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SCIENCE

geography biology health chemistry research physics environment nature

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SCHOOL

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Editorial

Dear readers,
Last year we introduced some innovations to Biological and Environmental Education journal. The first issue published in 2014 is not an exception. We are proud to present you the whole issue published in English for the first time. Biological and Environmental Education is published online for over a year to make the journal easily accessible for everyone. Although Internet is thought to be borderless, the language is often a problem to access the content of interest. Taking these limitations into account, we decided to publish the first issue of Biological and Environmental Education in English every year. We believe that English issue of Biological and Environmental Education will appear to our international readers interesting; we publish wide variety of articles from reviews in biology and environmental sciences to research articles in pedagogical sciences. We are looking forward to receive feedback from our international readership, and hope that our journal will help to communicate them with Polish scientists and school teachers.

We would like to stress, however, that Polish readers remain to be our main readership. For this reason, we continue to publish whole issue also in Polish language. This solution will grant full access to Biological and Environmental Education to Polish readers, and give chance to international readers to discover valuable contents, inaccessible until this opportunity.

In 1/2014 issue of Biological and Environmental Education, I strongly recommend the article submitted by plant physiologists from Adam Mickiewicz University in Poznań: *What do plants do in winter?* Actually we are going away from winter, but surely you will be fascinated by what plants really do during winter time. In SCIENCE section you will also find an article by dr. Eliza Rybska regarding symbolism of shells in culture. I hope that readers not necessarily working as biologists also will find something interesting for them in this article. In SCHOOL section, we have lecture scenario for the biology class, truly suitable for the beginning of spring. To be precise, it is written for a botanical garden in the city of Zielona Góra, but we encourage readers to adapt the scenario for your own surroundings – botanical gardens, parks or natural habitats in your neighborhood. If weather conditions appear not suitable for field activities, we also have interesting articles to offer; paper regarding PISA will engage everyone working at school. We are confident that this review will give you a new perspective to PISA studies. Additionally, you will find much more materials covering wide variety of fields which our readers are interested in.

Recently, editorial board of Biological and Environmental Education decided to act for better sexual education in Polish schools. We want our journal to serve as a trustworthy platform communicating about delicate issues regarding sexual education of young people. To begin with, we would like to show that human sexuality has much in common with health; in terms of not only *soma*, but also *psyche*. You are welcome to visit our website and Facebook profile to follow the latest information about this subject.

Takao Ishikawa

What do plants do in winter?

Łukasz Wojtyla, Małgorzata Adamiec, Ewa Sobieszczuk-Nowicka

coherence with the Curriculum – see. p. 11

Summary:

Due to degree of tolerance of low temperatures, plants can be divided into susceptible to cold or frost and resistant to temperature that drops below zero. In the temperate climate, most of plants are tolerant to low temperatures and have evolved several mechanisms which enable them to survive the winter and limit the negative effects of low temperatures. Extremely important in preparing the plant for the coming winter are gradual temperature drops and the gradual shortening day of the autumn. Reduction of cell membrane fluidity and a decrease in efficiency of photosynthesis are the main mechanisms involved in the perception of weather conditions. This leads to the induction of processes acquiring tolerance to unfavorable conditions by modulating genes expression, the accumulation of specific proteins with cryoprotective properties, the synthesis of osmotically active and antioxidant compounds. Some species overwinter as dormant, others, that are called evergreen, retain metabolic activity adjusting to winter conditions.

Key words: chill, photosynthesis, frost, low temperature, winter

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Introduction

One of the characteristics of a temperate climate is alternation of the seasons, including one with low temperature, often decreasing below zero, called winter. Plants that have ability to survive the winter need some preparation, which takes place in the months of autumn preceding the winter – a time of adverse environmental conditions. In the Northern Hemisphere, the autumn is the period when the average temperature begins to gradually decrease, the day is shorter and the amount of light reaching the earth's surface reduces. In the course of evolution, plants have evolved adaptive mechanisms to enable them to survive in the cyclically recurring adverse environmental conditions. The set of adaptive mechanisms are switch on in response to changes occurring in the environment (Starck, 2002). Both the climate and the weather significantly affect the physiological processes occurring in plants, but the internal mechanisms regulating the growth phase also play an important function in vegetative and generative growth and dormancy. Physiological and biochemical processes occurring in plants in the absence or limited availability of light have been discussed earlier (Wojtyla and Adamiec, 2013). In this work, we will try to answer the questions about the way in which plants respond to low temperature, what changes occur in the metabolism of plants in winter and how plants "know" that the winter is coming.

Depending on the criterion adopted, several terms could be considered as the beginning of winter. Calendar-base winter begins in the Northern Hemisphere on December the 1st and lasts for three months, commonly referred to as the winter (December, January and February). The astronomical winter begins at the winter solstice on 21st or 22nd December and ends at the vernal equinoxes around 20th March. Meteorological winter in the Northern Hemisphere lasts from 8th December to 9th of March, covering the period when average daily temperature is equal to or less than zero of Celsius. Ecological and phenological winter cover the time of winter together with the approach of winter and early spring which are characterized by plant dormancy (Trenberth, 1983). In this paper we will focus on mechanisms that plants run for toleration and adaptations to overwintering.

How plants know that winter is coming – the mechanisms of the perception of low temperatures by plants

Plants begin to prepare for winter already in early autumn. Most plants, in order to survive the winter period, fall to a state of dormancy, which is a reversible inhibition of growth and metabolic activity (Lewak, 2012). Whole plants, as well as their parts e.g. shoots, buds, rhizomes, tubers and seeds, can fall to dormancy, and this process is induced, depending on the species, by the shortening day or low temperature. Leaves senescence induced by the shortening day and the formation of the winter bud has been described in detail by the Swedish group of researchers on the example of aspen (*Populus tremula* L.) (Fracheboud et al., 2009). The ageing process of leaves is preceded by the stoppage of growth and forming the winter bud. Senescence of the leaves begins with the decrease of chlorophyll content and degradation of proteins constituting the photosystems located in the chloroplasts. The degradation of the photosynthetic apparatus aims to recover the maximum amount of organic matter, mainly nitrogen-rich compounds, which are reversed to the shoot and stored there in the form of reserve proteins in the vacuoles of cells of the ground tissue of the cortex. Swedish researchers suggest that in this way up to 90% of the total nitrogen pool of the leaf

can be recovered (Fracheboud et al., 2009). Simultaneously, with the degradation of the photosynthetic apparatus, the amount of chloroplasts falls and a change occurs in their ultrastructure, as a result of which chloroplasts transform into gerontoplasts, or ageing plastids, which are devoid of lamellar structures (Keskitalo et al., 2005). These processes lead to the complete disappearance of photosynthetic activity, which is a signal for increased reversing of nutrients from the leaves. Then the death of cells occurs in the process of programmed cell death (PCD), forming an abscission layer leading to falling of the leaves. The autumn senescence of leaves is subject to precise gene and hormonal regulation. In the course of leaf senescence a decline in the level of cytokinins is observed, as well as the increase in the level of plant hormones such as anabscisic acid, salicylic acid, jasmonic acid, and ethylene (Buchanan-Wollaston et al., 2005, Zhang and Zhou 2013).

The decrease in temperature causes in people the feeling of coolness or coldness. The functions of receptors of coldness in human skin are fulfilled by end-bulbs of Krause, which react by sending a nervous impulse when the skin cools. Plants do not have a nervous system, however, they have the ability to respond to changes in thermal conditions by adjusting to changing environmental conditions by regulating biochemical reactions and molecular processes. The cell membrane participates in plants' perception of low temperatures, and more accurately, the change in its fluidity (Murata and Los, 1997). Along with the decrease in the temperature, the fluidity of biological membranes reduces, which in assuming a more crystalline structure increase their permeability and lose the ability to selectively transport ions, which enables free influx of calcium ions to the inside of the cell. The influx of Ca^{2+} ions, in addition to the signalling function, also leads to the depolarization of the cell membrane. At the same time, a change in the structure of the cell membrane reduces the activity of enzymatic proteins connected with membranes, including ATPases. Both low temperature and the increase in Ca^{2+} ions concentration in the cytoplasm result in the destabilisation of the cytoskeleton and the depolymerisation of actin microfilaments, which processes are most probably involved in the gene expression regulation induced by low temperature (Örvar et al., 2000). The effect of coolness also leads to the depolymerisation of microtubules co-creating the cytoskeleton, another of the mechanisms involved in the perception of low-temperatures stress in plants (Nick, 2013).

The process of photosynthesis is also involved in the perception of temperature changes, which thanks to high sensitivity to changes in environmental conditions and precise regulation can affect the metabolic processes occurring within the entire cell (Ensminger et al., 2006). It has been suggested that in the perception of thermal changes in the environment, the key role is played by the redox state of elements of photosynthetic transport of electrons (the degree of their reduction/oxidation), which regulates the photophysical, photochemical and metabolic reactions taking place in chloroplasts. One of the elements responsible for the regulation of the redox state is plastochinon – a molecule involved in the photosynthetic transport of electrons. Changes in the intensity of photosynthesis, resulting from external factors, including environmental ones such as low temperature, lead to a shift in the ratio of the reduced plastochinon to the oxidised plastochinon. The pool of the reduced plastochinon through the retrograde (backward) pathway of sending a signal from chloroplast to nucleus, regulates the level of nuclear genes expression (Adamiec et al., 2008). The involvement of photosynthesis in the perception of low temperature and in crosstalk between the redox state, low-temperature adjustment and signalling pathways through sugar molecules, is an essential element in the overall response to and the acquisition of tolerance to low temperatures (Ensminger et al., 2006). The pathways of signal transduction using molecules of sugars interact with hormonal pathways in response to changes of the external environment, thereby creating in plant cells a complex and extensive signalling network. A number of dependencies have been demonstrated between sugars and plant hormones in the adjustment of plants to cold (Ciereszko 2006). A complex coordination of signalling and metabolic processes is an essential element in response and acquiring tolerance to low temperature by plants.

Mitochondria are also involved in the mechanism of perception of low temperature. Temperature drop induces changes in the flow of electrons in the mitochondrial chain of electron transport, and just as it takes place in chloroplasts, changes of the degree of reduction of individual components of the chain, which affect the redox state of mitochondria, and through the retrograde pathway leading to the cellular nucleus regulate nuclear genes expression shaping the cell's response (Dutielleul et al., 2003).

