mentioned single-crop farming, and the use of chemicals in agriculture. Other hazards arising from human activities include heavy metal pollution, grass burning, the introduction of alien plant species and alien pollinating insects (Kosior et al., 2007).

The process of pollination is one of the ecosystem services – processes from which mankind benefits without paying for it (Rosin et al., 2011). Deficiencies in the number of pollinators cause the deterioration of the quality of the crop. Evidence of this phenomenon is the formation of shapeless and about 20% smaller strawberry and raspberry fruit as compared to fruits obtained from flowers pollinated by bees. A similar effect was observed in the absence of the participation of bees in pollination of flowers of rape and sprouts, there were 20-40% less seeds than with pollination of plants by bees (Majewski, 2009).

In many countries, attempts were made to estimate the value of ecosystem services provided by pollinators. The estimates take into account the pollination of crops in the European Union in the years 1991-2009 amounts to 14.6 billion euros per year. In the United States in 2000 - 14.6 billion dollars. In the UK in 2007 - 918 million pounds. Studies carried out in Poland in 2008 made it possible to estimate the value of pollination of main crops at 0.6-1.2 billion zlotych (Majewski, 2014). The values obtained by researchers from around the world are different from each other. They should not be taken literally, but are an important argument for the need to protect ecosystems. Trends in the number of pollinators in Poland and in the world are alarming, for this reason the subject requires attention of both scientists, and all the inhabitants of the Earth.

In the face of threats to biodiversity and the loss of pollinating insects more and more important are efforts to disseminate reliable knowledge about the functioning of wildlife and pollinators. Formal education is not enough. The Polish program of formal education on the subjects: biology and nature, does not allow to implement activities on the ecology of the species of pollinators and threats to biodiversity. Increasingly important task is to popularize the environmental knowledge through the non-formal education the media and literature. From an early age positive attitude to nature should be developed. This attitude is the basis of understanding of the needs of environmental protection and maintaining sustainable ecosystems. In society there is a great need to spread knowledge about insects, especially pollinating ones. Effective conservation requires public participation in efforts to protect biodiversity. Therefore it is important to give reliable knowledge about nature to preschool children. This will guarantee a conscious action of successive generations respecting the natural

environment. Understanding that humankind existence depends on other living organisms and nature, is crucial to feel respect for all living organisms and a sense of responsibility for the world around us. It is compatible with the idea of sustainable development. According to this idea, society should strive for this level of resource utilization that will enable future generations to satisfy their needs through access to the same resources (Budniak, 2014).

The aim of this study is to assess availability and quality of literature about nature with particular emphasis to pollinating insects, dedicated to preschool children. We analyzed credibility of children's literature in two categories: overall theme of nature and entomological content. Children's literature plays important role in creating basic knowledge about processes we can observe in the environment. Therefore the quality of children's literature and the level of knowledge presented in it has significant influence on children's attitude towards nature and willingness to protect it.

Materials and methods

Analysis of the entomological content in children's literature

In the years 2015-2016 quantitative and qualitative research was carried out. The study proceeded in two stages - the first stage evaluated the availability in bookstores of children's literature about nature with a focus on the content on pollinating insects. In the second stage, an analysis of the content of selected positions in the entomological literature for children was performed. Assessment of the entomological content in the children's literature was based on the analysis of 51 books available in the bookstores in Krakow, Poland. The bookstores chose for our study has outlets in many Polish cities. It can therefore be assumed that the availability of the analysed literature in most Polish cities of our country is similar, and the results obtained in Krakow are representative and adequate to what we can find in bookstores in other regions of our country. Each of the 51 books were analysed in terms of the same 10 criteria.

Criteria for children's literature analysis

The first of these was to determine the number of species of insects presented in books using text. In the case of insects presented in the text, determination of systematic assignment was also made. In order to further analyse insects described in the literature, children's books were grouped in two categories: the first one - 39 books on the overall theme of nature and second one - 12 books directly related to entomological knowledge, dedicated to insects (Table 1. and Table 2.).

Table 1. List of books about the overall theme of nature

No.	Author(s) and book title (in polish)	Book number related to tab.3.
1	Sójka A., Perkowski P. (il.), Person S. (il.), 2011. Czytanki z obrazkami. Wyd. Papilon. Poznań.	1
2	Podgórska A., Nowicki A. (il.), 2012. Co się dzieje pod ziemią? Na wsi. Wyd. Aksjomat. Kraków.	2
3	Nawrocka E., 2014. Wokół nas. Zwierzęta. Wyd. Zielona Sowa. Warszawa.	3
4	Nesme A., Berkane N., Zarawska P. (tłum.), 2006. Marysia w ogrodzie. Wyd. Debit. Bielsko-Biała.	5
5	Wachowiak J., Głowińska A. (il.), 2015. Historyjki dla małych uszu. Wyd. Bis. Warszawa.	6
6	Berłowska K., Marlier M. (il.), 2015. Martynka poznaje zwierzęta. Pierwsza encyklopedia. Wyd. Papilon. Poznań.	7
7	Brykczyński M., Latour de D., 2014. Opowiem ci, mamo, co robią pająki. Wyd. Nasza Księgarnia. Warszawa.	8
8	Sarna K., Gensler A., 2015. Dwie minutki z bajki. Wyd. Wilga. Warszawa.	9
9	Jasiński M., Nowacki P., 2013. Detektyw Miś Zbyś na tropie. Lis, ule i miodowe kule. Wyd. Kultura Gniewu. Warszawa.	10
10	Casta S., Mossberg B., Biliński W. (tłum.), 2015. Mrówka Zofia opowiada o kwiatach, drzewach, jagodach, grzybach. Wyd. Multico. Warszawa.	11
11	Strzałkowska M., Miler Z. (il.), Miler K. (il.), 2015. Krecik i motyle. Wyd. Bajka. Warszawa.	12
12	Kozłowska U., Strzeszewska A., 2015. Modna świnka. Wyd. Wilga. Warszawa. Wyprodukowano w Polsce	13
13	Kwiecińska M., Krogulska-Nowicka D., 2015. Na spacerze. Wyd. Zielona Sowa. Warszawa.	15
14	Podgórska A. (red.), Żyśk A. (konsultacja nauk.), Karlik B (korekta), Adamus J. (il.), 2008. Dzikie zwierzęta. Owady. Ptaki. Wyd. Aksjomat. Kraków.	17
15	Paviet B., Giraud F., Decaux G. (il.), Kozłowski J. (tłum.) 2001. Życie zwierząt. Wyd. Hubert. Warszawa.	18
16	O'Neill A., Kraszewska M. (tłum.), 2004. Ciekawe dlaczego pająki tkają sieci. Wyd. Book House. Bydgoszcz.	19
17	Romanowicz R., 2015. Zwierzęta. Wyd. Tashka. Warszawa.	20
18	Mizielińska A., Mizieliński D., 2015. Pod ziemią. Pod wodą. Wyd. Dwie Siostry. Warszawa.	24
19	Wechterowicz P., Dziubak E., 2015. Uśmiech dla żabki. Wyd. EZOP Agencja Edytorska. Warszawa.	25
20	Scott K. (il.), Broom J., Rosłan K. (tłum.), 2015. Animalium. Wyd. Dwie Siostry. Warszawa.	27
21	Chrystall C. (il.), Goldsock G., Zarawska P. (tłum.), 2007. Piesek Łatek. Wyd. Debit. Bielsko-Biała.	28
22	Bădescu R., Chaud B. (il.), Skalska K. (tłum.), 2014. Pomelo ma się dobrze pod swoim dmuchawcem. Wyd. Zakamarki. Poznań.	29
23	Mathers M. (il.), Willman A., 2008. Owieczka, co się wybiera do fryzjera. Wyd. Debit. Wyprodukowano w Chinach.	30
24	Malicki M., Ludwikowska J. (il.), 2008. Nasze zwierzęta. Wyd. Book House.	31
25	Noa S., Berska J. (tłum.), 2008. Zwierzęta i ich środowisko. Wyd. MAK. Kraków.	32
26	Aladjidi V., Tchoukrie E., Kamińska-Maurugeon M., Skalska K. (tłum.), 2015. Ilustrowany inwentarz zwierząt. Wyd. Zakamarki. Poznań.	33
27	Davies N., Layton N. (il.), Jędryas J. (tłum.), 2013. Robale, czyli co nas zżera. Przegląd pasożytów. Wyd. Dwie Siostry. Warszawa.	34
28	Bauman A., Byliniak M. (tłum.), 2013. Narwańcy, uwodziciele, samotnicy. Atlas tych, co fruwają, skaczą i nurkują. Wyd. Dwie Siostry. Warszawa.	36
29	Davies N., Layton N. (il.), Jędryas J. (tłum.), 2011. Gadu gadu, kwa kwa, czyli zwierzęce rozmówki. Wyd. Dwie Siostry. Warszawa.	37
30	Apsley B., Wyd. Wilga (tłum.), 2014. Zwierzęta i ich dzieci. Wyd. Wilga.	39
31	Wasilewicz G., Nawrocka E. (il.), Wrzosek P. (oprac. graficzne), 2015. Owieczka. Wyd. Aksjomat. Kraków.	40
32	Drabik W., Nowak A. (il.), 2015. Żaba modnisia. Wyd. Skrzat. Kraków.	41
33	Zawadzka D., Nowak A. (il.), 2011. Miś Gaduła. Wyd. Skrzat. Kraków	42
34	La Fontaine de J., Krasicki J. (tłum.)., Molenda M. (il.), 2015. Czapla, ryby i rak. Wyd. Liwona. Warszawa.	43
35	Ostrowska-Myślak M. (il.), Pruchnicka E., 2014. My jesteśmy krasnoludki. Wyd. Wilga. Warszawa.	44
36	Dębicka-Cieszyńska A., 2015. W lesie i na łące. Wyd. Metody Krakowskiej. Kraków.	45
37	Carle E., Perzyna M. (tłum.), Butkiewicz W. (korekta), 2014. Pajączek. Wyd. Tatarak. Warszawa.	49
38	Beaumont E., Michelet S., Boradyń-Bajkowska A. (tłum.), 2013. Obrazki dla maluchów. Przyroda. Wyd. Olesiejuk. Ożarów Mazowiecki.	51
39	Galewska-Kustra M., Kłos J. (il.), 2015. Z muchą na luzie ćwiczymy buzie, czyli zabawy logopedyczne dla dzieci. Wyd. Nasza Księgarnia. Warszawa.	38

Table 2. List of books with entomological content

No.	Book title	Book numer related to tab.3.
1	Volke G., Moserly D., 2011. Pani biedronka. Wyd. ARTI. Wyprodukowano w Chinach.	4
2	Todorski S., Walaszek J., 2012. Mali sąsiedzi. Wyd. Liwona. Warszawa.	14
3	Möller A., Samborski W. (tłum.), 2007. Jak owady troszczą się o swoje dzieci? Wyd. Multico. Warszawa.	16
4	Carle E., Perzyna M. (tłum.), Podhajska K. (red.), 2015. Biedronka. Wyd. Tatarak. Warszawa.	21
5	Wechterowicz P., Dziubak E. (il.), 2012. W pogoni za życiem. Wyd. EZOP Agencja Edytorska. Warszawa.	22
6	Carle E., Lutz M. (tłum.), 2015. Bardzo głodna gąsienica. Wyd. Tatarak. Warszawa.	23
7	Socha P., Grajkowski W., 2015. Pszczoły. Wyd. Dwie Siostry. Warszawa.	26
8	Mamagu, 2015. Bardzo zabiegana mrówka. Wyd. Wilga. Warszawa.	46
9	Mamagu, 2015. Bardzo pracowity świetlik. Wyd. Wilga. Warszawa.	47
10	Bajerowicz K., Brykczyński M., 2015. Opowiem ci, mamo, skąd się bierze miód. Wyd. Nasza Księgarnia. Warszawa.	48
11	Bajerowicz K., Brykczyński M. 2013. Opowiem ci, mamo, co robią mrówki. Wyd. Nasza Księgarnia. Warszawa.	50
12	Mamagu, 2015. Bardzo zdolna biedronka. Wyd. Wilga. Warszawa	35

The third criterion was the correctness of book contents (from biological point of view). Particular attention was paid to substantive errors regarding insects. Another element of the analysis was to determine whether children's books included the contents of the ecological role of insects in the environment. It was also checked if the presented behaviour of insects are authentic and are a reliable source of information on the biology of the species. Next criterion we took into account was anthropomorphisation, or transmitting to insects attributes and behaviours typical to people. We also determine if in analysed literature, insect interaction with other living organisms are presented in authentic way. The eighth criterion of the analysis was to determine the availability of information about the consequences of the extinction of insects or information regarding their protection. A very important point in review of the literature for children was ninth criterion - evaluation what kind of relation is shaped in the readers towards insects. Attitudes towards insects were classified into one of three categories: positive, neutral, negative. The last, tenth criterion of the analysis was to evaluate the information aimed at shaping attitudes towards the environment among young audiences.