The negative effects of winter

Low temperature causes many adverse physiological, metabolic and structural changes that lead to the accumulation of damage, which can result even in the death of the plant cells. The observed effects of low temperatures are changes in the structure and permeability of the cell membrane, disorganization of the cytoskeleton structure, changes in the enzyme activity of enzymes, inhibition of photosynthesis as well as growth and cell division arrest (Ruelland and Zachowski, 2010). Inactivation of ATP synthases also called as ATPases takes place under the influence of cold (Rorat, 2010). These enzymes are present mainly in the plasma mem-

brane, mitochondrial inner membrane and chloroplast tylakoids of chloroplasts. ATPases catalyze the reaction of production the compounds with highly energetic bonds, such as ATP from ADP and inorganic phosphate Pi. They have also an important function in the transport of ions through the plasma membrane and are responsible for the selective permeability of membranes. Moreover, they participate in the maintenance of an electrochemical potential gradient across the membrane. At low temperatures, most of the enzymes and metabolic processes decrease the activity, including the efficiency of photosynthesis. The drop in temperature causes a reduction in the cells demand for the products of photosynthesis and reduces the rate of CO_2 assimilation by carboxylase/oxygenase ribulose-1,5-bisphosphate (RuBisCO). This leads to an excess of ATP and NADPH as well as to a deficit of $NADP^+$ and phosphate residues, which leads to a decrease in photosynthetic efficiency, referred to as inhibition of photosynthesis. Inhibition of photosynthesis is caused by excessive reduction of components of chloroplast electron transport chain, which leads to the leakage of electrons and increased generation of reactive oxygen species (ROS). Increasing of the concentration of ROS is referred to as oxidative stress and is dangerous for the cell. ROS in addition to the functions as a signal molecules and in regulation of genes expression cause also damage to proteins, cell membranes and the nucleic acids, including DNA (Ruelland and Zachowski, 2010).

When the temperature drops below zero, there is a change of the state of the water in molecules, which leads to the crystallization. Ice formation in the intercellular spaces is the main source of most of the damages associated with freeze. The formation of ice crystals in the intercellular space leads to the decrease of the water potential, which leads to water leakage from the cell and further growth of ice crystals. Water flow from the cell stops when the water potential between the cell and ice crystal becomes balanced. Ice crystals expanding in the intercellular spaces cause mechanical damage to the cell wall, the plasma membrane, the cytoskeleton and the intercellular junctions. Mechanical damage to the cells is one of the main causes of plant death due to the frost.

The decrease of temperature below zero leads to dehydration of the cells and at the same time causes supercooling of cytoplasm and its crystallization. Crystallization of water inside the cell leads to its irreversible damage and death (Rorat, 2010). This process is one of the reason of plants freeze. Frost and plant freeze is the most common cause of winter damage to plants leading to their death. In addition to freeze, there also some other adverse effects of winter on plants in the temperate climate zone are observed, such as: waterlogging, frost-drought (desiccation and scorch), displacement, washing, blowing, smothering, snow mould and attacks by pests (Grzesiuk, 1999).

Waterlogging is associated with long-term retention of water in cultivated fields, often combined with the frost. Desiccation is caused by freezing water in soil, which prevent its uptake by the roots. Despite a significant reduction in transpiration, especially in evergreen plants, it still occurs even during freezing temperatures. Scorch in turn is a result of the dry and cold winds intensifying plant dehydration. Frost-heaving which cover displacement, washing and stripping, leads to expose the underground parts of plants, such as tillers in monocot plants, root neck in dicotyledonous as well as roots, tubers or bulbs, which greatly increases their susceptibility to frost and drying, leading to damage and death of plant. Smothering define the process of plant dying under a residual snow cover, when the temperature increase under zero. Lack of light under the snow leads to depletion of stored substances and starvation leading to exhaustion of the plants and induction of senescence. Moreover, this process is often accompanied by infestation by fungi, particularly by snow mould (Grzesiuk, 1999; Link et al., 2010). Winter-hardiness is associated with resistance to all these factors. However, the most important aspect is frost-hardiness.

The presence of snow cover also influence the plant hardiness, mainly due to its physical properties as a good thermal insulator to protect wintering plants from direct exposure to the cold and wind. By reflecting a large amount of light by the snow cover, it maintains a more stable and thus a higher temperature at the soil surface, bridging diurnal variation and preventing overheating of plants during the day. Moreover during the time of strong frosts the ground under the snow freezes not too deep, which favours plants overwintering (fig. 1). The negative effects of winter play a particularly important role in terms of crops, which are manifested by a decrease in yield, production and profitability for farmers.

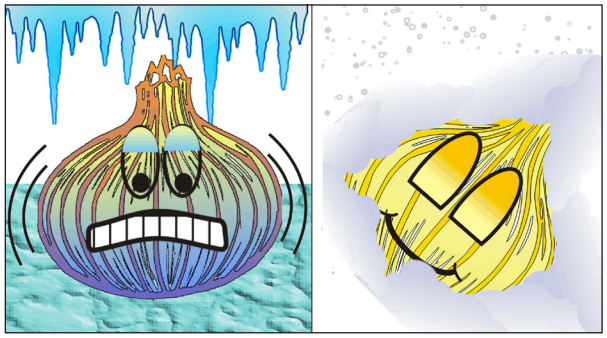

Fig. 1. Under snow cover

Winter crops are exposed to extreme weather conditions, large variations in heat and strong winds are responsible for a high degree of plant frost. Plants that are under snow cover are subjected to less temperature changes, are protected from direct exposure to wind and sunlight, which contributes to their overwintering [M. Adamiec].

Plant strategies for low temperatures and frost tolerance

In biology, plant stress is defined as the influence of adverse environmental conditions or substances on the growth and development (Lichtenthaler, 1996). The major difference between the response of plants and animals to the stress stimulus is, that unlike most animals, which may escape from the effects of stressor, plants do not have the ability to active movement towards the stressor free space. Unable to escape from the stress stimulus, plants developed, in the course of the evolution, broad range of defensive reactions that enable them to survive in adverse environmental conditions.

Cold and frost are, except drought, the major natural factors limiting crop production by slowing or stopping the plant growth. At the same time low, especially subzero temperatures often cause plant death. For this reason, the cold tolerance mechanisms are essential for plants inhabiting areas where during the winter the temperature drop below 0 °C.

Some plants, such as trees and shrubs, form resting buds, which protect shoot apical meristems (fig. 2A and 2A1). There are also evergreen species, which include a large group of conifers (fig. 2B), but also some deciduous, like rhododendrons. Another overwintering strategy was developed by perennials, which form overwintering organs from modified shoots transforming them into bulbs, stem tubers and rhizomes or from modified roots for example storage roots known also as tuberous roots (fig. 2C–F) (Szweykowska and Szweykowski, 2000). Many plants, including annual species, overwinter as a seeds (fig. 2G). This form of survival of adverse environmental conditions is also associated with reproduction and spreading the species. Molecular mechanisms of freezing tolerance mainly include rearrangement biological membranes structure (i.a. cell membrane), changing the direction of metabolic reactions by affecting the ATP availability and reduced pyridine nucleotides, modification of water relations, physiological drought and synthesis of compatible and protective substances. All these mechanisms can be divided into two groups depending on the strategy, in which they are involved: preventing water crystallization of water within the plant tissue water within the plant tissue or tolerating the effects of extracellular water of crystallization (Kacperska, 2012).

Temperature changes influence the cells functions at different levels. Changing the cell membrane fluidity is one of the most important elements directly reacting to changes in temperature (fig. 3). Reduction of membrane fluidity causes a number of adverse biological changes that have already been discussed. In response to low temperature, the content of unsaturated fatty acid as the acyl chains of phospho- and galactolipids in plant cell membranes increases, preventing loss of membrane fluidity in parallel with decreasing temperature (Theocharis et al., 2012). It was also observed that presence of certain sterols such as stigmasterol and sitosterol in plant cell membranes is essential for maintenance of their fluidity and permeability (Senthil-Kumar et al., 2013). The function of plant sterols is very similar to the one performed by cholesterol in the membranes of animal cells and referred as "temperature buffer" for the membrane because it resists the changes in membrane fluidity caused by changes in temperature (Urry, 2008). In addition to the rearrangement of the cell membranes composition in response to low temperatures changes in genes expression are also observed. Cold-induced genes encode proteins involved in acquisition of low temperatures and frost tolerance and transcription factors activating expression of genes involved in metabolic adaptation process. Most of these genes can be described by common name: COR (cold responsive genes). Their expression is regulated by transcription factors belonging to the CBF family (C-repeat binding factor) which in turn are regulated by presence of ICE1 activator (inducer of CBF expression 1). ICE1 is a constitutive protein, present in plant cells, that is activated in response to low temperature- induced signal transduction cascade (Chinnusamy et al., 2003). To the proteins accumulated in response to low temperature stress belongs late embryogenesis abundant proteins family (LEA). Among them especially important role is played by LEA2 subfamily proteins also known as dehydrins. Dehydrins are highly hydrophilic proteins, performing protective functions by stabilizing

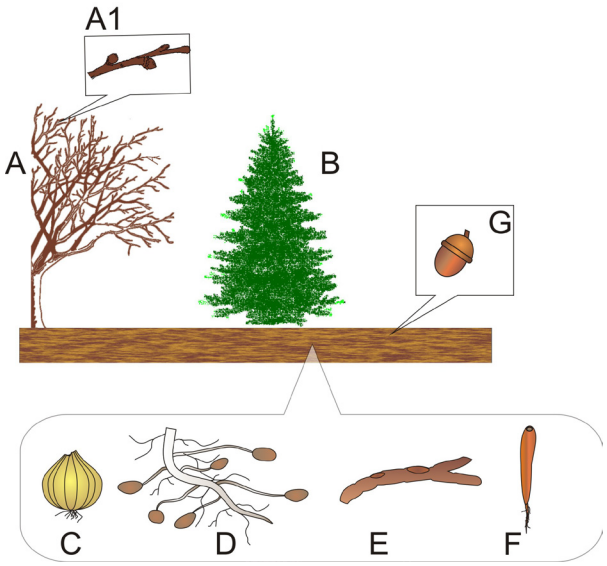

Fig. 2. The structures responsible for plant overwintering

A – deciduous plant in winter, A1 – overwintering buds of trees and shrubs, B – evergreen plant, C – the transformation of momentum, onions, D – transformation of shoot, tubers shoots, E – transforming momentum, rhizome, F – the root of bulb, G – seed.
Based on Szweykowska and Szweykowski, 2000; M. Adamiec.