Results

The results of the analysis of children's literature were grouped into three categories according to criteria subject. The first category form the criteria for determining the correct substantive content in children's literature (criteria III and V). The second category were classified criteria for the ecological importance of insects (criteria IV, VII and VII). Third category (criteria VI, IX and X) concerns the attitude towards insects created by children's literature. In addition, the diversity of insects presented in the text and graphics was examined.

The contents of children's literature

The results concerning the content of children's literature are presented in Table 3. Information about the titles and authors of number of books are included in tables 1 and 2 (last column). More details are presented in the following sections. The first section contains a list of insects included in the text of analysed children's literature. The following sections are the other criteria for the analysis of literature: correct biological content of the books, the ecological importance of insects and attitude created towards insects.

Table 3. The results of the analysis of children's literature according to ten criteria

Book no.	criteria									
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
1	1	7	yes	yes	authentic	yes	no	no	positive	no
2	5	5	no	no	authentic	no	no	no	neutral	no
3	0	5	no	no	authentic	yes	no	no	positive	no
4	4	5	yes	yes	authentic	yes	no	no	positive	no
5	3	2	yes	no	authentic	yes	no	no	positive	no
6	9	6	yes	no	fictitious	yes	no	no	neutral	no
7	13	9	no	yes	authentic	no	yes	no	positive	no
8	6	15	no	no	authentic	yes	no	no	positive	no
9	2	3	no	no	fictitious	yes	no	no	positive	no
10	1	2	yes	no	authentic	yes	no	no	neutral	no
11	54	51	no	yes	authentic	yes	yes	no	positive	yes
12	0	1	yes	no	authentic	yes	no	no	negative	yes
13	0	3	yes	no	authentic	yes	no	no	positive	no
14	8	7	no	no	authentic	yes	no	no	positive	no
15	1	2	no	no	authentic	no	no	no	neutral	no
16	12	14	no	yes	authentic	no	yes	no	neutral	no
17	12	18	no	yes	authentic	no	yes	no	neutral	no
18	11	8	yes	no	authentic	no	yes	no	negative	no
19	36	39	no	yes	authentic	yes	yes	no	negative	no
20	3	3	yes	no	authentic	yes	no	no	positive	no
21	6	6	yes	yes	authentic	yes	yes	no	positive	no
22	3	3	no	no	authentic	yes	no	no	neutral	no
23	1	1	no	no	authentic	yes	no	no	neutral	no
24	8	8	no	no	authentic	no	yes	no	neutral	no
25	1	3	no	no	authentic	yes	no	no	neutral	no
26	20	4	no	yes	authentic	no	yes	yes	positive	yes
27	11	15	yes	yes	authentic	no	yes	no	neutral	no
28	0	2	yes	no	authentic	yes	no	no	neutral	no
29	2	4	yes	no	authentic	yes	no	no	neutral	no
30	0	3	yes	no	authentic	yes	no	no	positive	no
31	4	7	yes	yes	authentic	no	yes	no	positive	no
32	10	14	no	no	authentic	no	no	no	neutral	no
33	15	15	no	yes	authentic	no	yes	no	positive	no
34	18	8	yes	yes	authentic	yes	yes	no	neutral	no
35	1	1	yes	no	fictitious	yes	no	no	positive	no
36	82	82	yes	no	authentic	yes	no	yes	positive	no
37	10	9	yes	yes	authentic	yes	yes	no	positive	no
38	1	1	yes	no	fictitious	yes	no	no	positive	no
39	1	1	no	no	authentic	no	no	no	neutral	no
40	1	4	yes	no	authentic	yes	no	no	positive	no
41	0	8	yes	no	authentic	yes	yes	no	positive	no
42	1	4	yes	no	authentic	yes	no	no	positive	no
43	0	4	yes	no	authentic	yes	no	no	positive	no
44	0	3	yes	no	authentic	yes	no	no	positive	no
45	3	5	yes	yes	authentic	no	no	no	neutral	no
46	1	1	no	no	authentic	yes	no	no	positive	no
47	1	1	no	no	authentic	yes	no	no	positive	no
48	8	28	no	yes	authentic	yes	yes	yes	positive	no
49	1	1	no	no	authentic	no	yes	no	neutral	no
50	8	42	no	yes	authentic	yes	yes	no	positive	no
51	0	2	yes	no	authentic	no	no	no	positive	no

Legend:

I – number of insect species presented in the text; II – number of insect species presented in the pictures

III – factual errors ; IV – ecological role of the species in the environment

V – species behaviour ; VI – anthropomorphism

VII – interspecific interactions, VIII – consequences of species extinction or threats to the species

IX – created relationship towards insects

X – created attitudes to environmental protection

The insect species presented in the literature using text

Based on the analysis of 51 books we calculated the mean number of insects presented in the text of average book. This value is 8 insects of different systematic ranks per book. 76.5% of the analysed publications were books about the overall theme of nature. In their content we recorded 187 names of different insects of various ranks (from species to orders). These insects were representatives of 17 orders (Annex 1 and Tab. 4). The most frequently presented insect orders were: butterflies, bees (Hymenoptera), beetles and flies. Among the butterflies the most frequently presented species was the European Peacoc (Aglais io), Maculinea butterflies and the Swallowtail (Papilio machaon). The hymenoptera representatives presented in children's literature were: ants, bees, bumblebees and wasps. The most common beetle in the literature are ladybug, the European spruce bark beetle (Ips typographus) and dung beetles (Geotrupes). The most frequently mentioned by the authors representatives of Diptera are: mosquito and a fly. Authors of children books present definitely less representatives of other insect orders than mentioned above.

Table 4. The frequency of insect groups in the text of children's literature.

Order	Frequency in childrens literature
Lepidoptera	83
Hymenoptera	71
Coleoptera	65
Diptera	28
Orthoptera	22
Hemiptera	13
Odonata	9
Siphonaptera	6
Isoptera	4
Phthiraptera	3
Phasmatodea	2
Dermaptera	2
Blattodea	2
Mantodea	2
Collembola	1
Neuroptera	1
Ephemeroptera	1

The remaining 12 books (23.5%) were classified as focused on the entomological theme. In their contents we recorded 46 names of insects of different systematic ranks (from species to orders), which accounted for representatives of 10 insect orders (Tab. 5 and Tab. 6). Frequently mentioned insects represent orders of Hymenoptera, butterflies, beetles and flies. The most frequently reported representatives of Hymenoptera were bees and wasps. Insects belonging to the order Lepidoptera occur with a similar frequency. While among beetles clearly

most frequently mentioned were ladybugs. Among Diptera most frequently presented representatives were flies.

Table. 5. List of insect species that occur in the text of children's literature of overall entomological theme.

Lp.	species	Numer of books in which species occurs	Taxonomic position (order)
1	barciel pszczołowiec (*Trichodes apiarius*)	1	Lepidoptera
2	biedronka siedmiokropka (*Coccinella septempunctata*)	6	Coleoptera
3	bujanka większa (*Bombylius major*)	2	Diptera
4	bzyg prążkowany (*Episyrphus balteatus*)	1	Diptera
5	jętka pospolita (*Ephemera vulgata*)	1	Ephemeroptera
6	latolistek cytrynek (*Gonepteryx rhamni*)	1	Lepidoptera
7	makatka wełnista (*Anthidium punctatum*)	1	Hymenoptera
8	miesierka (Megachile Latr.)	1	Hymenoptera
9	modliszka zwyczajna *(Mantis religiosa*)	1	Mantodea
10	modraszek teleius (*Phengaris teleius*)	1	Lepidoptera
11	mrówka rudnica (*Formica rufa*)	6	Hymenoptera
12	mrówkolew (*Myrmeleon formicarius*)	1	Neuroptera
13	mszyce (Aphidoidea)	2	Hemiptera
14	mucha domowa (*Musca domestica*)	3	Diptera
15	murarka ogrodowa (*Osmia rufa*)	2	Hymenoptera
16	osa pospolita (*Vespula vulgaris*)	5	Hymenoptera
17	kopułka wysmukła (*Eumenes coarctatus*)	1	Hymenoptera
18	pasikonik zielony (*Tettigonia viridissima*)	2	Orthoptera
19	poświętnik (skarabeusz) (*Scarabaeus sacer*)	1	Coleoptera
20	pszczolinka ruda (*Andrena fulva*)	2	Hymenoptera
21	pszczoła miodna (*Apis mellifera*)	7	Hymenoptera
22	pszczoła olbrzymia (*Apis dorsata*)	1	Hymenoptera
23	rohatyniec (*Oryctes nasicornis*)	1	Hymenoptera
24	rusałka pawik (*Inachis io*)	2	Lepidoptera
25	szerszeń azjatycki (*Vespa mandarinia*)	1	Hymenoptera
26	świerszcz polny (*Gryllus campestris*)	1	Orthoptera
27	Świetlik świętojański (*Lampyris noctiluca*)	2	Coleoptera
28	Trzmiel ziemny (*Bombus terrestris*)	3	Hymenoptera
29	tutkarz cygarowiec (*Bycticus betulae*)	1	Coleoptera
30	Łątka zielona (*Coenagrion armatum*)	2	Odonata
31	Zawisak tawulec (*Sphinx ligustri*)	1	Lepidoptera
32	złotook pospolity (*Chrysopa perla*)	1	Neuroptera
33	zmiennik ziemniaczak (*Lygus pratensis*)	1	Hemiptera
34	zmierzchnica trupia główka (*Acherontia atropos*)	1	Lepidoptera
35	Żywicówka osowata (*Anthidium strigatum*)	1	Hymenoptera

Table. 6. Biodiversity of pollinating and nonpollinating insects described in the text of childrens literature about overall theme of nature

Insect order	Number of pollinating insects	Number of nonpollinating insects
Lepidoptera	2	1
Hymenoptera	6	1
Coleoptera	0	1

Factual correctness

Literature content was analyzed in terms of the substantive correctness (Tab. 7). In 27 out of 51 (53%) of analyzed children's books, there were factual errors. The errors related to the content of the text and illustrations.

Table 7. The correctness of factual content in children's literature

Criterium	Results of the analysis [% of books]	
	yes	no
Are there any factual errors?	53	47
Is insect behaviour presented in authentical way?	92	8

The most frequent errors occurring in the text included enclosing organisms belonging to other taxonomic groups to insects. An example of such a phenomenon is classification of ticks (representatives of arachnids) and Porcellionidae (representatives of Malacostraca) as insects.