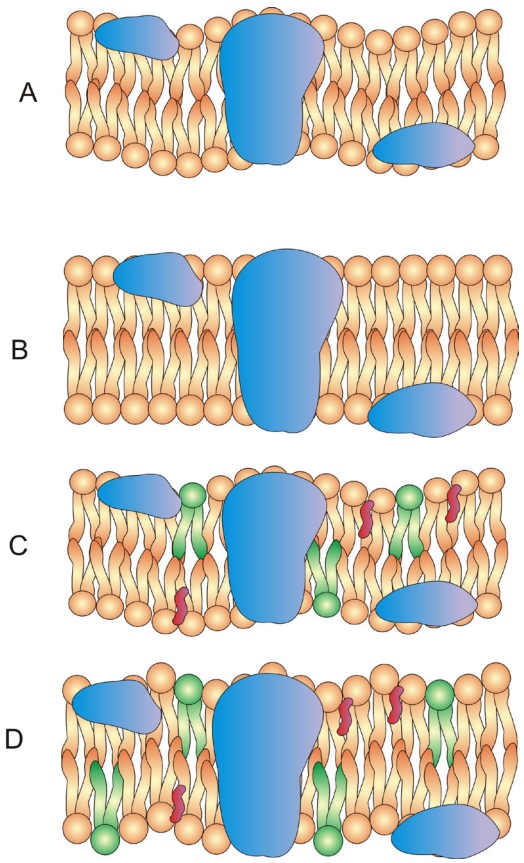

Fig. 3. Structure of the cell membrane in response to changes in temperature

A – fluid structure of the cell membrane under optimal thermal conditions, B – rigid crystal structure of the cell membrane at reduced temperature, C – continuous structure comprising cell membrane fatty acids and phospholipids in the particles at the optimum temperature of phytosterols, D – fluid cell membrane structure including unsaturated fatty acids and phytosterols at reduced temperatures. Orange – phospholipids building framework of membrane, blue – membrane proteins, green – phospholipids and galactolipids containing unsaturated fatty acids, red – plant sterols. Based on literature data (Theocharis et al., 2012, Senthil-Kumar et al., 2013), modified – M. Adamiec.

the structure of proteins and membranes under the water deficit and exhibiting cryoprotective activity (Rorat, 2006). Another group of proteins accumulated in response to low temperatures are antifreeze protein (AFP) described also as the thermal hysteresis protein (THP). These proteins lower the freezing point of aqueous solutions in which they are located below the melting point. The resulting difference between the freezing point and the melting point is called thermal hysteresis (Pukacki, 2011). The AFP proteins are predominantly accumulated in the apoplast, where they prevent water from freezing. Due to high affinity of AFP protein to ice (higher than to water molecules), the growth of the ice crystals is limited and their crystallographic structure is affected thus determining the hexagonal structure (Pukacki, 2011). The third group of proteins involved in the acquisition of low temperatures tolerance are cold shock protein (CSP), involved also in developmental processes and in abiotic stress response. It was confirmed that presence of CSP enhance low temperature tolerance, however, the precise mechanism of their action in plant cells has not yet been described. It has been suggested that, like in yeast or animals cells, CSP may be involved in maintenance the proper chromosomes structure and perform a protective function of the DNA during replication and transcription and RNA and polypeptides during translation (Chaikam and Karlson, 2010). The protective function is also carried by heat shock proteins (HSPs) which increased accumulation level was observed at low temperatures as well (Kmieć et al., 2005). Apart from proteins accumulated peculiarly in response to low temperature, synthesis of an osmotically active and cryoprotective substances is also observed. These compounds are defined as compatible substances and include soluble carbohydrates, such as sucrose, sorbitol or mannitol, plant sterols, amino acids such as alanine, glycine, proline, or serine, polyamines, betaines (Theocharis et al., 2012). Like any other stressors, low temperature and frost lead to increased production of ROS. At the same time, the increase in the antioxidant content is observed. These compounds have radical scavenger properties and are able to remove excess of ROS. The most important non-enzymatic antioxidants include glutathione, ascorbic acid, flavonoids, α-tocopherol and carotenoids. The increased level of the low molecular weight antioxidants is accompanied by increased activity of antioxidant enzymes, mainly superoxide dismutase, catalase and peroxidases (Pukacki, 2011). The simultaneous triggering of broad range of low temperatures defensive reactions allows the plant to acquire resistance to cold and frost, which features to a large extent determine plant cold resistance (fig. 4).

However, even plant species that are able to survive a few months of subzero temperatures without major damage in their natural conditions, have not developed the constitutive mechanisms of frost resistance, which is acquired only as a result of a gradual temperature lowering. Immediate plant transfer from the optimal environment conditions to subzero temperature will cause permanent damage, resulting in cell death and, in consequence, death of the whole organism. The process leading to activation of mechanism responsible for acquisition of frost resistance is called hardiness or low temperature acclimation (Theocharis et al., 2012).

What plants do during the winter – about the processes taking place in the leaves of an evergreen plant

Declining temperature leads to a number of changes in the metabolism of plant cells in order to prepare the plants for surviving the winter, and especially for frosts. Most species go to a dormant state, and their metabolism is very limited. However, there is a fairly large

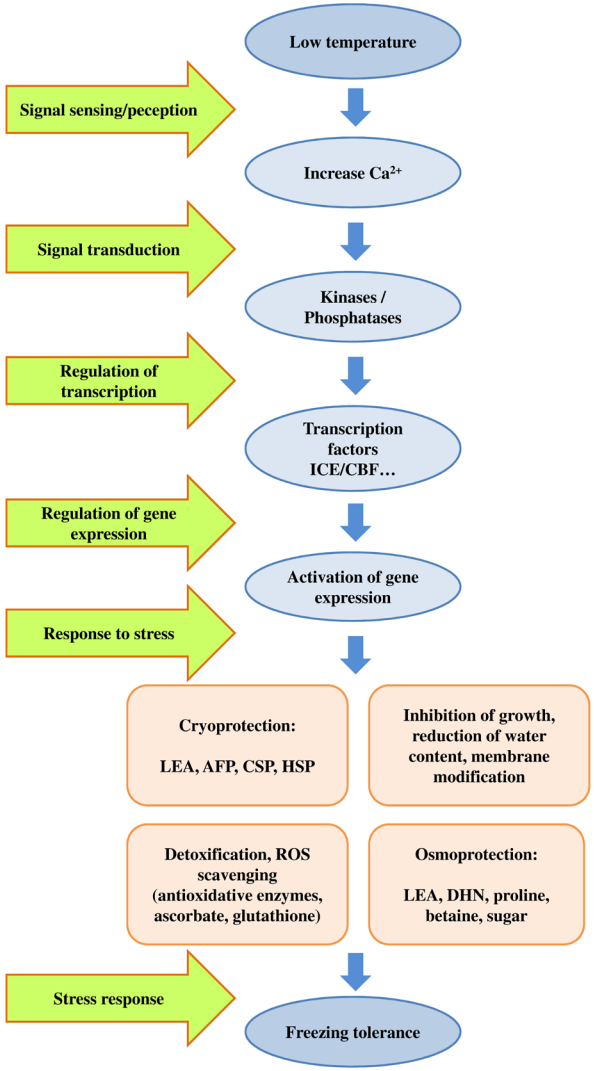

Fig. 4. Diagram shows the plant mechanism of stress tolerance to low temperature

Based on (García Bañuelos et al., 2008), modified – Ł. Wojtyla.

group of so-called evergreen plants, otherwise known as winter-green, which include pine trees (coniferous) occurring in Poland, with the exception of the larch, some shrubs (rhododendrons, lingonberry, holly, buxes), as well as herbaceous plants (periwinkle); in addition, this group includes ivy and viscum. These plants, in addition to low-temperature tolerance, by preventing the formation of ice crystals inside the cells, must cope with serious metabolic changes associated with the energy of the cell. In the winter, the amount of light that enters the leaf surface is reduced, which affects the efficiency of the photosynthetic process. However, at temperatures below 0 °C, the greater danger is related to the potential damages of cell components through ROS. This takes place during clear, sunny and frosty weather. ROS production is a result of a significant inhibition of enzyme activity involved in the light-independent phase of photosynthesis. This causes inhibition of photosynthesis through saturation and excessive reduction of components of the photosynthetic chain of electron transport in chloroplasts. Disorders in linear electron transport, which are the consequence of changing climatic conditions, can also result in the inhibition of gene transcription for LHC proteins. Antenna systems of LHC (light-harvesting complex) are complexes gathering light energy. These are complexes of proteins and photosynthetic pigments located in thylakoid membranes. These complexes absorb light quanta and transfer their energy to the reaction centres of photosystems, where the proper photochemical reaction takes place. Dysfunction in the synthesis of LHC proteins leads to the inhibition of photosynthesis (Jackowski, 2001). In evergreen plants the inhibition of LHC transcription also takes place. These plants can, however, prevent impaired synthesis of LHC proteins by synthesising ELIP (early light-induced protein) similar in construction and function to LHC proteins, which allows the continuation of the process of photosynthesis (Montané and Kloppstech, 2000). During photosynthesis inhibition induced by low temperature, also damage to the enzyme manganese-schiff base complex may occur, which is a catalysts for water photolysis. The water photolysis through the complex, which is mediated by light, is an integral component of the photosynthesis light reactions. Dissociation manganese ions from the complex, as a result of photoinhibition leads to disorders in linear electron transport, that in turn, also results in ROS production (Pilarski et al., 2008). In the leaves of evergreen plants an increase in the content of low-molecular antioxidants has been found, as well as increased enzyme activity involved in the process of sweeping free radicals (Wang et al., 2009).

One of the mechanisms that protect cells against excessive ROS production and damage within the photosystems is the xanthophyll cyclethatrelies on the reversible conversion ofxanthophylls-violaxanthin to zeaxanthin, both are pigments included in the antenna complexes. The decrease in pH inside thethylakoid observed during temperature decrease and strong light illumination,favors the conversion of violaxanthin to zeaxanthin. This forces changes in antenna protein conformation and leads to dissipation of energy (in a form of heat) between the pigments molecules instead of passing it to the PS II reaction centers. Thus, the xanthophyll cycle is a kind of molecular switch between energy capture and dissipation (Demmig-Adams et al., 1996). Starting photo protection mechanisms in the form of an antioxidant system, xanthophyll cycle or ELIP expression are not the only mechanisms of reducing hazards in the cells of a leaf's mesophyll caused by the adverse effects of winter on the process of photosynthesis.

Characteristic for evergreen plants are also changes in ultrastructure of mesophyll cells and leaf morphology resulting from changes in the intensity and spectral

composition of light reaching the surface of the leaf. At a low intensity of sunlight red radiation predominates, leading to the expansion of the antenna system in the photosynethic apparatus, absorbing radiation, while the amount of synthesised RuBisCO decreases. Chloroplasts formed in these conditions are characterized by a small amount of grana, with the predominance of stroma thylakoids. In the membranes of grana thylakoids mainly PS II complexes are located, while stroma thylakoids abound in PS I. The large size of antennas arises from the need for maximum absorption and utilization of small quantities of light. In addition, in conditions of low light intensity, the value of the ratio of chlorophyll *a/b*, as well as PS II/PS I decreases (Pilarski et al., 2012). Furthermore, the amount of energy reaching the leaf and the inside of chloroplast is adjusted through adaptive changes associated with the thermonastic movement of the leaf. During the period of frost the leaves of plants of the genera Kalmia, huckleberry, and rhododendron change their position from horizontal to vertical, which significantly limits the amount of light reaching the leaf, reducing the risk of injuries related to the inhibition of photosynthesis in conditions of sunlight on the leaf at negative temperatures (Russell et al., 2009).