In several books we found wrong descriptions of insect species presented in the photographs, for example: grasshopper signed as crickets and bumblebee defined as a honeybee. The mistake, which is worth noting, despite the fact that only appeared in one of the analyzed books was information on the development of insects. In the book "Animalium" (K. Scott and J. Broom) stated that all insects in their lifetime undergo metamorphosis, which results in the appearance of adult insect that "changes a lot."

Factual errors occurred more often in graphic form than in the text. The most frequent errors in the illustrated insects were a number of legs (usually two pairs instead of three) or total lack of legs. The second most common mistakes were irregularities in presentation of insects wings. Repeatedly ladybugs are portrayed with two pairs of membranous wings and a pair of outer covers or devoid of membranous wings, using covers to. Oversights also concerned other insects, for example: dragonflies equipped with one pair of wings instead of two pairs, bees with disproportionately small size of the wings in relation to the rest of the body, ladybugs by an abnormal number of spots on the covers.

Another criterion of analysis was to assess the authenticity of the behaviors among described insect species. 92% of analyzed literature were considered as books that described behavior rated as authentic, being a reliable source of information about the lifestyle of individual insect species. In children's literature the authors most often presented the development of insect from larval stage to the formation of adult form. In most cases, this process is imaged on the example of the butterfly (eg. Swallowtail). Less frequently than butterflies were described ants, bees, wasps and dragonflies.

Considerable attention was paid to the characteristics of social insects, especially ants and bees. Books considered the social structure and division of labour among individuals of different castes. The authors of two books ("Pszczoły", "Pod ziemią. Pod wodą") described the phenomenon of mating flight of ants and bees. The life of these insects in organized communities is possible through communication, such as secreted pheromones or dance performed by bees, which has also been considered by many authors. Several authors concluded in the content of books facts related to the construction of nests and egg deposition by some insects (including common wasp, representatives of Megachilidae, butterflies and moths).

The authors of several books presented what and how insects eat. The most commonly reported were butterflies and bees, feeding mainly on nectar and pollen of flowers. Less often were presented herbivore aphids, locusts, predatory ladybugs, parasitic fleas and lice. One book ("Animalium") specifies that some adult insects such as Attacus atlas, do not feed at all. The 5 books described mating rituals of insects: male songs that attract females (common green grasshopper (Omocestus viridulus), European mole cricket (Gryllotalpa gryllotalpa)), light signals (firefly (Lampyris noctiluca)) or smell signals (among Hemiptera representatives). Also five books contain information on some defence mechanisms of entomofauna. These are shown on the example of a ladybug hemolymph secreting an unpleasant odour and taste in an emergency situation, which is to deter predators. Others, such as hornets and wasps are equipped with a sting, which they use in case of threat. Other books drew readers attention to the color of praying mantis and moths providing them camouflage in an environment in which they live.

In 8% of analysed children's literature insects behaviour were considered fictitious, having no reflection in reality. Inauthentic behaviour of insects resulted from the anthropomorphisation, therefore, this procedure has been taken as one of the criteria for analysis.

Ecological importance of insects

One of the criteria was to assess knowledge presented in children's literature considering the role of insects in the environment. At least one function of insects

was mentioned in 17 out of the 51 items of literature, which is one-third of the tested material (Tab. 8). Insects functions presented most frequently in the literature were those that are important for the material benefit of man: production of honey, wax and other products used in industry like sourcing silk. Also pollination and pests biocontrol were presented as important benefits that humankind receives from insects.

Table 8. Ecological role of insects presented in children's literature

Book analysis criteria	results [%of books]	
	yes	no
Is the role of insects in environment presented?	33	67
Are interspecific interactions shown?	35	65
Is consequence of insects extinction or conservation status shown?	6	94

In 7 out of 17 books it was highlighted that insects, especially bees (less butterflies and bumblebees) play key role in the pollination of flowering plants. Only two books ("Pszczoły", "Martynka meets animals. The first encyclopedia") linked the process of pollination by insects to the formation of fruit, vegetables and seeds. However, in only one book ("Pszczoły") authors explained the relationship: seeds create new plants, which are important both for biodiversity formation and human prosperity. Also, in one book ("How insects take care about their children?) authors drew the reader's attention to the fact that insects are eaten by birds, spiders and predatory insects. The last function of the insects mentioned in two books ("Ciekawe dlaczego pająki tkają sieć", "Martynka meets animals. The first encyclopedia.") was the fact that invertebrates take part in purifying the soil by decomposition of dead organic matter.

In the following analysis of children's literature we determined that 35% of books show interspecific interactions involving insects. The most common type of interaction was predation. Insects are presented both as predators (ladybugs feed on aphids, dragonflies, grasshoppers and wasps that feed on smaller insects), as well as victims of predators (birds, spiders, fish, frogs and insects prey). The second type of interaction occurring between insects and other organisms and presented in children's books was mutualism. This relationship is shown mainly on the example of angiosperms and bees. Less frequently authors present this type of interaction on the example of ants breeding fungi to feed the larvae. In one book are given information about ants spreading seeds of hepatica, which they feed. In some books authors refer to the parasitism. There are examples of mosquitoes, horse-flies, fleas and lice feed on the blood of mammals, including humans.

In the vast majority of analysed books (94%) we did not found information about consequences of the extinction of individual species or the state of their risk. Only two books described consequences of the extinction of pollinators. First book as the consequence of pollinators extinction presented the lack of fruits and vegetables. The second book gave information about the Chinese province of Maoxian, where the plants are pollinated by people due to the total extinction of bees in this region.

Shaping attitudes toward insects

In 69% of analysed books insects possessed properties and / or behavior typical for humans (Tab. 9). The most common broadcast human characteristic, located in 15 books was the ability to smile. The second most common anthropomorphisation (11 books) was ability to speak - insects have a conversation or even function of the narrator. Seven books presented insects that had the characteristics of human appearance, such as wearing clothes, shoes, jewellery.

In order to illustrate some of the phenomena and behaviors occurring in the world of insects authors presented them very literally. A good example is presenting the mother bee with a crown on her head, bees dancing on one pair of legs or a grasshopper playing the violin. In the analyzed literature insects rarely received other human attributes: sometimes they used cutlery, food products for human consumption (lollipops, cakes, cheese), they drink beverages with cups, sleep in bed, sometimes they represent different professions.

In 31% of books no anthropomorphization was applied. These were books in which the insects were the main characters or narrators. Ten literature positions took the form of albums without plot, which shows the appearance and selected information on the ecology of animals, including insects. The content have been formulated in a factual, objective way, making it more suitable for older children.

Table 9. Shaping attitudes toward insects by children's literature

Criteria for analyzing the books	Results [%]		
	yes	no	
Is antropomorphization applied?	69	31	
Does it shape positive atiitudes toward environment?	6	94	
Attitude towards insects	positive	neutral	negative
	59	35	6

Attitude created towards insects by children's literature was assessed. It was found that the content of 30 of the 51 books forms a positive attitude to this animals. High impact on the optimistic perception of insect has a child-friendly graphic form, often assisted by anthropomorphisation. Most of the information forming positive attitudes involved stinging insects, which in many people arouse

fear. The authors pointed to the fact that these insects are not aggressive toward humans and attack them only if threatened. They also added that the bee stings are usually harmless to health.

In several books it was mentioned that insects are useful from human point of view. In one book there was an example of ladybugs feeding on aphids and thus protect horticultural crops. In some works, the text had the emotional colouring through adjectives describing insects as beautiful and friendly. Two books presented direct human contact with insects. They show situations in which man relax close to nature, observing butterflies, ants and ladybugs. In 35% of analysed books we found no effect on the attitude of the reader to insects. The contents of these books were devoid of emotional colouring.

In only 3 books we found assigning insects disadvantages, negatively perceived by humans. In two of these books parasitic insects, feeding on the blood of other organisms were called "vampires". Mosquitoes carrying malaria was defined as the "real killers". One of these books contained the description that the bugs "are looking for the sleeping people to bite them" and "beetles have no respect for the dead" ("Ciekawe dlaczego pająki tkają sieci"). In the third book, a negative attitude to insects was shaped by the statement that "greedy" caterpillars of butterflies injurious in home gardens.

The last criterion of analysis was attitude towards environmental protection. It was found that the content shaping these attitudes occurred in only 3 of the 51 books. The first book presents positive attitude by taking care for the plants in the gardens by watering them ("Krecik i motyle"). In the second book attention was drawn to the ban on breaking and destroying plant species threatened with extinction. While in the third book it was explained how you can contribute to the protection of pollinators. This book provides instructions how to build the hotel for bees by yourself.

Discussion and conclusions

Children's knowledge about biodiversity derive mainly from the media. Although there are many programs about nature, often they create wrong understanding of biodiversity. Very often programs present organisms that are most spectacular in appearance, live in extreme conditions and usually in the distant regions of the world. That results in misunderstanding of problems of local biodiversity, the existence of which children cannot realize (Ballouard et al. 2011). A survey conducted by Ballouard and co-authors (2011) on a group of French students has shown that children have better ability to recognize the photographs of exotic animals than local ones. In addition, the responses testify that children are more likely to protect species not known from their local environment. Species requiring priority protection are, according to them, giant panda and the

polar bear. While the local species were detected less frequently or at all. Thus, the children rarely considered local species as a ones that need conservation.

Illustrators of books for children should pay attention not only to the aesthetics of created graphics, but also the correctness of the factual content that they present. Preschool children pay more attention to the graphics contained in the literature, because at this age they do not have the reading skills. These situations may seem trivial, but the books are repeatedly viewed by children. Illustrations containing errors are passed in their memory, creating misconceptions and incorrect knowledge base.

The role of insects in the environment have been overlooked by most authors of children's literature. While the functions of insects that are included in the literature mainly related to the benefits derived by humans. It follows that the tendency to exalt material needs of man above the welfare of other living beings is manifested even in children's literature. This phenomenon should not have happened, as the goal of modern society is the implementation of biodiversity protection and reducing negative impact on environment. The impact on the environment exerts every man by every day decisions: the choice of products in the store, the choice of means of transportation, energy and water consumption (Bołtromiuk, 2010). It may seem that these actions have nothing to do with global phenomenon of biodiversity loss, yet they contribute to use of the planet's resources and the emission of pollutants that threaten living organisms. We must change the mindset of society so that the needs of other species are treated as seriously as human needs. The life of human and other organisms is highly dependent on natural resources (Rosin et al., 2011). Children should be aware that clean air and water is the basis of life on Earth. It is important to know that plants and animals are a source of products ensuring the proper functioning of the human body. Understanding these relationships will contribute to the respect to resources and the desire to protect them.

The number of books, which included interspecific interactions is low. The basis for the understanding of nature conservation is awareness that the occurrence of some species is possible by the existence of others. Children's literature should support the education of children in this subject, especially that other studies showed that their contact with the natural environment is becoming more and more restricted in favour of other activities (Martyka, 2012). Children should be aware that living organisms are not isolated from each other and, above all, are not self-sufficient. In addition, the vast majority of the analysed books contain no information on the consequences of the extinction of presented species. These findings indicate that the phenomenon of worldwide biodiversity decline is treated superficially by the authors of children's literature or is completely overlooked. The reason may be very simple - the lack of biological or environmental education among the authors. The authors of many books are humanists and artists, who

are not aware of the negative phenomena in nature, resulting from the negative impact of man. Despite the fact that children's literature on specialized topics (including entomological), is consulted with specialists, errors appear in some books. Moreover, the cause of some errors may be wrong translation of the literature published in a foreign language.

It's not a surprise, that authors of a significant number of children's books used anthropomorphisation. The recipients of analysed literature are mostly small children, thus occurring characters and different stories is more interesting and makes books are willingly chosen by children. Authors used the treatment of anthropomorphisation as well as an element of humour. Thanks to that the reader's interest is maintained, and the perception of presented content is accompanied by positive emotions.

Most of the analysed items of children's literature builds a positive attitude towards insects. However six books show these invertebrates in a negative way. Insects were called "vampires" and "killers", what discourages several years old readers to insects. In addition, it evokes fear in children, which later is difficult to deprive. Insects, like other groups of animals have developed different ways of living to survive. Everybody has the right to life, even if it has a negative impact on other living beings. Parasitic life history is just one of the types of interactions between species.

Children's literature is only one of many potential sources of knowledge about insects. Television and Internet are the media of great power, and they are used for raising environmental awareness. However, the most effective way to educate people is direct involvement in activities to protect pollinating insects (Kadej & Smolis, 2015).

In environmental education the increasing importance play educational gardens, nature trails and educational activities for groups. Very often educational activities are part of information campaigns and projects lead by non-governmental organizations (such as "Adoptuj pszczołę", "Przychylmy pszczołom nieba", by Greenpeace). Places, and events dedicated to pollinating insects enable participants to acquire basic knowledge about these invertebrates and their importance in nature. This is possible thanks to the presence of experienced beekeepers and educators. Many of these events are addressed to children. Through fun and physical activity, they learn about the natural environment and create positive attitudes towards nature. During the educational workshops for both older and younger participants there is opportunity to observe the behaviour of bees, build the hotel for insects and learn the secrets of beekeeping (Kadej and Smolis 2015). By experience, and high quality education (formal and non-formal), it's possible to create knowledge-based society, which will take action and responsibility to protect local and global environment.

Annex 1. List of insects presented in the text of children's literature about overall theme of nature

No.	species	Number of books in which it occurs	Systematic position (order)
1	*Acalymma vittatum*	1	Coleoptera
2	*Andrena lathyn*	1	Hymenoptera
3	*Leptura quadrifasciata*	1	Coleoptera
4	*Rutpela maculata*	1	Coleoptera
5	*Trichodes apiarius*	1	Coleoptera
6	Macrothylacia rubi	1	Lepidoptera
7	*Tabanus bovinus*	1	Diptera
8	*Psyllobora vigintiduopunctata*	1	Coleoptera
9	*Coccinella septempunctata*	3	Coleoptera
10	*Carabus coriaceus*	1	Coleoptera
11	*Pieris napi*	1	Lepidoptera
12	*Pieris brassicae*	2	Lepidoptera
13	*Buprestis octoguttata*	1	Coleoptera
14	*Diaperis boleti*	1	Coleoptera
15	*Brachystola magna*	1	Othoptera
16	*Bombylius major*	1	Diptera
17	*Scaeva pyrastri*	1	Diptera
18	*Syrphus ribesii*	1	Diptera
19	Magicicada	1	Hemiptera
20	Pseudococcidae	1	Hemiptera
21	Lycaena virgaureae	1	Lepidoptera
22	*Camponotus fallax*	1	Hymenoptera
23	*Graellsia isabellae*	1	Lepidoptera
24	Agelastica alni	1	Coleoptera
25	Husarz władca (*Anax imperator*)	2	Odonata
26	Lucanus cervus	3	Coleoptera
27	Karaczan prusak (*Blatella germanica*)	1	Blattodea
28	Karaczan wschodni (*Blatta orientalis*)	1	Blattodea
29	Ochlodes sylvanus	1	Lepidoptera
30	Biston betularia	1	Lepidoptera
31	Kołatek domowy (Anobium punctatum)	1	Coleoptera
32	Komar widliszek (Anopheles maculipennis)	8	Diptera
33	Komarnica błotniarka (*Tipula paludosa)*	1	Diptera
34	konik polny (*Omocestud viridulus*)	5	Orthoptera
35	kornik drukarz (*Ips typographus*)	3	Coleoptera
36	kowal bezskrzydły (*Pyrrhocoris apterus*)	2	Hemiptera
37	kozioróg bukowiec (*Cerambyx scopolii*)	1	Coleoptera
38	kraśnik sześcioplamek (*Zygaena filipendulae*)	1	Lepidoptera
39	kruszczyca złotawka (*Cetonia aurata*)	3	Coleoptera
40	księżycówka amerykańska (*Actias luna*)	1	Lepidoptera

41	kuprówka złotnica (*Euproctis simillis*)	1	Lepidoptera
42	latolistek cytrynek (*Gonepteryx rhamni*)	3	Lepidoptera
43	*Libelloides coccajus*	1	Neuroptera
44	lucilia skórnica *(Lucilia sericata*)	1	Diptera
45	łątka dzieweczka (*Coenagrion puella*)	1	Odonata
46	majka lekarska (*Lytta vesicatoria*)	1	Coleoptera
47	mączlik szklarniowy (*Trialeurodes vaporariorum*)	1	Hemiptera
48	*Messor aciculatus*	1	Hymenoptera
49	Miesierka różówka (*Megachile centulcularis*)	1	Hymenoptera
50	modliszka zwyczajna (*Mantis religiosa*)	2	Mantodea
51	modraszek ikar (*Polyommatus icarus*)	3	Lepidoptera
52	modraszek semiargus (*Polyommatus semiargus*)	1	Lepidoptera
53	Monarch *(Danaus plexippus*)	1	Lepidoptera
54	*Morpho menelaus*	1	Lepidoptera
55	motyl (butterfly – no information about species)	12	Lepidoptera
56	mrówka (ant – no information about species)	10	Hymenoptera
57	mrówka grzybiarka (*Acromyrmex octospinosus*)	3	Hymenoptera
58	Hurtnica pospolita (*Lasius niger*)	1	Hymenoptera
59	mrówka rudnica (*Formica rufa*)	3	Hymenoptera
60	Mszyce (*Aphis sp*.)	1	Hemiptera
61	mucha domowa (*Musca domestica*)	7	Diptera
62	muszka owocowa (*Drosophila melanogaster*)	1	Diptera
63	nadobnica alpejska (*Rosalia alpina*)	1	Coleoptera
64	nastrosz lipowiec (*Mimas tiliae*)	1	Lepidoptera
65	niedźwiedziówka nożówka (*Arctia caja*)	1	Lepidoptera
66	niepylak apollo (*Parnassius apollo*)	2	Lepidoptera
67	Ociernica (*Hispa atra*)	1	Coleoptera
68	odorek zieleniak (*Palomena prasina*)	1	Hemiptera
69	ogłodek wiązowiec (*Scolytus scolytus*)	1	Coleoptera
70	ogniczek większy (*Pyrochroa coccinea*)	1	Coleoptera
71	omomiłek wiejski (*Cantharis rustica*)	1	Coleoptera
72	opaślik nadrzewny (*Barbitistes serricauda*)	1	Orthoptera
73	Queen Alexandra's birdwing *(Ornithoptera aleksandrae)*	1	Lepidoptera
74	*Orophus tesselatus*	1	Orthoptera
75	Orszoł prążkowany (Trichius fasciatus)	2	Coleoptera
76	Klecanka rdzaworożna (Polistes dominula)	1	Hymenoptera
77	osa kopułka (*Eumenes coarctatus*)	1	Hymenoptera
78	osa pospolita (*Vespula vulgaris*)	8	Hymenoptera
79	osadnik Megera (*Lasiommata megera*)	1	Lepidoptera
80	*Osmia pilicornis*	1	Hymenoptera
81	pachnica dębowa (*Osmoderma eremita*)	1	Coleoptera
82	padlinówka cesarska (*Lucilia caesar*)	1	Diptera
83	pałątka niebieskooka (*Lestes dryas*)	1	Odonata
84	*Papilio polymnestor*	1	Lepidoptera
85	Pasikonik zielony (*Tettigonia viridissima*)	4	Orthoptera

86	Patyczak rogaty (*Medauroidea extradentata*)	1	Phasmida
87	pawica atlas (*Attacus atlas*)	1	Lepidoptera
88	pawica gruszówka (*Saturnia pyri*)	1	Lepidoptera
89	paź korsykański (*Papilio hospiton*)	1	Lepidoptera
90	paź królowej (*Papilio machaon*)	5	Lepidoptera
91	paź żeglarz (*Iphiclides podalirius*)	1	Lepidoptera
92	Pchlica wodna (*Podura aquatica*)	1	Collembola
93	Pchła ludzka (*Pulex irritans*)	3	Siphonaptera
94	pchła kocia (*Ctenocephalides felis*)	1	Siphonaptera
95	pchła królicza (*Spilopsyllus cuniculi*)	1	Siphonaptera
96	perłowiec malinowiec (*Argynnis paphia*)	1	Lepidoptera
97	pędruś koniczynowiec (*Protapion apricans*)	1	Coleoptera
98	Pętlak czteropaskowy (*Leptura quadrifasciata*)	1	Coleoptera
99	pienik ślinianka (*Philaenus spumarius*)	1	Hemiptera
100	plujka pospolita (*Calliphora vicina*)	1	Diptera
101	Pluskolec (*Notonecta spp.*)	1	Hemiptera
102	pływak żółtobrzeżek (*Dytiscus marginalis*)	1	Coleoptera
103	podziemnica zwyczajna (*Lasius flavus*)	1	Hymenoptera
104	pokłonnik osinowiec (*Limenitis populi*)	1	Lepidoptera
105	poświętnik (skarabeusz) (*Scarabaeus sacer*)	3	Coleoptera
106	proporzyca marzymłódka (*Tyria jacobaeae*)	1	Hymenoptera
107	przestrojnik jurtina (*Maniola jurtina*)	1	Lepidoptera
108	*Pseudophilotes sinaicus*	1	Lepidoptera
109	Pszczolinka napiaskowa (*Andrena vaga*)	1	Hymenoptera
110	pszczoła miodna (*Apis mellifera*)	12	Hymenoptera
111	pszczoła olbrzymia (*Apis dorsata*)	1	Hymenoptera
112	rohatyniec nosorożec (*Oryctes nasicornis*)	2	Coleoptera
113	rusałka admirał (*Vanessa atalanta*)	2	Lepidoptera
114	rusałka osetnik (*Vanessa cardui*)	1	Lepidoptera
115	rusałka pawik (*Inachis io*)	6	Lepidoptera
116	rusałka pokrzywnik (*Aglais urticae*)	2	Lepidoptera
117	rynnica topolowa (*Chrysomela populi*)	1	Coleoptera
118	rzemlik topolowiec (*Saperda carcharias*)	1	Coleoptera
119	rzęsielnica (*Donacia sp.)*	1	Coleoptera
120	skoczek zielony (*Omocestus viridulus*)	1	Orthoptera
121	skorek pospolity (*Forficula auricularia*)	2	Dermaptera
122	*Sphex pensylvanicus*	1	Hymenoptera
123	stonka ziemniaczana (*Leptinotarsa decemlineata*)	2	Coleoptera
124	strangalia czerniawa (*Stenurella melanura*)	1	Coleoptera
125	straszyk australijski (*Extatosoma tiaratum*)	1	Phasmatodea
126	strojnica baldaszkówka (*Graphosoma lineatum*)	2	Hemiptera
127	Szarańcza wędrowna (*Locusta migratoria*)	2	Orthoptera
128	szczerklina piaskowa (*Ammophila sabulosa*)	1	Hymenoptera
129	szczotecznica szarawka (*Calliteara pudibunda*)	2	Lepidoptera
130	Szerszeń europejski (*Vespa crabro*)	1	Hymenoptera