Are plants able to warm up?

Most plants assume the ambient temperature because their metabolic reactions proceed gently without production an excess heat that could significantly increase the temperature of their bodies. There is, however, a group of several-hundred plant species producing enough heat to maintain temperature higher than the ambient one.These include, among others: *Amorphophallus paeoniifolius* (also known as Stink lily), *Sauromatum guttatum* ("voodoo lily"), *Victoria cruziana* (tropical water lily) or inhabiting a temperate zone *Symplocarpus foetidus* commonly known as swamp cabbage, or because of its unpleasant smell, skunk cabbage. Swamp cabbage plant flowers early in the year, sometimes by New Year's Day in mid-Atlantic states.Its teardrop-shaped bloom can melt holes in the snow cover or bloom inside a snowbank and create their own ice caves. *Symplocarpus foetidus* maintains a constant flower temperature of about 15 °C even when the air temperature drops to -15 °C (Milius). These thermogenic plants can greatly increase the rate of their metabolism and maintain it for a few hours, days or even weeks. As result of accelerated metabolism not only the increased temperature is observed but also enhanced secretion of strong odors, allowing the pollinators attraction from a very large distances. Inflorescences of many thermogenic plants formed a special organ- the floral chamber, which is the most thermogenic part of the blossom. The floral chamber protects sensitive structures against cold, provides a pollinator-friendly, living environment and protects pollinators against predators (Lamprecht et al., 2002).

In thermogenic plants acceleration of metabolic reactions occurs so quickly that the process is often referred to as "metabolic explosion". The amount of heat generated as a result of a such acceleratedmetabolism causes the increase in the plant temperature by a few or even several degrees in relation to the ambient temperature and is maintained at a constant level irrespective to air temperature. Increase in heat evolution in response to chilling is observed, although to a very limited extent, also in other plants such as lima bean, soybean, cucumber, cotton, tomato, pea, potato or mouse-ear cress (Moynihan et al., 1995).

Heat production in plants is generally thought to be associated with an increase in the mitochondria activity. A crucial role in this process is played by the cyanide-resistant electron transport pathway, which seems to be present in all plants at variable capacity, but it is particularly active in thermogenic species. (Watling et al., 2006). A key enzyme of this process is the "alternative oxidase" (AOX) located in the inner mitochondrial membrane. AOX accepts electrons from the ubiquinone pool and uses them to reduce oxygen to water. The alternative oxidase is not a proton pump and is not able to supply the oxidative phosphorylation (the metabolic pathway leading to the synthesis of ATP), the free energy released during the reaction catalyzed by it is dissipated as heat (Michejda, 2000). Beside the alternative cell respiration pathway in *Symplocarpusfoetidus,* another mechanism of heat production exists. The mechanism is similar to the one present in mammals cells respiratory pathway, called non-shivering thermogenesis. A crucial role in this process is played by uncoupling proteins (UCPs), located in the inner mitochondrial membrane (Onda et al., 2008). UCPs dissipate the proton gradient generatedacross the mitochondrial membrane by the electron transport via the respiratory chain. As a result of this process, synthesis of ATP does not occur, and the accumulated energy is dissipated as a heat.

Conclusion

Plants, in response to changes in environmental conditions, trigger physiological, biochemical and molecular mechanisms that allow them to adapt to new ones. In response to the signals of coming winter, plants can get ready, in a manner which is specific of every species, to its arrival. It makes them able to survive the winter months. The winter season is extremely dynamic for plants. It is characterized by alternating periods of freezing and thawing or cloudy or sunshine days. Therefore, the plants, especially the evergreen species (wintergreen), need to dynamically adapt to extreme

weather conditions. These plants effectively regulate rates of metabolic changes, mainly of photosynthesis. Carbon dioxide assimilation, as well as energy production is also necessary to maintain cell viability. Living organisms have to continuously ongoing metabolic processes, even if the metabolism is very limited, inhibition of cell growth and cell division occur, and requirement for carbon skeletons of organic compounds is reduced, to survive. An appropriate amount of ATP has to be synthesized. Photosynthesis and cellular respiration are processes that correspond toward it.

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ES-N participation in the text writing and English correction.

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Contents of education – detailed requirements:

5. Land plants. A student:

1) compares living conditions of plants in water and on land and indicates the features of plants, which enabled to conquer land environment;

8. Plants – reproduction. A student:

1) provides basic features of germ and seed, and indicates their adaptive importance to living on land.

Mitochondrial diseases

Volha Paulouskaya

Abstract:

Mitochondria are found in every nucleated cell of the human body. The major function of these cell compartments is energy production. Mitochondria are the only orgenalles of the human cells that have their own genetic material – mitochondrial DNA, that is because of their bacterial ancestry. Mutations in the mtDNA as well as in the nuclear genome cause mitochondrial diseases, the symptoms of which are very diverse. Mitochondrial dysfunction is a common phenomenon of many disorders, also of neurodegenarative diseases.

Key words: inheritance, mitochondrial genome, mtDNA, mutation, neurodegeneration

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Contents of education – detailed requirements:

I Structure and functioning of a cell. A student:

2) describes cell membrane (...),

4) describes structure and functions of mitochondria and chloroplasts, provides arguments for their endo-symbiotic origin;

VI. Genetics and biotechnology. 7. Genetic diseases. A student: provides examples of human genetic diseases caused by gene mutations.

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Introduction

Mitochondria are cell compartments that can be found in every nucleated cell of the human body. They are mostly known for their role in energy production – 90% of cellular energy stored in ATP (adenosine triphosphate) is generated in mitochondria. That's why mitochondria are often called "powerhouses of the cell". Besides energy production mitochondria participate in other vital cellular processes: programmed cell death (apoptosis), biosynthesis of amino acids and lipids, maintenance of cytosolic calcium homeostasis to name only a few. Mitochondrial dysfunctions result in a diverse and variable group of disorders.

Origin and structure of mitochondria

At the beginning of the 20th century researchers realized the structural similarities between bacteria and mitochondria. Now it is generally accepted that mitochondria are of bacterial ancestry. According to the endosymbiotic theory, mitochondria derived from bacteria, which became an endosymbiont of the early eukaryotic cell. As a result, mitochondria retain many prokaryotic features: a bacterial shape, a double membrane and a circular genome (Andersson et al., 1998). The size and shape of human mitochondria varies between tissues (from 0.5 to 10 micrometers), but all of these organelles have the same structure. Mitochondria are bounded by two phospholipid membranes: outer mitochondrial membrane (OMM) and inner (IMM). The space between IMM and OMM is called intermembrane space (IMS). OMM is permeable to most small molecules, that's why the content of the intermembrane space is similar to that of the cytoplasm. In the cytoplasm mitochondria are connected with endoplasmic reticulum (ER). Several protein complexes tether OMM to ER. These connections are crucial for proper mitochondrial function. The space enclosed by the inner mitochondrial membrane is the matrix. Mitochondria are the only organelles of the human cells that have their own genetic material – mitochondrial DNA (mtDNA). mtDNA is packaged in DNA-protein complexes called nucleoids. Nucleoids are bound to the IMM and are located in the matrix.

Mitochondrial genome

Mitochondrial genome retains bacteria-like features, but is smaller than bacterial one. During evolution, most mitochondrial genes have been transferred to the nucleus and now only some mitochondrial proteins are encoded by mitochondrial genome, the rest are encoded by nuclear genome. The human mitochondrial genome is a double stranded circular DNA molecule consisting of only 16 569 base pairs. mtDNA contains 37 genes: 13 of these genes encode proteins, the other 24 genes encode 22 tRNA and 2 rRNA, which are required for the translation of 13 mtDNA-encoded proteins (Anderson et al., 1981). All of these proteins are components of the oxidative phosphorylation system (OXPHOS) – a metabolic pathway in which ATP is produced. In comparison with nuclear genes, human mitochondrial genes have no introns. Codon usage in mitochondrial genome differs slightly from that of the nuclear genome. For example, AUA in mtDNA codes for methionine, not isoleucine; AGA and AGG are stop codons. mtDNA is associated with several proteins, but not histones (Strachan and Read, 1999). Mitochondrial genome is maternally inherited and is polyploidic, which means that it is present in several thousand copies per cell. That's why mitochondrila genetics is different from Mendelian genetics.

Homoplasmy and heteroplasmy

When we are born, copies of mtDNA are thought to be identical in most people. But during our life mutations in some molecules of mtDNA are accumulating, so that not all of the mtDNA copies are identical. This phenomenon leads to the state which is called heteroplasmy. In simple words, heteroplasmy is when copies of the mtDNA within the cell are heterogeneous, when there is two or more mitochondrial genotypes, homoplasmy is when all of the copies of the mtDNA within the cell are the same. These expressions are useful when we talk about mutations in mtDNA that lead to disease. Homoplasmic mutations occur in all the molecules of the mtDNA, whereas heteroplasmic mutations affect only some copies of mtDNA. Due to the fact that there are thousands of mtDNA copies in the cell, there is a threshold level of mutation of mtDNA that becomes visible phenotypically. Usually from 60% to 90% of mtDNA molecules should carry the same pathogenic mutation before the disease symptoms occur. The level of mutations between cells usually differ due to random replication of the mitochondrial genome. There are numerous copies of mtDNA in the cell and it is hard to believe that all of the copies are identical. Although it is said that in the absence of detected mtDNA mutation a person is homoplasmic, in every cell of our organism different mitochondrial genotypes could be found (Taylor and Turnbull, 2005).

The mtDNA genetic bottleneck

Mitochondrial DNA is maternally inherited. It is logical to suppose that every of the maternally related mammals would have the same mitochondrial genotype. But actually different variants of mtDNA (called polymorphisms) can be found within one maternal lineage. And it is not a result of heteroplasmy when copies of mtDNA in one individual are not identical. It means that offsprings of the same mother have different mitochondrial variants. In 1982 researchers from Florida noticed that within one maternal lineage of Holstein cows existed two variants of mtDNA (Hauswirth and Laipis, 1982).

The reason of this phenomenon was unclear. Now we are aware of the mtDNA genetic bottleneck. A primordial gem cell (PGC) contains thousands of mitochondria and different variants of the mtDNA. Into each of the primary oocytes, that stems from the primordial germ cell during its division, only some mitochondria from the PGC are transported. Therefore, primary oocytes have different populations of the mtDNA. During oocyte maturation these mtDNA populations are replicated. It is also proposed that during the oocyte growth only some subpopulations of mitochondrial genomes are replicated, others are not. Both of these processes, selective replication of subpopulation of mitochondrial genomes and transfer of selected number of mitochondria to primary oocytes, generate more than one genotype in one maternal lineage. But the reasons why only some subpopulations of mtDNA are replicated and which one mtDNA molecule would be replicated remain unclear. Because of the mtDNA genetic bottleneck it is very difficult to predict whether a child of a mother with mtDNA mutation would be affected. It depends on the subpopulation of mtDNA that it will inherit and many other factors. A child of heteroplasmic mother with pathogenic mutation might have low level of mutation and be healthy, have intermediate level of mutated mtDNA and be mildly affected, or carry high level of mutation and have a mitochondrial disease (Wai et al., 2008).

Mitochondrial proteome

As it has already been mentioned, mtDNA encodes 13 proteins that are essential for the production of cellular ATP. The rest of the proteins that are crucial for mitochondrial metabolism and maintenance are coded by the nuclear genome. These proteins are synthesised in the cytosol, they possess targeting signals in their amino acid sequence that allow them to be transported to the mitochondria. It is estimated that the human mitochondrial proteome consists of nearly 1400-1500 proteins, almost all of which are encoded by the nuclear genome. Nearly 1100 of these proteins have been identified so far (Calvo and Mootha, 2010). There are different strategies for identifying the proteins, but none is ideal. An interesting fact about the mitochondrial proteome is that approximately half of its proteins are found in every tissue and the other half are tissue-specific (Mootha et al., 2003). Some of the mitochondrial proteins take part in energy production, programmed cell death, metabolism of lipids and amino acids and other vital processes, but cellular functions of the rest of the mitochondrial proteins are not yet investigated. Dysfunctions of the mitochondrial proteins lead to the mitochondrial diseases, which can be caused by mutations in mtDNA as well as in the nuclear genes.

Clinical features of mtDNA diseases

The process of ATP production, in which 13 mtDNA-encoded proteins participate, takes place in mitochondria. That is the reason why mutations in the mtDNA usually affect tissues with high energy demand, such as skeletal muscle, heart and nervous system. However, other tissues also could be involved. mtDNA disorders can develop at any age, early in child-

hood or in adult life. The clinical features of these diseases are variable, involve many organ systems and can include: peripheral neuropathy (damage of the peripheral nervous system), dementia, myopathy (muscular weakness), epilepsy, ataxia (lack of coordination of movements), speech disorder, dysphagia (difficulties in swallowing), cardiomyopathy, diabetes, optic atrophy (optic nerve damage), ophthalmoplegia (weakness of the muscles that are responsible for eye movement), ptosis (drooping eyelids) (Taylor and Turnbull, 2005). Such variety of symptoms normally makes the diagnosis of the mtDNA diseases a real challenge. It is not so hard to diagnose the classic syndromes, but some patients with mtDNA diseases might have nonspecific symptoms.

Main mtDNA-related diseases

mtDNA-related diseases were first reported in 1988. Since then, a lot of other mutations in the mitochondrial genome have been identified and more diseases have been described.

The most common mtDNA-related disorder is Leber's hereditary optic neuropathy (LHON). It leads to acute loss of central vision in adults and affects mostly men. This disorder is caused by the mutations of one of the 13 mtDNA-encoded proteins which take part in energy production (Wallace et al., 1988).

Myoclonus epilepsy and ragged red fibres (MERRF) is a rather rare mitochondrial disease. It involves hearing loss, exercise intolerance, epilepsy and dementia; affected individuals sometimes have a short stature. Ragged red fibres are visible in microscope when patient's muscle is stained with Gomori Trichrome. The reason for this is the accumulation of dysfunctional mitochondria beneath cell membrane of the muscle fibres. The shape of the muscle fibres becomes irregular, that's why it is said "ragged red fibres". MERRF is caused by mutations in tRNA-Lys of the mtDNA. These mutations result in impaired function of the protein vital for ATP production (Schon et al., 2012).

Mitochondrial encephalomyopathy, lactic acidosis and stroke-like episodes (MELAS) is a disorder that affects mainly nervous system and muscles. Most of the patient with MELAS experience stroke-like episodes which include vision abnormalities, paralysis of one side of the body and migraines. A unique feature of this syndrome among other mtDNA diseases is angiopathy. The most common mutation in MELAS is mutation in tRNA gene of mtDNA, but many other mutations have been connected with this disease (Kaufmann et al., 2011).

Leigh's syndrome is a disease that affects the central nervous system, it is characterised by loss of mental and movement abilities and usually lead to death within a couple of years from the time the first symptoms appear. The first symptoms could be difficulties with swallowing and vomiting, which can result in lack of ability to grow. Patients also have breathing problems. Although generally mutations of the nuclear genes lead to Leigh's syndrome, nearly 25% of the cases are caused by mutations in the mtDNA. Genes connected with the disease are involved in energy production (Schon et al., 2012).

Neuropathy, ataxia and retinitis pigmentosa (NARP) is a disease causing symptoms that affect the nervous system. These symptoms are similar to that observed in Leigh's syndrome; NARP is also caused by mutations in the mtDNA, in the gene involved in energy production. When nearly 70% of the mtDNA carry the mutation, a patient has NARP, but when mutation load is more than 90%, a patient has maternally inherited Leigh's syndrome – MILS – that is caused by mutations in the mtDNA (Schon et al., 2012).

Reversible respiratory chain deficiency is a rare disease caused by homoplasmic mutation in the mitochondrial tRNA gene. It is characterised by general muscle weakness. Interestingly, it is an uncommon disorder, affected individuals can recover naturally within two years; that's why it is called "reversible".

Kearns-Sayre syndrome (KSS) is developed before the age of 20, patients have impaired eye movement due to the weakness of the eye muscles, they may also have ataxia, dementia, deafness, problems with kidneys or diabetes. KSS is a result of the deletion of the mtDNA which removes 12 mitochondrial genes (Moraes et al., 1989).

Progressive external ophthalmoplegia (PEO) is generally developed between the age of 18 and 40. The common symptoms are drooping eyelids and weakness of the muscles that move the eye. Weakness of the skeletal muscles can also be observed. The disorder is caused by mutations in the mtDNA, but also in the nuclear genes that are vital for DNA maintenance (Moraes et al., 1989).

Pearson's syndrome results in problems with blood cells development, other organs might also be affected. The disorder is triggered by the mtDNA deletions (Pearson et al., 1979). Half of the affected patients die in early childhood, those who survive develop KSS in their teenage years.

Models of mtDNA diseases

As it has already been mentioned, mutations in the mtDNA as well as in the nuclear genome cause mitochondrial diseases. But how can that be checked whether this particular mutation in the mtDNA causes any disease or not? Or is phenotype caused by mutation in the nuclear genome or the mitochondrial? Currently no method is known for introducing exogenous mtDNA into the mitochondria that later will lead to a stable in-

heritance of the introduced mtDNA. For a long time this fact have been impeding efforts to study the connection between mtDNA mutation and the phenotype it causes. In spite of this fact, the consequences of many mtDNA mutations have been verified through cytoplasmic hybrid (cybrid) technology (King and Attardi, 1989). In this method, mitochondria that carry mutated mtDNA are transplanted into the cells that do not contain its own mtDNA (ρ^0 cells). The most popular technique for making ρ^0 cells is to introduce the cells to the ethidium bromide (EtBr) solution, which unables mtDNA replication. The cells without mtDNA need uridine and pyruvate for growth. The ρ^0 cells are fused with cytoplasts that were delivered form the patients' cells. Cytoplast is an enucleated cell, it contains all compartments of the cell except the nucleus. After fusion of the ρ^0 cells with cytoplasts, cells are cultured in media without uridine and pyruvate; that allows the growth of the cells that have mitochondria from the patient and nucleus from the ρ^0 cells, but the other cells do not grow on this medium. The cybrid technology makes it possible to analyse the consequences of the mtDNA mutations; it is helpful to decide whether the observed phenotype is caused by mutations in mtDNA or nuclear genes. Additionally, threshold levels for mtDNA mutations can be tested using this technology.

Inheritance of mitochondrial diseases

A type of inheritance of mitochondrial disorders depends on the gene which causes this particular disorder. If a mutation is in the nuclear gene, the following types of inheritance are possible: autosomal recessive (AR), autosomal dominant (AD) or X-linked inheritance. Rarely, Y-linked inheritance is also possible. But when a mutation is in the mtDNA, the manner of inheritance is hard to predict, because of the heteroplasmy and genetic bottleneck. The only thing that can be said for sure is that if a man carries mtDNA mutation, he won't transmit it to his children, since mtDNA is maternally inherited.

Dynamic nature of mitochondria

In the past it was a common knowledge that mitochondria are oval-shaped cell compartments. The latest research has shown that mitochondria are highly dynamic organelles: they continuously move and undergo fusion and fission (Chan, 2006). In addition, mitochondria differ in size and shape between the tissues and even within one cell. The dynamic nature of mitochondria is essential for their cellular functions. As it has already been mentioned, mitochondria play a crucial role in cellular ATP production. In humans neurons can be up to one meter in length and consume high amounts of energy that is required for synaptic transmission. Energy demand is higher at various locations in neurons, for example, in pre- and postsynaptic domains. Consequently, mitochondria in neurons must be located in areas of high energy demand; it is of vital importance to transport mitochondria to these areas.

Mitochondrial transport in neurons

In neurons, most mitochondria are located in axons and dendrites, but these are not parts of the cell where mitochondria are developed. There are cellular mechanisms that deliver functional mitochondria to the sites of high energy consumption and damaged mitochondria to the cell body, where they can be repaired or degraded. Mitochondria can move in two directions (to the periphery and to the cell body), during the transport they can stop, then continue moving in the same direction or change it. Mitochondria are transported along cytoskeletal structures (microtubules) by motor proteins – kinesin and dynein. Kinesin moves mitochondria towards the plus end of a microtubule, which means from the cell body to its periphery in axons; dynein transports mitochondria towards the minus end of mitochondria, or from the periphery to the cell body in axons. Kinesin and dynein use ATP for their motor functions. Mitochondrial transport is a very important mechanism that regulates local energy supply in the cells (Glater et al., 2006; Hollenbeck and Saxton, 2005).