131	ścierwica mięsówka (*Sarcophaga carnaria*)	1	Diptera
132	świerszcz domowy (*Acheta domesticus*)	5	Orthoptera
133	świetlik świętojański (*Lampyris noctiluca*)	2	Coleoptera
134	taszczyn pszczeli (*Philanthus triangulum*)	1	Hymenoptera
135	termity, termites (Isoptera)	4	Isoptera
136	trzmiel kamiennik (*Bombus lapidarius*)	1	Hymenoptera
137	trzmiel ogrodowy (*Bombus hortorum*)	1	Hymenoptera
138	trzmiel ozdobny (*Bombus distinguendus*)	1	Hymenoptera
139	trzmiel parkowy (*Bombus hypnorum*)	1	Hymenoptera
140	trzmiel paskowany (*Bombus subterraneus*)	1	Hymenoptera
141	trzmiel różnobarwny (*Bombus soroeensis*)	1	Hymenoptera
142	trzmiel rudy (*Bombus pascuorum*)	1	Hymenoptera
143	trzmiel ziemny (*Bombus terrestris*)	9	Hymenoptera
144	Trzmielówka leśna (*Volucella pellucens*)	1	Diptera
145	trzyszcz polny (*Cicindela campestris*)	2	Hymenoptera
146	turkuć podjadek (*Gryllotalpa gryllotalpa*)	2	Orthoptera
147	*Vespa velutina*	1	Hymenoptera
148	ważka (no species information)	4	Odonata
149	ważka płaskobrzucha (*Libellula depressa*)	1	Odonata
150	wesz ludzka (*Pediculus humanus*)	1	Phthiraptera
151	wesz głowowa (*Pediculus humanus humanus*)	1	Phthiraptera
152	wieczernica klonówka (*Acronicta aceris*)	1	Lepidoptera
153	wonnica piżmówka (*Aromia moschata*)	1	Coleoptera
154	wszoł (*Mallophaga*)	1	Phthiraptera
155	wujek żółtaczek (*Empis livida*)	1	Diptera
156	zawisak tawulec (*Sphinx ligustri*)	2	Lepidoptera
157	zieleńczyk ostrężyniec (*Callophrys rubi*)	1	Lepidoptera
158	zmierzchnica trupia główka (*Acherontia atropos*)	2	Lepidoptera
159	zmrocznik gładysz (*Deilephila elpenor*)	2	Lepidoptera
160	zmrocznik pazik (*Deilephila porcellus*)	1	Lepidoptera
161	zorzynek rzeżuchowiec (*Anthocharis cardamines*)	2	Lepidoptera
162	zwójka zieloneczka (*Tortrix viridana*)	1	Lepidoptera
163	żuk gnojowy (*Geotrupes stercocrarius*)	2	Coleoptera
164	żuk grabarz (*Nicrophorus vespillo*)	1	Coleoptera
165	żuk leśny (*Anoplotrupes stercorosus*)	1	Coleoptera
166	żyrafka madagaskarska (*Trachelophorus giraffa*)	1	Coleoptera

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Fun with Optics - teaching by images

1. Searching for Fun with Physics

Learning physics, in any place, seems a difficult, and therefore a boring task: "Physics is not my favourite subjects" – you can hear from a driver in a taxi, from Seoul to Sao Paolo. In times of Aristotle, physics was still a narrative science, not much different from philosophy. Aristotle's Zoology was much more detailed than Physics, which dealt mainly with defining the motion (Aristotle 1965, 1957). For Galileo Physics (Galilei, 1610) started becoming mathematical, but even Galileo did not use any symbol notions and his dialogues resembled more those by Plato than Euclid's Elements. However, an earlier to Galileo, Copernicus' De Revolutionibus was already a very "tough" treaty, filled with tables and mathematical considerations (and therefore, probably little read through centuries). Full of mathematics is just Netwon's Philosophiæ Naturalis Principia Mathematica. At that time physics became the reason for inventing new disciplines of mathematics, like differential calculus. Without this mathematics (and modern computers) it would not be possible to shut "New Horizon" spacecraft to a distance of 5 billion kilometers towards Pluto with a precision of 5 thousand kilometers. How can we convince school pupils on that?

The same mathematics that become an extraordinary source of scientific successes, is the reason that physics is highly unwilled in school. School textbooks from elementary, say in Poland, (Poznańska, 2002, p. 28) to academic in Italy, see for ex. (Allegrini, 2000) focus on mathematical aspects. Mathematics, of course, is the precise language of physics: laws of physics, are expressed in a mathematical form. But teaching becomes ineffective if the other, human side is forgotten. R. K. Wassef (1995) writes: The "Human face" of physics could be shown by this contextual approach, highlighting the people involved, their motives and how they achieved what they reached. On the other side of approach is some "conceptual" teaching, or teaching just by images: beautiful, colorful album about light, but without any physical equation (Parker, 2006).

Our key idea is that in the first approach physics should become again a qualitative science (Karwasz, 2003), without the necessity of introducing complicated mathematics: physics deals with phenomena of all-day life – the intrinsic understanding of the laws of motion allows to one-years infant to walk on two legs. In the same manner we would never expect a ball thrown horizontally (unless it is a boomerang) to come suddenly back. So, in the first instance, physics is a qualitative science and only later, mathematical one (Karwasz, 2003, 2011).

Phenomenological descriptions of physics date from at least a century (Perelman, 2011) and were written in all different languages and by highest ranks

physicists, see for ex. (Landau, 1965; Frova 2001), Ernst; 2010; Hewitt, 2014). The social role of these volumes is difficult to be overestimated: they trigger interest in physics, even if do not constitute real-type textbooks.

The second strategy would be school experiments. It is widely acknowledged in contemporary science education, that the observation is an important skill to be developed in students. Teachers should encourage their students to use all their senses (Delagrey, 2001). Students love to watch all kinds of experiments, therefore demonstrations are a traditional part of teaching physics (Hendolin, 2011). However, usually in schools experiments are ready-to-use: "switch on the current and watch happens". Obviously, something will happen: we hardly trigger the sense of observation in this way.

Nowadays real experiment are subject to substitution by a virtual world. Students, in particularly teenagers, love to scroll over virtual experiments (Cegła, 2014). They find physical applets on internet with a surprising velocity. However, internet resources are frequently not didactically (and scientifically) correct: they can happen to be programmed by non-specialists, so they do not necessarily reflect the physical reality. In this sends real films are better as they reflect the reality of the physical instruments.

Still another strategy to publicize physics are interactive exhibitions. In Poland they were introduced some 20 years ago, imported from Trento University in Italy (Karwasz, 2000). The first, portable exhibition, of some 40-50 objects were shown in 1998 at II Science Festival in Warsaw and in Słupsk in the Municipal Hall, with 14,000 visitors; next year at National Congress of Polish Physical Society in Białystok, then at the Congress in Gdańsk in 2003 and Warsaw in 2005. In some 10 years, interactive centers, mainly for physics, exploded all over Poland, with 1 million visitors in one year only at "Kopernik" center in Warsaw, see (Karwasz, 2012).

Fig. 1. a) Interactive exhibition "Fiat Lux" organized by authors at Regional Museum in Toruń (2008) (Karwasz 2010); b) "Schrödinger's cat" – burned inside a glass cube shows both the left and right profile; c) - d) two semi-cubes filled with liquids and a gap in-between them: a crocodile picture is inserted in the gap; depending on the angle of observation the crocodile is visible or not (due to the total internal reflection between the liquid and the air in the gap) – the object noticed by Maria Karwasz in a TV shop.

However, in parallel with this extraordinary success, the main risk of "Physics and Toys" is to show objects, without prior preparation of cognitive categories: why do I show this object. This reflects in comments frequently heard from some (semi)professional science divulgators: "I have also got it!" or "I have already seen it!". Such comments prove that the interest of spectators is still concentrated on the object and not on the phenomena itself, or more precisely – on physics.

In this work we show a methodological extension of interactive physics: visiting an exhibition or participating in an interactive lecture is only a departure point for own, independent search for phenomena around us. We concentrate on optics, as the vision is our most important sense. A thematic, interdisciplinary exhibition on optics "Fiat Lux! or playing with light" was organized in collaboration with the Regional Museum in Toruń in the medieval cellar of Toruń Town Hall in 2008 and then travelling to other 20 musea all over Poland for several years. Teaching optics is a powerful tool to trigger interest in the external work: we use our vision continuously but between the light, the object seen and our impression there is also our eye and our brain. So optics is not only physics but also psychology and arts.

The main scope of the present report is not to numerate optical phenomena but to go beyond "organized" exhibitions and ready books: the aim of this paper is to induce the reader (or rather spectator) to search in any time and any place of optical impressions. For didactical simplicity one should follow three branches of optics: geometrical optics, wave optics (interference, diffraction), and chromatography, which for us is the science of colours (Karwasz 2012). Due to the black-and-white printing limitations, here we concentrate only on the geometrical optics.

2. Fun with flat mirrors

Modern geometrical physics starts from Vitelo (1237-1300?), Türingen - Polish medieval priest and scientist, who studied the laws of reflection. Nowadays, several centuries later, the mirror image is one of the phenomena most misunderstood in early physics education (Böhm 2011, p. 7): to determine in what way is formed is not always easy (Goldberg 1986, p. 472). Students have their (not always correct) beliefs on this subject (Galili 1996, p. 847).

Among the objects drawn in Vitelo's Perspectiva we find a periscope, one of the most simple optical devices. It consists of two flat mirrors positioned at 45º, see fig. 2a. The resulting image is virtual, straight and of the same size as the object. If mirrors are positioned at +45º and -45º, see fig. 2b, the image is inverted. If you want to observe the whole horizon you must to turn your head with the periscope.

Fig.2. Fun with periscope: a) a scheme of a correct construction and b) its application – how to see the world like an adult ("Fiat Lux" exhibition in Toruń, 2007); c) a toy periscope that allows to rotate the upper part: the images rotate with turning the periscope; d) a scheme of a "wrongly" mounted periscope.

Two flat mirrors can be placed also in another ways: one behind another, like in fig. 2c, giving an infinite number of successive reflections. This is what happens staying between two mirrors in a hair-dresser workshop. In fig. 3a we show a parallel positioning of two mirrors in which the front mirror is semitransparent and the reflected object is placed behind it (i.e. between the two mirrors). An infinite number of successive reflections – every next smaller – is seen. But if the photographer is illuminated, he is also reflected from the front glass, see fig. 3b.

Fig. 3. Parallel mirrors and the question of reflection from glass surfaces: a) an infinite number of reflections of a chain of lamps positioned between a mirror behind and a glass window in front. b) The same object but the photo taken not in darkness – a reflection of author (GK) is seen. c) a pile of transparences: a piece of paper with printed text is positioned under 20 of them – the text is still visible; another piece of paper positioned under 50 transparences (lower half of the photo) is barely visible, instead – the reflection of the photographer can be seen. d) internal car mirror (here shown vertically) – two reflections of the author are seen: on in the mirror behind and one in the protecting glass in front of the mirror.

The latter photo induces us to the question of reflections – is a window glass transparent or is it a mirror? An answer is given in fig. 3c – where a stack (about

fifty) of transparent plastic foils is positioned. If they are few (a dozen) they are transparent – a piece of paper below them is quite well visible even if a reflection of the objects above the stack (including the photographer) is also present. To conclude the question of semitransparent and non transparent mirrors in fig. 3d we show an object that we see every day – an interior car mirror. At darkness, in order not to get blind due to lamps of a car behind, we "switch" the mirror off. In practice, we change the angle of the mirror in a way, that the light from behind is reflected above our eyes. Why, therefore, we see anyway the lights of the car behind? The light reflects from the glass[1] that is placed in front of the mirror, fig. 3d. Check it before you start driving!