Fusion and fission

Mitochondrial morphology is dynamic; the size, length and number of mitochondria in the cell is changing due to its fusion and fission. When two or more mitochondria become one, it is called fusion; on the contrary, when one mitochondrion is divided into a couple, the process is named fission. Mitochondria have two membranes: IMM and OMM, both of them are involved in processes of fusion and fission. During fusion, inner and outer mitochondrial membrane join and contents of two mitochondria, including mtDNA, are mixed. This process is regulated by several proteins; in humans, two mitofusins (MFN1 and MFN2) are essential for outer membrane fusion, and the protein OPA1 is required for tethering mitochondrial inner membranes (Chen et al., 2003). Mitochondrial fission is under control of the protein DRP1, which must be recruited to the mitochondrial outer membrane to enable division, and other proteins, some of that are located on the OMM surface (Smirnova et al., 2001). Fusion and fission change mitochondrial shape, they lead to fewer but longer organelles or result in more but shorter mitochondria, respectively. In normal cells, mitochondria are undergoing fusion and fission so that the number of these organelles remains more or less the same. An

important question is what is the reason for these processes. Under stress conditions, starvation, mitochondria fuse; and fission makes the quality control of mitochondria possible: when some part of mitochondrium is damaged, fission allows isolation of this disfunctional part and its further degradation (Chen et al., 2005). In normal cells, most mitochondria work properly, but some of them are dysfunctional, for example, they might be deficient in mtDNA or have mutated mtDNA molecules. The dysfunctional mitochondria can fuse with functional ones, contents of the two organelles exchange and mitochondrial genomes are mixed, and then the fused mitochondria undergo fission. As a result of these events, dysfunctional mitochondria receive functional mitochondrial genome which allows them to work properly (Detmer and Chan, 2007). In case proteins required for fusion or fission do not function properly, the functions of impaired mitochondria can not be restored. Abnormalities in mitochondrial fusion and fission cause a number of human diseases.

Role in neurodegeneration

Cells that are particularly sensitive to defects in mitochondrial dynamics – fusion, fission and transport – are neurons. Defects in the proteins that are essential for mitochondrial dynamics lead to neurodegenerative diseases. Interestingly, mutations in *MFN2* and *OPA1*, both affecting mitochondrial fusion, cause different diseases: Charcot-Marie-Tooth disease type 2 (CMT2A) and dominant optic atrophy (DOA), respectively. CMT2A is a neuropathy that affects motor and sensor neurons and DOA leads to degeneration of retinal ganglia cells and to vision problems or blindness. Among other cellular functions, mitochondria play a central role in activating cell death in human cells (apoptosis). Therefore, alterations in mitochondrial dynamics may lead to the death of the neuron cells. Recent research has shown that mitochondrial fusion and fission are altered in major neurodegenerative diseases, such as Alzheimer's, Parkinson's and Huntington's disease. Moreover, control of the mitochondrial dynamics can to a certain degree prevent neuron death in these diseases (Chen and Chan, 2009).

Huntington's disease

Huntington's disease (HD) is an autosomal dominant disorder which is caused by expanded repeat of the trinucleotide (CAG, encoding glutamine) in the huntingtin gene. The disease occurs when expansion of the trinucleotide CAG is more than 36; huntingtin with more than 36 glutamine residues is prone to aggregation. Usually the symptoms of the disease begin nearly at the age of 40 and include movement and cognitive disorders: impairment in movements, difficulties with swallowing, rigid muscles, loss of previously learned skills and behavioural problems. Mitochondrial dysfunction, disproportion of fusion and fission and impaired mitochondrial movement have been noticed in the cells of HD patients. Huntingtin is localised in the cytoplasm and is connected to cellular compartments: ER and mitochondria. Although huntingtin is expressed in every cell, mutant form of this protein affects medium spiny striatal neurons, which leads to their loss due to apoptosis. The reason for this phenomenon remains unclear. It has been described that cells expressing huntingtin with 74 glutamine expansions have reduced mitochondrial fusion. The level of DRP1 protein is increased in these cells which leads to increased mitochondrial fragmentation. Overexpression of the MFN2 protein, which is essential for the outer membrane fusion, can save mutant phenotype and reduce cell death. That means that inhibition of fission (of the DRP1 protein) can partially prevent neuron apoptosis, and might be helpful to prevent Huntington's disease. However, the molecular mechanisms which lead to cellular dysfunction in Huntington's disease are not yet known and it is hard to say that decreased mitochondrial fission can prevent neuron dysfunction and death (Costa et al., 2010).

Alzheimer's disease

Alzheimer's disease (AD) is the most common dementia of elderly age, it is characterised by memory loss, problems with intellectual abilities and behaviour which are caused by degeneration of the neurons in the cerebral cortex. It is a progressive disease, symptoms worsen with time. The molecular mechanism underlying pathogenesis of Alzheimer's disease is not completely understood, but it is known that in the brains of AD patients amyloid β (Aβ) plaques are found; Aβ derivers from precursor protein called APP as a result of its proteolytic cleavage. Mouse overexpressing APP have Aβ plaques in their brains which lead to the neuronal death. Mitochondrial structure abnormalities are also typical for the brains of AD patients. It has been proposed that Aβ can associate with mitochondria and it might be the reason of its toxic effect on this organelle. Cells in which Aβ plaques are found have increased mitochondrial fission, impairment of ATP production and structural changes. It is suggested that Aβ might activate DRP1 and intensify fission. Accumulation of the Aβ plaques can also affect mitochondrial transport (Santos et al., 2010).

Parkinson's disease

Parkinson's disease (PD) is the second most common neurodegenerative disorder of elderly age, it leads to the loss of dopaminergic neurons and include different symptoms, such as shaking, slow movement,

stiff muscles and slow speech. Treatment can make the symptoms less severe, but there is no cure for PD. In contrast to HD and AD, mitochondrial dysfunction is a cause rather than a consequence of PD. Research has shown that mitochondrial toxins (for example, rotenone) cause symptoms that are characteristic for PD. Parkinson's disease can be caused by mutations in nuclear genes encoding several proteins, alpha-synuclein, PINK1 and Parkin among them. Mutations in the mtDNA might also be a cause of the PD. Alpha-synuclein is a small protein which plays a role in neurotransmission, but an exact function of this protein has not yet been investigated. Alpha-synuclein has a mitochondrial targeting sequence and its accumulation result in increased production of reactive oxygen species (ROS) by mitochondria. Mutations in *PINK1* also affect mitochondrial function. PINK1 is expressed in brain; it localises in mitochondria. Mutated *PINK1* leads to the loss of dopaminergic neurons, but how it happens is elusive. Parkin is a protein involved in mitochondrial quality control, it is found in the cytoplasm, but under stress conditions is recruited to the mitochondria; after this, damaged mitochondria are degraded. That means that parkin may lead to elimination of dysfunctional mitochondria. Recent research has shown that both PINK1 and Parkin are involved in the process of mitochondrial fission. Nevertheless, the connection between these proteins and mitochondrial fission may not be straight. Enlarged mitochondria are noticed in the cells with mutated PINK1 and Parkin (Exner et al., 2012).

In conclusion, perturbations in mitochondrial dynamics are a common feature of many neurodegenerative diseases, but the exact mechanisms that underlie these observations have not yet been investigated. Although misbalance of fusion or fission is observed in AD, HD and PD, the connection between altered mitochondrial dynamics and fusion/fission protein is not straightforward. Obviously, proper mitochondrial dynamics is crucial for normal cellular function. It is a challenging task to unravel the real connection between mitochondrial dysfunction and neurodegenerative diseases. These findings may make the diseases curable.

Conclusion

Mitochondria play an important role in many cellular processes. Dysfunctions of these organelles lead to mitochondrial diseases, which can be caused either by mutations in the mtDNA or in the nuclear genes. Due to heteroplasmy and genetic bottleneck the inheritance of mtDNA-related diseases is hard to predict. Mitochondria are motile organelles, they undergo fission and fusion and are transported to the sights of the cell with high energy demand. Neurons are particularly sensitive to disturbances of mitochondrial dynamics, which is a result or a cause of many neurodegenerative diseases. Better understanding of the role of mitochondrial functions in these disease may be helpful for the invention of new therapies.

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Symbolism of shells in world culture

Eliza Rybska

Summary:

The article presents a collection of reflections on the shell as an object placed in a cultural context. Symbolism of the shell and its possible artistic representations are the main focus. There are over 30 symbols or symbolic representations of the shell classified into 7 categories. These are described with supporting examples from culture, art and myth. Particular attention was paid to the anthropological meanings of the shell with reference to characteristics or aspects of human behaviour.

Key words: symbol, shell symbolism, nature, culture

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Coherent with
the Polish core curriculum:

supplementary subject Nature – 4th educational stage

Thematic threads:

16. Science and art

22. Beauty and charm.

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Introduction

The need for integrated or holistic teaching is not a new phenomenon and has been described repeatedly (Bereźnicki, 1999). Integrated (holistic) teaching is understood here as an opportunity to merge otherwise scattered information (content) (Zaczyński, 1996). This information is mostly spread between different classroom subjects. So far it has been difficult to put this type of teaching into practice, especially at junior high and high schools. One concept for cross-curricular paths to deal with a holistic view of the world was described in the previous Polish core curriculum (Journal of Laws 2002 No. 51 item 458). The current core curriculum from 2008 (Journal of Laws 2009 No. 4 item 17) also provides some opportunities for integrated and holistic teaching by introducing project work at the third level of education. The next opportunity emerges as a new subject Nature at level 4. In the description of this subject in the Core Curriculum, thread 16. – art and science, theme 3 reads as follows: "16.3. Identification of plant and animal materials used by ancient artists, symbolic representations of plants and animals in paintings, art and epidemiology (disease of humans, animals and plants preserved in ancient art)". This highlights the need to integrate information from various fields of science with culture. The role of art in education was demonstrated by the founders of the Leonard Bernstein Centre, which prepares of teachers, schools and communities to introduce the artistic process to teaching in all subjects (http://www.leonardbernstein.com/lbcenter.htm). In the centre a method called "Artful Learning" (learning through art) was developed and introduced to schools scoring test results above the lower quartile. Teachers and parents noted significant progress in children's achievement. There is evidence that the introduction of art as a tool in education yields tangible benefits. Art might be treated as a tool that helps us with many issues during education such as: improvement of reading skills when integrated with visual art (especially for elementary school pupils), reading comprehension, critical thinking skills (Ewing, 2010) developing creative problem solving (Foshay, 1998) and writing skills by encouraging creative thinking (Gibson and Larson, 2007). Vetulani (2011) emphasised that "art, its reception and creation, are immanent and specific characteristics of human nature and are factors that activate the whole brain. Learning perception of art and art production expands our cognition (cognitive attention), and with it, all cognitive aspects of the brain and should be especially promoted at all (...) levels of education."