A number of other plays can be done with flat mirrors, the most funny is so-called kaleidoscope, i.e. "nice vision" in Greek. It consists of three mirror, forming angles of 60º, see fig. 4a. Other configurations, see fig. 4b are also possible. In front of the mirrors small objects – pieces of colorful glass, beads, feathers are placed. Their casual position is reflected in the mirrors giving a symmetric, "nice" picture, see fig. 4c. A variation of the kaleidoscope includes a big glass sphere in front of the tube with mirrors. Images of objects in front of the sphere are formed immediately after it, inside the tube. Such a kaleidoscope can be used to multiply the external world.

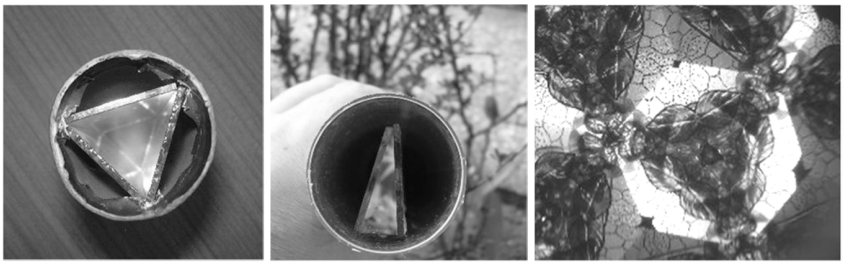

Fig. 4. a, b) Two types of kaleidoscopes and images formed in them: b) a flower from outside, c) small pieces of colorful glass. (Photo GK)

Other kaleidoscope-like configurations of mirrors are shown in fig. 5. In fig. 5a there are three mirrors in a "classical" configuration of 60º but the spectator is inside. An infinite number of successive reflections of the author (KS) crowd the image. Exactly 6 images are obtained when two mirrors are positioned exactly at 60º. But taking two flat mirrors from bathroom (for make-up) one can experiment all different angles, as shown in fig. 5b. Check, which of the images are non-inverted and which are left-right flipped.

[1] The coefficient of reflection from the front (and rear) surface of a window depends from the dielectric constant of the glass. Typically 4% of impacting light intensity is reflected from each surface. So the intensity of light transmitted from a single glass sheet is (0.96x0.96) = 0.922.

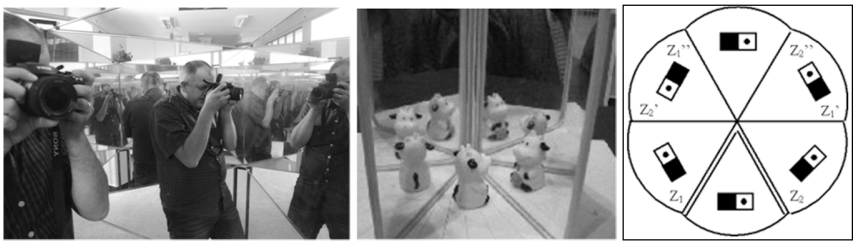

Fig. 5. Fun with flat mirrors, continued: a) inside a giant kaleidoscope made of three mirrors positioned at 60º; b) similar to the previous - photo taken from outside and the angle slightly smaller than 60º (Open Days at University Udine, 2008); c) a scheme of successive reflections.

Similar to the previous configuration is the hair-dresser room (author M. Brozis, 2006), with three mirrors in 3D configuration at 90º angles, fig. 6. Depending on the angle of observation, several reflections can be seen. In photo 6b we show not only the two primary reflections (left-right inverted) but also reflection of reflections (twice inverted, i.e. non-inverted) – the first from right.

Fig. 6. "Hair-dresser room", i.e. three flat mirrors under 90º - a) reflections from three mirrors (the picture taken along the symmetry axis) ; b) in pictures from left to right we see the reflection of the battery in the left mirror (inverted left-right), the battery itself, the reflection of the battery in the right mirror (inverted) and reflection of the reflection (non inverted). c) Photo of the author – the image is upside-down. Photo GK & dr Tomasz Wróblewski.

Even a single mirror can produce quite a fun. In photo 7a, our colleague Waldek seems to levitate. In practice he stands on his left leg, hidden behind a big mirror. In a "Soviet bank" ("Insert a coin and you will never get it back!"), fig. 7b, a flat mirror is placed in a small box under 45º and half of a star is glued to it in the center. The other half, seen by the observer is just the image in the mirror. The bottom of the box is lined with a design not allowing to evaluate the perspective; the distance between the image and the observer eye is constant for every point of the mirror, see fig. 7d. In this way the observer is convinced to see he whole box, but the "bank" is hidden behind the mirror and inserted coins disappear.

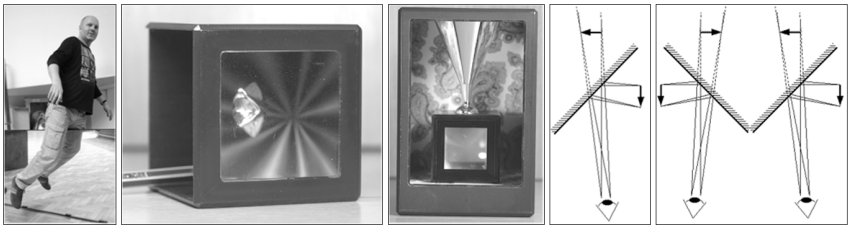

Fig. 7. Fun with single flat mirrors. a) Waldek, apparently hanging in air, is standing on his left leg behind a big flat mirror, and his right leg is in front of the mirror. b), c) "Soviet bank" – a mirror placed at 45°: the observer is convinced to see the whole box but coins are dropped behind the mirror – one can hear them but not see; an additional Fresnel lens shows the coin "shrunk" d), e) Creating the image in moneyboxes. Photo KS.

3. Fun with spherical mirrors

Vitelo's treaty on optics De perspective (Vitelo 2003) was used as an university textbook till times of Newton – even Kepler wrote a comment on it. His imaginary portrait (painted by Giangacomo del Forno in 1942) is shown as one of 40 most prominent scientists at the Rectorate Aula of Padova University, fig. 8a. Vitelo was first to study experimentally reflections, not only from flat mirrors, but also spherical and cylindrical, both convex and concave. His experimental set-ups (reconstructed on the project by prof. Andrzej Bielski at UMK) are shown in fig. 8b and 8c.

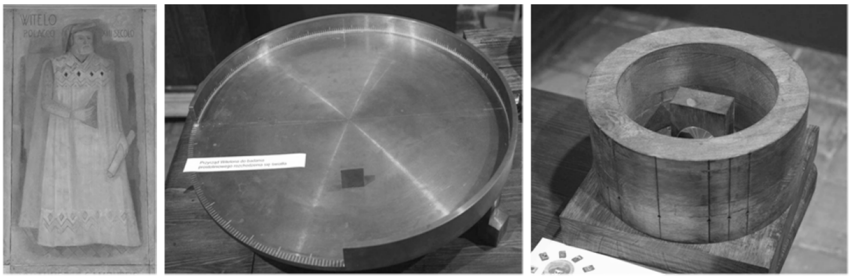

Fig. 8. Vitelo and his experimental set-up. 8a Imaginary portrait by Giangiacomo del Forno (1942) in Sala dei Quaranta, Palazzo Bo', University of Padova (shown here with kind permission from Università degli Studi di Padova). b) set up (diameter 60 cm) to study the angle of reflection with 1° precision (reconstruction by A. Bielski, UMK). c) set up to study angles of reflection from cylindrical and spherical mirrors (diameter 30 cm).

Today, cylindrical mirrors are rarely used but spherical ones, in particular convex are on every second crossing of narrow streets in old Italian cities (and inside shops, see fig. 9a). They allow to observe wider angles than flat mirrors; the image in convex mirrors is reduced and but straight (non inverted). It would

be a disaster to see in a mirror a car coming upside-down! Also external mirror in cars are frequently convex. In Australia a warning is written on these mirrors: an image is reduced, so a car approaching from behind seems to be more distant than it is in reality, see fig. 9b.

Fig. 9. a) A semispherical convex mirror in a shop with newspapers facilitates the surveillance. b) An external mirror in Australian car is convex: a warning (barely visible above the lower edge) says: "Objects in mirror are closer than they appear". c) A concave mirror (in a window shop in Paris) gives an inverted image of buildings behind the observer. Photos Maria Karwasz.

Convex spherical mirrors can be found in many other places: in shops - to see clients in every angle, in cities – to reflects the architecture etc. In Chicago a big sphere (or rather an ellipsoid) is a part of the urban landscape itself, fig. 10a. Taking a photo of the city reflected in such a sphere is not an easy task – if you stay too close, the photographer is so big that it obscures the rest of the landscape. Clearly, the size of the image depends on the distance of the object that is taken, fig. 10b. Moreover, the reduction in size depends also on the radius of the ball. It is particularly visible on the Christmas tree, fig. 10c.

Fig. 10. Fun with spherical mirrors. a) A giant ellipsoidal ball, with pigeons on the top, as a part of the urban landscape, Golden Mile in Chicago (2009): nothing is inverted in convex mirrors, independently of the distance. b) Buildings in London (going down to Millennium Bridge) reflected in a street sphere (2014): convex mirrors give reduced images – more distant is the object, more reduced is the image, the effect is greater than in flat mirrors. c) Skating at Stanislas Square in Nancy reflected in Christmas ball (2010): images in small mirrors are more reduced than in big ones. Photos Maria Karwasz.

However, to get convex and concave mirrors there is no need to go to France or Australia – just ask a spoon in a good restaurant, where spoons are not washed in automatic machines so they shine. A convex surface gives always a straight image, while the concave – straight only if you put your nose close to it (automatic camera hardly makes a photo for such a short distance), fig. 11a and b. Moreover, in Korean restaurant (they always use spoons apart from sticks) you can check another law: smaller spoon, at the same distance from the object gives a smaller image. This logic! but not so easy to calculate.

Fig. 11. Spoons as mirrors: a) a convex surface gives non-inverted image, b) a concave mirror – an inverted image (hand of Ula Kordowska, a constant distant from the spoon was kept). c) In Korea two types of spoons are used at table: the smaller one gives a smaller image (a concave surface, image of the rose on the table that was above the spoon).

As far as convex mirrors give always reduced (and upright) images, independently from the distance of the objects, concave mirrors, like that used for make-up, can give images:

1) upright and enlarged (when the object is close to the mirror)
2) inverted and enlarged (when the object is "somewhat" further)
3) inverted and reduced (for large distances).

We illustrate it in fig. 12. A single mathematical model describes all these three cases (and the convex mirror also). We come to mathematics later.

Cylindrical mirror act in the same way as spherical: convex make straight (and reduced) images and concave – depending on a distance. For short distances (as compared to the radius of curvature) the image in a concave cylindrical mirror is of the same type as in a spherical mirror when the object is close, i.e. non-inverted and enlarged. Obviously, cylindrical mirror "deform" objects only in the direction in which the mirror is curved, fig. 13.

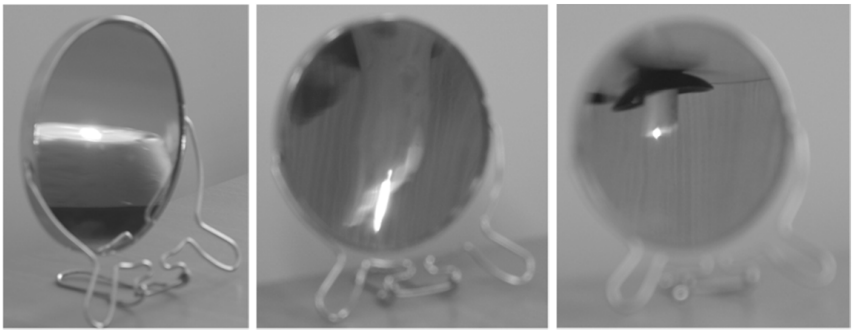

Fig. 12. "School-like" images formed in a concave mirror: a) enlarged and non-inverted, with the candle close to the mirror (less than R/2 where R is the radius of curvature), b) enlarged and inverted at the distance between R/2 and R, and c) inverted and reduced, with the distance higher than R.