Art and symbolism

Culture and art in particular seem to be an intrinsic to Homo sapiens. The first cave paintings appeared as representations of the surrounding world. Many scholars and scientists have deliberated whether art should be considered one of the characteristics of human nature (Gombrich, 2008; Vetulani, 2010; Gazzaniga, 2011). For the artist, art is a form of communication with the world. It can be considered as a form of communication, the task of which is not only to express the artist's emotions, but also to evoke specific emotions in the audience. Gibson (2009) claimed that "art communicates with the recipient mainly by anecdotes and symbolism and the symbol is something that has to be deciphered to understand the meaning of the whole work". The brain also uses symbols, not only images, but also a symbolic system of words, i.e., language (see Maruszewski, 2011). Ramachandran (2004) claims that "every painting is a 'super stimulus', crafted by an artist to strongly stimulate the human brain". For the purposes of this article, the definition of a symbol is ac-

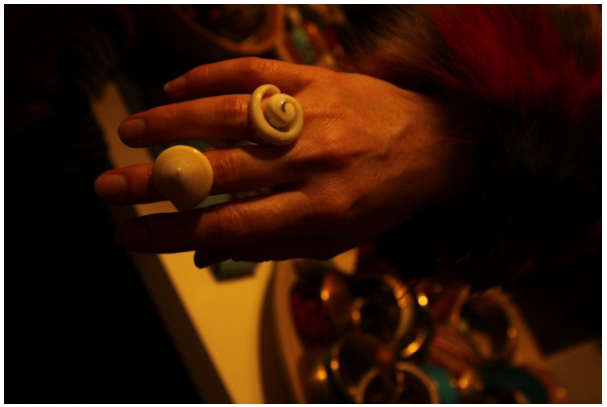
cepted after Kopaliński (2007) who states that symbols may be understood as objects – notions, ideas, feelings associated with one's attitude (i.e., those which seem similar or to have "the same rhythm") as an object or concept. Thus, analysis of the meaning of a symbol is not easy, as it could be ambiguous, "every object that is a symbol tends to have many meanings, to be stable and unstable (…) one of the properties of a symbol is its indefiniteness, and also ambiguity, contradictions, and the fact that its real meaning is revealed only to those in the know". In the introduction to *Symbols of nature*, Impelluso (2006) suggested that before the Enlightenment "the world of nature had many symbolic meanings, which were so complex that today humans are not capable of understanding them and objects represented in still life works may have a great variety of meanings, in which every fruit, flower and animal denotes one particular characteristic". He also remarked that symbolism is deeply rooted in culture, where the human being is at the centre, but they are always intimate with nature and its representations such as the beauty of a flower in full bloom. Also Eliade (1998) claimed that "thinking in symbols is not only a domain of a child, poet, or a mentally ill person; it is closely associated with human existence, it appears earlier than the ability to speak and think discursively. A symbol reveals some aspects of reality – usually those implicit – which cannot be easily understood".

Shells in culture

Shells have always delighted with their beauty and have inspired multitudes of artists. As Zieliński (2001) points out, in the 16th and 17th century, shells were the theme of many artistic still life representations. In France and the Netherlands there were art schools which specifically taught how to create an image of the beauty of colours and shapes produced by marine molluscs. Shells were often used by goldsmiths and sculptors as raw material to produce objects. Many unrivalled jewellery designs and other artistic crafted objects date from the 16th and 17th century. Among these were Nautilus cups made out of snail and nautiloid cephalopod shells (*Nautilus sp.*) (see phot. 1). Shells were often used in exchange for goods in trade, and in some cases they were exported to where people had never seen the sea. It would not be surprising for shells to have been perceived as wondrous or even magical objects in some regions. Cowry shells (e.g., *Cypraea annulus* and *C. moneta*), well known to travellers, were used as currency over 4000 years ago, long before the Phoenicians invented money as such (Samek, 1992; Biedermann, 2001; Lakshmi, 2011). The Chinese were probably the first to use these shells as legal tender (Lakshmi, 2011). Cowry shells (kauri) were also used as payment by Gorals from Podhale who made good quality linen canvas. As Zygmunt Kuchta (chief of the Bucovina People's House) explained, when the gorals earned well, they wanted to flaunt it and placed necklaces made of cowry shells on their hats. Roman Dzioboń, poet and activist of the Polish Podhale Society (Polish Highlanders Alliance), claimed that Gorals wore these shells, because their whiteness contrasted well with the black hat. If this were to have been the case, they would have used other ornamentation such as straps contrasting with the hat. Klein in "A Short description of the Tatra Mountains" (transl. Radzikowski, 1897, after Szaflarski, 1972) stated that Gorals brought shells from the Adriatic sea, processed them on stones, grinding away the bulge so that holes formed to allow the shells to be threaded onto often red woollen string. Since the shells serving as currency were quite small, Gorals used strings of a hundred to facilitate counting.

Phot. 1. Nautilus Cup, the Rosenborg Castle in Copenhagen, Denmark

The beauty of shells was very often an inspiration in the design of objects of applied art. Shells of *Cypraea* were used for example for spoons (phot. 3). Even today goldsmiths use some types of shells to produce jewellery. Good examples are Trochidae (*Tectus niloticus*) (Samek, 1992., Beads made 82 000 years ago were found in a limestone cave in Grotte des Pigeons (Taforalt, Morocco) in North Africa. They were perforated *Nas-*



Phot. 2. Modern jewellery made out of sea snails shells

sarius gibbosulus (Bouzouggar et al., 2007). In India, snail shells of many species (e.g., Cerithium, Cerithedia, Phalium, Planaxts and Conus) and mussels (e.g., Donax, Atactodea, Area, Cardium and Scaphopoda) are used in the production of dolls (Appukuttan and Ramadoss, 2000). The term *china* was coined probably during Marco Polo's journey to China. When he first saw shiny Chinese ceramic pottery he thought it similar to small *Cypraea lurida* shells from the Mediterranean which were used as amulets in Italy. The word *porceletta* in Italy means 'little pig' due to the fact that the head of the snail *C. lurida* looks like the head of a small pig. Even today such "porcelets" are produced as amulets in Italy, since people still believe that they bring good luck (Chądzyński, 2008). The other hypothesis about the origin of the term *china* is that it originated from the Portuguese word *porcella*, which means "shell" (Selwa, 2002).

Phot. 3. *Cypraea* spoon, the Rosenborg Castle in Copenhagen, Denmark

Shells are noticeable in painting. Their beauty, colours and shapes are valued by artists. Particularly noticeable is the shell in vanitas painting, referring to their transience and characterised by rich symbolism.

Shells have always been regarded as collectable items. Lakshmi (2011) remarked that the reasons people collected them probably numbered the same as the collectors. Also pointed to, was the contribution of the collectors to development of industry and research expeditions. For example, diving and snorkelling ventures in particular, were supported by people in the search for shells of some species of mollusc (Lakshmi, 2011). Collecting objects is nothing new and it its roots lie in antiquity. Aristotle was probably a shell collector because "their great variety of different shapes and colours not only take your breath away, but can also add wings to your imagination" (Chądzyński, 2008). Collecting works of art is also perceived as an aristocratic tradition. One of the oldest shell collections is in the ruins of Pompeii (Samek, 1992). People collected shells not only for their private collections, but also as souvenirs. In the production of shell souvenirs people often use the shells of Turbinidae (*Turbo sarmaticus*), Cypraeidae (*Cypraea tigris* – probably the most common), and Muricidae – *Murex ramosus* (Samek, 1992). In the Middle East area one can quite easily obtain oil lamps made from snail shells such as *Hippopus hippopus* or *Lambis sp.* (Lakshmi, 2011).

Shells were also of interest to architects and sculptors (phot. 4). The shape of shells was incorporated into building design and shell motifs are frequently found in the buildings of the Greeks, Romans, and Phoenicians (Lakshmi, 2011). As Zieliński (2001) points out, in about the year 1730 artists developed a new style of ornamentation, the characteristic of the rococo style, with a fancy asymmetric form, smooth and jagged contours and imitating the shapes of shells. In art,

Phot. 4. Jean Baptiste Carpeaux 1827-1875, *The Girl with the Conch Shell*, Ny Carlsberg Glyptotek in Copenhagen, Denmark

this is known as *rocaille*, sometimes also called *shell ornamentation*.

Shells were also often used in medicine (and are still used for various medical purposes). In the past, shells were thought to have supernatural properties, which could protect people against disease and bad luck. Today, shells, molluscs and products made from them are

still used in medicine. The venom of some Cone Shells (Conidae) is used to treat stroke patients and those with heart disease. Oyster shells are used as a source of calcium for supplements (Lakshmi, 2011).

For centuries people were fascinated by the beauty and symmetry of snail shells. Fibonacci numbers and the golden ratio, an inspiration for mathematicians as well as artists throughout history, is frequently visible in nature; for example, in pine cones, daisies, sunflowers, tobacco plants, the human face, teeth, fingers, arms, flowers, sea shells, snails, chairs and cars (Kaygin et al., 2011).

The shell as symbol

The beauty of shells inspired many artists use them in their work. In the course of time, shells became a mass medium and symbol, especially in vanitas painting. In his dictionary of symbols Kopaliński (2007) listed many symbolic meanings of the shell together with additional associated meanings:

- Moon, deity, word of God,
- pilgrimage, prophecy, the human soul,
- mind, scientific discovery,
- character, nobility, royalty,
- music, hearing, the sound of the sea, sailing,
- inaccessibility, life protection,
- sexual desire, longevity, fertility, virginity, the immaculate conception,
- immortality, death,
- self-restraint, idleness, laziness, personality,
- solitary, misanthropy.

These symbols can be classified into the following categories:

1) inanimate nature
2) the world of sounds and music
3) featuring in myths, legends or the attributes of deities
4) the motif of fertility and birth
5) the motif of salvation and pilgrimage
6) the motif of death, the grave and retreat
6) human characteristics: vulnerability, royalty, power, money, mind, character and jealousy.

Symbols associated with inanimate nature

According to Eliade (2009), sea molluscs shells symbolise water. For the pre-Columbian peoples of Mexico, shells were symbols of water, rain and storm – they saw a similarity between the spiral shape of the snail shell and the spiral pattern of the storm (Tax, 1995; Taube, 2004). The shell of Strombidae (*Lambis*), living on the coast of Japan and China, was an inspiration for the Japanese and Chinese sign of "sui", meaning 'water'. Perhaps for this reason, people used to nail the shells of this snail onto their doors to protect them against fire (Chądzyński, 2008). Shells of *Strombus costatus* were often used by the Olmec as a knuckle-duster, possible both a weapon or an emblem of clouds and rain (Taube, 2004).

Shells are also considered as amulets for sailors; they usually symbolised a good voyage (Kopaliński, 2007; Martin, 2005). The people of the Solomon Islands hung strings of the white shells of the snail *Ovula ovum* on the bows of their war boats. This amulet was purported to help the boats find the right direction, especially at night (Dworczyk and Dworczyk, 1996). Similarly, cowry shells (for example *C. tigris*) were attached to fishing nets to bring good luck to the fishermen and served as weights for the nets (Joseph, 2005). The shells were also a symbol of luck for seafaring, as they signified wind (it is possible to produce the sound of the wind by blowing air into the shell) (Kopaliński, 2007). Many Indian gods of wind were depicted in the form of a snail. For example, the Mayan god of wind was thought to inhabit snail shells (Ingalls, 2009). In ancient China, oysters and other molluscs were associated with the religious aspect of the moon and were also believed to have aquatic powers, that is, snail bodies were not full when the moon was "dead", and mussels like crabs and turtles expanded and shrank with the moon (Elide, 2009). In pagan and Christian art there is clear personification of wind in the form of a human being with distended cheeks blowing air into a shell or animal horn.