Fig. 13. Cylindrical mirrors. a) This mirror ("Questacom" Science Center in Canberra, 2006) seems to enlarge in the horizontal direction, so it could be concave with the vertical axis; but, as seen from its borders, it is convex with a horizontal axis: the image is shortened in the vertical direction what makes the same impression as enlarging in the horizontal. b) Publicity of a diet drugs: a cylindrical convex mirror with a vertical axis, c) Berlin modern architecture: a convex cylindrical wall reflects buildings on the other side of the street – images are shrunk (look at the right edge of the cylinder). Photos MK

Resuming, spherical mirrors (and also cylindrical) give several different types of images. For convex mirrors these are always reduced (and non-inverted). Dimensions of the images are smaller when objects are more distant. However, dimensions of images depend also on radii of mirrors: smaller radii give smaller images. The mathematical formulation waited Newton.

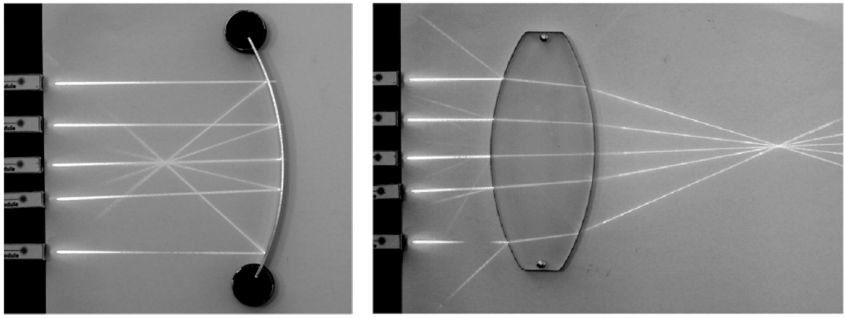

Fig. 14. Parallel rays of light reflecting in the concave (cylinder) mirror intersect at the focal point of the mirror. b) The same light passing through the convex lens intersect at the focus of the lens. Note the rays reflected from the left surface of the lens: four of them seem to come from the same point, which would be a (virtual) focus of a convex mirror. Additional reflected rays apparently coming out from the reflected central ray are in fact refracted rays, which entered the lens and reflected from the inner (i.e. right) surface. Photo KS.

4. Fun with refraction

First optical instrument, that revolutionized navigation, astronomy and war was the telescope. Made of two lenses it was constructed by a Dutch optician H. Jansen in 1604, but he might have used the existing Italian construction. Laws for the refraction of light, needed to understand lenses were formulated by Snelius in 1621. The exact mathematical formulation of it contains sinus of two angles: of the incidence α and refraction β and the intrinsic property of the material, that is called n – the index of refraction (1.33 for water, about 1.5 for glass).

$$\sin \alpha / \sin \beta = n \qquad (1)$$

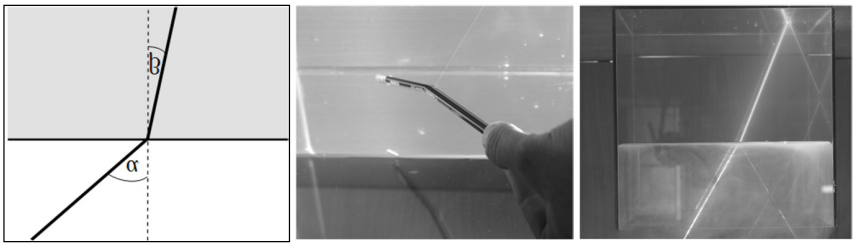

Fig. 15. a) The law of refraction: light is coming from air into glass (n>1); in this way the angle of incidence α is greater than the ingle of refraction β. You can see it observing a stick standing in water b) or laser beams entering an aquarium c). Note reflected rays in the latter photo. (KS)

As seen from fig. 15a, for light rays coming from air to glass the angle $\alpha > \beta$, in accordance with n>1 for glass. It seems that the ray is attracted into the glass. This could make think that light is a kind of particle; of this opinion was even Newton.

What makes this law difficult to students is the way of measuring these angles. Pupils, deceived by a flat picture (like fig. 14b) forget that lenses are 3D objects: it is much easier to measure an angle to the normal to the surface than angles between surfaces (ask your math professor). By the way, already in the "apparatus" by Vitelo angles were measured between the ray and the normal to the surface.

The light passing through a cube of glass undergoes two refractions, see fig. 16a. As a consequence, the image is shifted in respect to the objects, see fig. 16b. It also seems closer to the observer. Again, reflections on the inner surfaces of the cube can be seen, fig. 16c.

Fig. 16. (a) Light passing though a flat piece of glass (or a cube) is deviated twice. As a result, rays entering parallel exit also parallel. b) In this manner, the object below seems to be shifted. c) If the cube is rotated, not only the shifted image is seen but also a reflection of the object on the inner face of cube.

The law of refraction found recently a new fun: high power excimer lasers allow to print 3D images inside glass volumes – usually cubes. These cubes allow to see objects inside from three sides at a single glance, see fig. 17. What is seen in such cubes, is not the object but projections of it on the three perpendicular walls, fig. 17d. The projections are seen under difference angles, so they are re-dimensioned.

Fig. 17. Fun with refraction: seeing objects from three sides at the same time – objects are printed inside glass cubes and what is seen are projections of thee perspectives onto three perpendicular surfaces (a-c). As shown at c), i.e. an image of he sphere, these projections are rescaled in the directions of observation, as shown on the scheme d).

Another play with refraction is the magic eye, fig. 18. The “eye” resembles a plane-convex lens, but its convex surface is not spherical but shaped into a rosette from gothic temple - an array of radial planes, with a little circular centre, as if it were a bunch of glass prisms. Each of those prisms deflects the incoming light beam. We see a whole rosette of virtual images, set in a circle around the non-shifted image. By the way, several ways of shaping the “eye” are possible, so different types of multiple images are created.

Fig. 18. The “magic eye” uses the law of refraction. a) It is like a rosette with several surfaces cut under different angles. An object (shelter of the neighbor, b) is multiplied (c) into as many images as the number of separate surfaces in the “eye”.

The equation (1) for refraction allows to predict a strange phenomenon: if the ray goes from a medium which is optically more dense (like from water to air), above a certain angle β, sinα would go above 1, what is impossible. In other words, for a certain limiting angle β a ray will not exit from water. This phenomenon is called “total internal reflection” – you can spot such reflections from inner surface in fig. 16c and 17b. The limiting angle γ, above which the ray will not get out from water (or any other dense optically medium) is determined by the condition

$$\sin \gamma = 1/n \qquad (2)$$

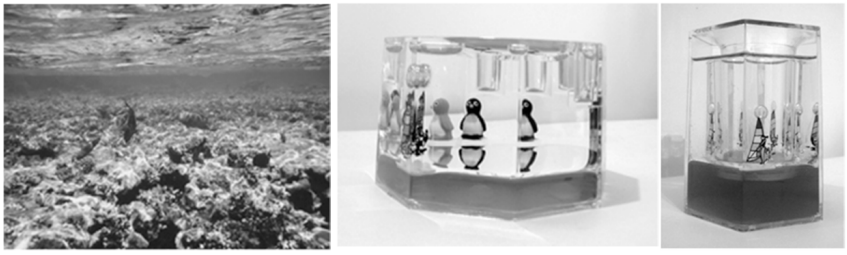

Fig. 19. a) While diving the sea bottom is nicely visible, and also its reflection in the wavy surface of the sea above; this comes from a total reflection for angles bigger than the limiting angle in eq. (2).

b) In a hexagonal prism there are only two penguins; the remaining ones come from the refraction (half of the central one) and other form total reflection on inner surfaces. c) In this prism, with a cylindrical hole in the center the reflected images are additionally shrunk. Objects and photos GK.

Under water, this phenomenon makes visible only a limited circle of the landscape above the head of the diver (the limiting angle is 49º) and the borders of the visual field seem to be a perfect mirror, see fig. 19a.

5. Fun with lenses

Vitelo studies of convex mirrors allowed to visualize the concept of focus, i.e. the place that rays coming from a distance converge to one point. It easy to show the focus (and measure the focal distance f) with a convergent lens, see fig. 20a. In the evening time the image of a lamp above our head, formed by a glass of water can be seen on the table, fig. 20b. In thick glasses, like that from Charlottenburg Museum, fig. 20c, the focus can fall inside that glass.

Fig. 20. a) Ad hoc showing the focus of a convergent lens (GK at "Fiat Lux" exhibition in Grudziądz, 2010-2011). b) Light focused by a water-filled glass: both the spot lamp and lateral stick-like neon lamps are focused on the table. Note also reflections from the concave surface of the glass. C) In these caliches the light coming from behind and above is focused in their basis (Berlin, 2006, photo MK).

Fig. 21. a) Convex lenses seem to behave like concave mirrors: they give enlarged or reduced images depending on the distance of the object. Concave lenses (the glass of the author, in the upper right corner) act like convex mirrors – they produce reduced (and non-inverted) images. Ad hoc lesson for lower secondary school in Grudziądz, 2010. Photo MK. b) A convex lens. With the object close to it gives non-inverted and enlarged picture, like a bathroom concave mirror, when used by girls for make-up. Opening of "Fiat Lux" in Frombork, 2011; in the background postcards with Fresnel concave and convex lenses. Photo W. Andrearczyk.

Detail studies of images formed by lenses can be done using the glasses of spectators. The optical glasses of short-seeing persons (i.e. concave lenses) give reduced images, see the upper-right corner in fig. 21a. The optical glasses of distant-seeing persons are convex, like the magnifying glass in fig. 21b (and fig. 21a). As in the case of concave mirrors, see fig. 12, types of images in magnifying glasses depend on the distance from the object: with objects far from the lens the image is inverted like fig. 21a; with objects close to the lens the image is straight (and enlarged), fig. 21b.

6. Fun with mathematics

Optics became fully mathematical only with Newton and his Opticks (Newton 1704). Geniality of Newton stands in observing that the laws for mirrors and for lenses are identical: the position q of the image, as compared to the position of the object p, depends solely on the focal length f. And these positions, for geometrical reasons, determine the magnification M, i.e. the ratio between the dimension of the image H and of the object h:

$$M = H/h = q/p \qquad (3)$$

The equation which governs images in mirrors and (thin) lenses is as follows:

$$1/p + 1/q = 1/f \qquad (4)$$

Drawing of light rays in mirrors are show in fig. 22. Usually we draw two rays: one parallel to the optical axis and one incident to the center of the mirror. Note that convex mirrors have focus behind the mirror; we call the focus "virtual". For the real focus (i.e. in the case of convex lenses and concave mirrors) we assume f positive; for de-focusing devices (concave lenses and convex mirrors) we assume f negative.

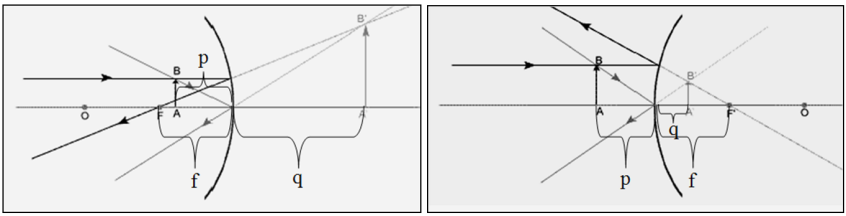

Fig. 22. Deriving the equation of mirrors: searching for similar geometrically triangles containing object and image. Two rays can be drawn easily – one incoming parallel (and reflected to the focus) and one incident to the center of mirror (where it is easy to draw the angle of reflection equal to the incident one). a) For a concave mirror, if the object is placed closer to the mirror than the focus, an image enlarged, upright (and behind the window, i.e. virtual) is formed. b) For convex mirrors, used on the streets, the image is always virtual and reduced.

In order to calculate explicitly the position q of the image we rewrite eq. (4) into the form

$$q = f + \frac{f^2}{p - f} \qquad (5)$$

From experimental playing shown above we note that this is the focal length which determines the kind of the image. Let's make some numerical study, assuming focal length f =1m. For convex lenses it will be with the sign positive, f = +1m. We chose some significant values for p from infinite to zero and calculate corresponding values for q.

p	∞	4	2	3/2	1	1/2	0
q	1	4/3	2	3	∞	-1	0

This table shows that the for p=2f the image is of the same size as the object (q/p=1), for p>2f the image is reduced, in-between f < p < 2f the image is enlarged. It is also clear, that for p = f the image is formed in the infinity; in experiment we observe highly deformed images, like we show it on next photos. For 0 < p< f , i.e. when the lens is close to the object, it works as a "magnifying lens", photo 21b. A negative sign of q informs us that the image is "virtual", i.e. seems to be positioned on the same side of the lens as the object.

A similar table can be done for de-magnifying (i.e. concave) lenses, see author's glasses in fig. 21a. We adopt f = -1m.

p	∞	4	2	1	1/2	0
q	-1	-4/5	-2/3	-1/2	-1/3	0

It is clear from the above, that lenses of a short-seeing person (concave lenses) give always reduced images. Images are always virtual, as the sign of q is always negative.

The equation (5) can be easily presented on the graph: it can be derived from a simpler form, q = f 2/p, which is subsequently shifted up by f and right by f, see fig. 23. The right part of this graph (i.e. for p of the same sign as f) corresponds to focusing devices (like convex lenses) and the left part – to de-focusing devices (like convex mirrors). Enlarged images are formed, when the curve (shown as thicker) lays above the line q=p (with q positive, see graph 23 for details).

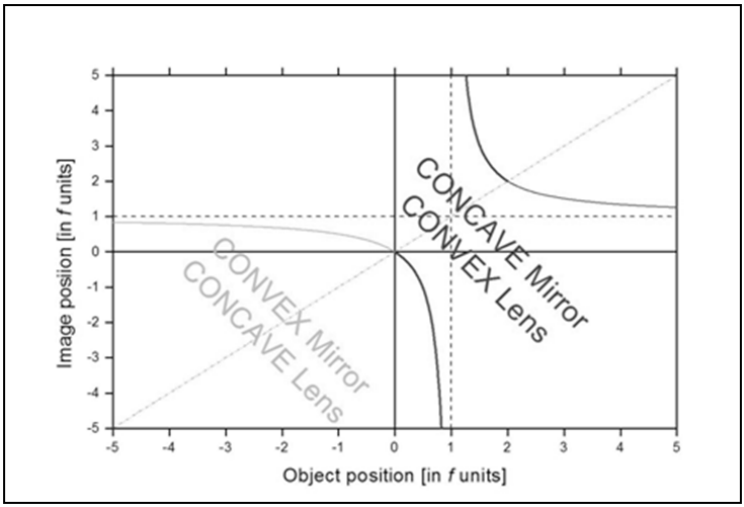

Fig. 23. Image formation in mirrors and lenses – using properties of the mathematical function eq. (5). Note the use of units f for expressing both the distance p of the object from the lens and the distance q of the image from the lens. The left part (i.e. for p < 0) of the graph corresponds to devices giving virutal images: concave lenses and convex mirrors; the images in these devices are reduced (q satisfies the condition |q|<|p|).

7. More fun with mirrors and lenses

The equation of Newton allows to explain types of images that are formed. However, a number of assumptions are needed to keep the equation applicable. For mirrors it is the requirement that rays travel near to the optical axis. In this case with good approximations all rays coming parallel to the optical axis are focused in one point . For lenses we also assume that they are thin, in a way that trav
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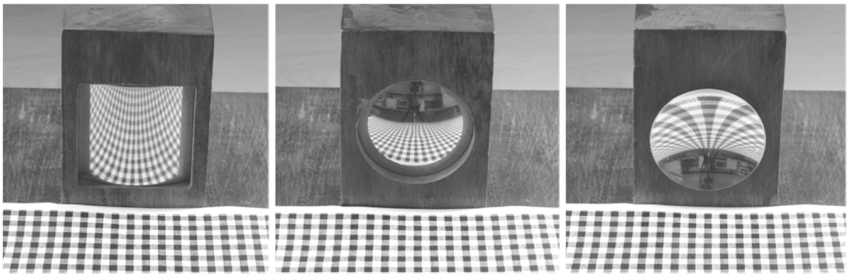

Fig. 24. Optics beyond Newton's approximation of big mirrors (i.e. eq. 2) – mirrors from Witelon's apparatus are small and images seem deformed. In reality this is what mirrors do: to calculate images more complex modeling is needed. a) cylindrical convex mirror, b) spherical convex, c) spherical concave mirror. Photos KS.

Photos in fig. 24 were done in a way to enhance the distortions made by mirrors – a square pattern was positioned on the table in front of the mirror. As far as distant objects (see fig. 24b and 24c) are not deformed, the rectangular patterns on borders of mirrors are strongly deformed. Clearly, the equation of Newton for mirrors, eq. (4) holds only for para-axis rays.

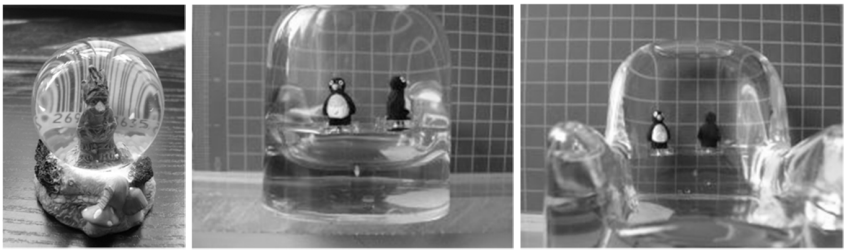

Fig. 25. "Deformations" of images behind these "lenses" come from two reasons: a) non-adequacy of the thin lenses approximation for objects like full spheres, b), c) complicated shapes of focusing objects, like this stand for portable phones. Objects and photos GK.

Figure 25 shows thick lenses – fig. 25 a small full sphere (filled with water) and fig. 25b, c – a complicated, chair-like shape filled with liquid. The latter "toy" forms in some points lenses-like shapes, with small radii: objects are strongly deformed by such lenses. Numerical simulations are needed to describe such "thick" lenses (Karwasz, 2004, 2005).

Till now we supposed that convex lenses are always focusing. But more precisely, it depends on indices of refraction – of the lens n_2 and of the medium outside the lens. This is codified by the equation

$$n_1/p + n_3/q = (n_2 - n_3)/R_2 + (n_2 - n_1)/R_1 \qquad (6)$$

where n_1 is the medium in which the object is placed and n_3 in which the image is formed. R_1 is the radius of curvature of the lens on the side of n_1 medium, and R_2 – of the n_2 medium. Radii are positive for convex surfaces.

A practical illustration of equation (6) is shown in fig. 26. Three batteries are immersed in cylindrical glasses and then in a rectangular aquarium. If the medium in both the glass and aquarium is the same (air or water), the image of the battery is like the battery itself. If water is poured in the glass, the image is broader than the object: the glass acts as a converging lens. If water is poured into aquarium and not into the glass, the latter acts like a diverging cylindrical lens: the image is thinner that the battery. We called this play "a shop with batteries": with no extra objects the seller can display three different types of batteries, differing in diameter, i.e. R6, R14, and R20.

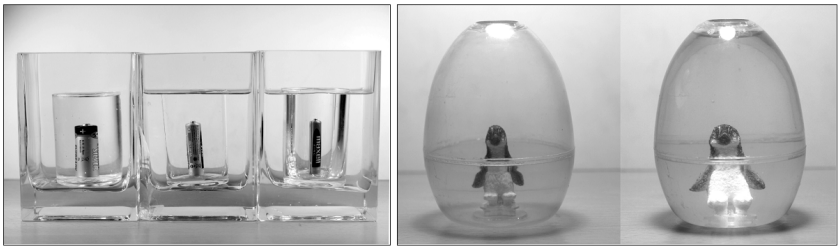

Fig. 26. a) "Shop" with batteries (project Mirosław Brozis): water fills the rectangular aquarium but not the inner glass (left panel); it fills the glass but not aquarium (central panel); it fills both the aquarium and the glass (right panel). b) "A fat penguin" – grows in diameter when water is filled into the (sphere-like) container. Photos KS.

Another yet example of phenomena described by eq. (6) is shown in fig. 27: this is a plastic rectangular ash-tray filled with water; the central part of the ash-tray forms a spherical lens. This spherical part acts as a magnifying lens, see fig. 27a. But if a (spherical-like) air bubble is formed inside, it acts as a de-magnifying lens.

Fig. 27. A toy ash-tray filled with water: the central convex part acts as a magnifying lens, spherical-like air bubbles in water act as a de-magnifying lens. Objects and photo GK.

Resuming, physics contributes in a special way to general education of students. Therefore, physics education may not be restricted to pure physical topics but have to be combined with everyday life phenomena and problems; optics is one of most popular subjects (Schlichting 2005). However, the first step is to train teachers in a way that they understand all possible aspects of experiments, and not only the basics of them (Gioka 2011). Students who develop understanding of simple phenomena but complex, interdisciplinary explanations of them, can be successful teachers not only of physics but of other sciences as well.

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Fun with Optics - teaching by images

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TABLE OF CONTENTS

LIST OF AUTHORS

Martin Bílek

Department of Chemistry, Faculty of Science, University of Hradec Králové, Czech Republic

Comparison of the Achievements of the Student with Difficulties in Learning Chemistry and Using "Entertainment-Education" and Traditional Teaching

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Effectiveness of Excursion to Water Treatment Plant in Prague Podolí

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How to Motivate Pupils to Be Interested in Maths: an Inspiration Resulting from One Mathematical Competition

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What and why – non-formal education of children in Poland – possibilities and experiences

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Fun with Optics - teaching by images

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The Role of the Fun in Science Teaching

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How to Motivate Pupils to Be Interested in Maths: an Inspiration Resulting from One Mathematical Competition

Wileta Kopek-Putała

Department of Chemistry, Faculty of Science, University of Hradec Králové, Czech Republic

Is Cola healthy? Theoretical and lab classes for students of different age groups (preschool to junior high school)

Comparison of the Achievements of the Student with Difficulties in Learning Chemistry and Using "Entertainment-Education" and Traditional Teaching

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What and why – non-formal education of children in Poland – possibilities and experiences

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Value of children's literature as a source of information about biology and ecology of pollinating insects

Małgorzata Nodzyńska

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The Role of the Fun in Science Teaching

Is Cola healthy? Theoretical and lab classes for students of different age groups (preschool to junior high school)

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Value of children's literature as a source of information about biology and ecology of pollinating insects

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Effectiveness of Excursion to Water Treatment Plant in Prague Podolí

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Didactics of Physics Division, Nicolaus Copernicus University, Toruń, Poland

Multimedia in science education

Fun with Optics - teaching by images

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What and why – non-formal education of children in Poland – possibilities and experiences

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What and why – non-formal education of children in Poland – possibilities and experiences