Symbols associated with sounds and music

The soul of music slumbers in the shell
(*Human Life* by Samuel Rogers)

Long before people invented new systems of communication, they used trumpets made from shells producing a sound audible over many kilometres (Lakshmi, 2011). Shells served as primitive musical instruments which were played to call for prayers (like the bells and rattles devised later), especially during religious ceremonies, weddings and funerals (Kopaliński, 2007). The shells of the snail species most frequently used for such purposes were *Charonia tritonis, Ch. variegata, Cassis cornuta*, and *Strombus gigas* (Dworczyk and Dworczyk, 1996). Warriors also used shells to trumpet their terrifying battle signals, and shells are still used during Hindu ceremonies and those of Tibetan lamas (Kopaliński, 2007; Lakshmi, 2011). Shell trumpets were also used to herald the entry of dignitaries such as a kings or heros (Lakshmi, 2011). The sounds made using the shell of *Charonia tritonis* could be heard during funerals of nobility on the Fiji Islands and in ancient Egypt (Dworczyk and Dworczyk, 1996). *Strombus gigas* (also called "the queen conch" or *Lambi*) was frequently used for many purposes by the Amerindian people, settled in different countries and in the Caribbean and was

used as a means of communication, as a symbol of mobilisation and gathering for battle. Frenkiel and Aranda (2003) reported that "queen conches made it possible to communicate from hill to hill to announce major life events; birth, marriage, death and rebellion. The sound signalled the return of fishing boats and the start of yam crop season". A salient symbol associated with this species is "the call for freedom" which was announced the end of slavery during the Danish colonial era (Toller and Lewis, 2003).

In Hinduism shells signify the sound of Dharma and the teaching of enlightened people. A shell is also the symbol of the deity, Vishnu. The use of a Shank shell signifies victory for the saints. Its sound is regarded as a symbol of their gods (Lakshimi, 2011).

The shell as a symbol in myths, legends and as an attribute of deities

Because many species of snails live in the sea, their shells were commonly symbols for marine deities. A sea shell towed by dolphins or hippocampus was the chariot of sea deities – Poseidon (Neptune) and Galatea – often symbolised by the shell. In this form shells can be interpreted in many artworks, for example in Rafaello Santi's *Triumph of Galatea* (1511) and Gian Lorenzo Bernini's sculpture *Neptune and Triton* (1620). The shell is also an attribute of Aphrodite (Venus), born from the sea spume according to myth. The motif of birth with the goddess emerging from the spume on a shell, introduced wall paintings in Pompeii (Pliny the Elder, Joseph 2005) was frequently adopted in the works of Sandro Botticelli and Titian (Biedermann, 2001). It is noteworthy that the goddess is portrayed on a *Pecten jacobeus* shell in Botticelli's *The Birth of Venus* (painted ca. 1485) and Titian's *Venus Anadyomene* (painted in 1520). In the latter there is also a small *Pecten* shell. Aphrodite was shown lying on a slightly distorted *Pecten* shell in one of the Pompeii frescos; however, the *Pecten* shell was not associated with the goddess of love in this case. The cult of Aphrodite is associated with shells of *Cypraea tigris*, the main temple of the goddess being in Knidos, Cyprus. The Latin name of the most common species of *Cypraea* originates from the name *Cyprus*, the place of Aphrodite's birth. The association of this shell with the goddess of love was mentioned by Pliny the Elder (Joseph, 2005; Melvill, 1888).

Shells were also considered attributes of mermaids, sea nymphs, and Nereids, as they have been shown in the paintings by Sir Edward John *Poynter At Low Tide* (1913), and *The Cave of the Storm Nymphs* (1903, private collection), or the animated musical fantasy film *The Little Mermaid*, based on the fairytale by Hans Christian Andersen. The bridge of Alexander III in Paris, built in 1900 for the World Exhibition is particularly richly decorated with shell motifs. Apart from a nymph holding a shell in her hand, listening to the sound of the sea, there is also the motif of a Nereid face and the old water god Oceanus. There are also festoons of laurel wreaths woven with shells, draped between the faces of the Nereids, symbols of triumph and prosperity. The ornamentation symbolises triumph, glory and abundance. The bridge leading from the Petit Palais and the Grand Palais to the Invalides Palace is considered the most beautiful in Paris.

The Hindu god Vishnu is often depicted, posing with a *Turbinella* shell in his hand, as a symbol of the ocean, the first breath of life and the first sound (Biedermann, 2001; Lakshimi, 2011). The shell, like the mace, discus and lotus flower, is one of the traditional attributes of Vishnu, "the Guardian of life". The shell in his hand can also be interpreted as a battle trumpet (Gibson, 2009). Moreover, the snail shell is also one of the eight propitious symbols in Buddhism, which according to the tradition appeared for the first time on Buddha's feet (more precisely on the soles of his feet). Hence conches are often presented in the footprints of his feet. In this case the shell signifies Buddha's voice and his teaching (Gibson, 2009). Pre-Columbian peoples living in Mexico used shells as a symbol of the god/prophet, Quetzalcoatl – often depicted with a shell necklace (Taube, 1992; Claassen, 2008). In the Mayan culture, the god probably associated with the sea was called GI (the real name remains unknown), and was depicted as a creature with *Spondylus* shells in his ears (Tuszyńska, 2011). Similarly, Chaak (Xoc), who according to the classification proposed by Schellhas was first simply called "god B", a god of rain and thunder. In classical Mayan iconography, the god is recognised by the characteristic *Spondylus* shells in each ear. During the classical period Mayan people often depicted the god called Chaaka with a conch weapon – a knuckle-duster made out of a shell – the weapon was thought to be used by the god to induce rainfall (Taube, 2004). Conches are also one of the attributes of the "N" god, who was probably born in a *Spondylus* shell, related to the idea of rebirth. In Mayan belief, a human could access the other world (i.e., one of three worlds) through portals, often opened by self-sacrifice, creating a liminal space depicted as jaws, water bands and shells – quite often *Spondylus* shells (Ingalls, 2009).

Motif of fertility of birth

The shells of molluscs, which live in water (thought to be the source of life), were perceived as symbols of fertility and femininity. In the Middle Ages people thought that androgynous molluscs were fertilised by blue dew and for this reason the shell of molluscs became a symbol of virginity and the Immaculate Conception; in the course of time also a symbol of Virgin Mary (Biedermann, 2001; Kopaliński, 2007). The association of the shell with fertility was not confined

to humans as it also embraced agriculture, especially crops. Hence in India people played on conches not only during holiday ceremonies but also during various agricultural events and activities. In Siam priests played on shell trumpets to announce the onset of sowing time and similar customs were observed by Aztecs and on the Malabar coast (Eliade, 2009). Shells often signify femininity because their shape can be similar to the vulva (Kopaliński, 2007), and for this reason were also a very powerful symbol (mainly sexual) (Lakshimi, 2011; Zabilska, 2012). Shells of sea molluscs and pearls worn by women as amulets were thought to endow them with fertility. For example, the Akamba women (a Bantu tribal group inhabiting areas of Kenya) wear special belts made from oyster shells until the birth of their first child (Eliade, 2009). According to old Japanese beliefs, some molluscs facilitate giving birth and hence in Japanese the name for cowry shells literally means "the easy delivery shell". In China these properties are attributed only to oyster shells (Eliade, 2009). As has been already mentioned, in ancient times the emblem of the goddess of love (i.e., Aphrodite) was the cowry shell. For the status of the goddess among the other deities, these shells were also regarded as amulets against infertility and miscarriage (Dworczyk and Dworczyk, 1996; Lakshimi, 2011). In some Christian churches the baptismal fonts were made out of *Tridacna gigas* because they symbolised birth (Lakshimi, 2011). Some old buildings on the Polish coast (for example in some of the old churches in Gdynia), still also have stoups in the form of the big molluscs, usually the clam species (Zieliński, 2001). A shell can also be seen in the hands of John the Baptist (see Impelluso, 2006), especially in the paintings of the baptism of Christ; for example, El Greco's (1614–1618) and Piero della Francesca's (ca. 1440–1450).

Motif of salvation and pilgrimage

As Zieliński (2001) points out "shell symbolism, associated with immortality of the soul (symbolised by a pearl closed in a shell), was an important point of reference for many famous Renaissance painters and their subsequent followers". The *Pecten jacobaeus* shell is one of the attributes of Saint Jacob the Elder and pilgrimages to the sanctuary of His name in Santiago de Compostela (north-western part of Spain). The shell of this snail is sometimes defined as that of *Pecten pilgrimea*, but for pilgrimage purposes, people also used the shells of *Pecten maximus* (Biedermann, 2001). The most common painting of Saint Jacob shows an ornamental hat decorated with a shell (Jagla, 2005). She also gives a list of as many as ten similar paintings of Saint Jacob from Poland in Silesia, Pomerania and Varmia. In other famous paintings Saint Jacob holds the shell in his hands.

The *Pecten* shell is still considered indicative of a good pilgrimage and is used as a water bowl. This shell is also associated with Saint Rocco and the Disciples who met Jesus on His way to Emmaus and with archangel Raphael, who accompanied Tobias on his way on his way to obtain a cure for his father (Biedermann, 2001; Jagla, 2005).

Motif of death, the grave, retreat or leaving

The conch can be associated with the grave, eternal life and the resurrection (Kobielus, 2002). The funereal symbolism of the shell is associated with re-birth and resurrection and it was present in many Roman funerary buildings. This denotation of the shell was also later incorporated into Christian art (Eliade, 2009). The symbolism of the shell with this meaning was established by the observation that the Roman snail (*Helix pomatia*) can produce a special seal to close the shell. After a period of spring drought, the seal is detached and so the snail and its shell were seen as a symbol of resurrection (Biedermann, 2001). Owing to very hard surface of the shells people perceived them as a symbol of the grave, a place where the dead waited for resurrection and salvation. Many gravestones included conches but usually without symbolic significance, they are probably neorococo elements. However, in some graveyards close to Żuławy Wiślane (i.e., the alluvial delta area of the Vistula in northern Poland) there are gravestones ornamented with shells for symbolic reasons. Domino (2009) states that a wide pearl shell on a gravestone suggests that the buried person concealed a "pearl" inside their body (the pearl is sometimes part of the shell), which signified purity and virtue. A spiral shell denoted eternity and the route to God (Domino, 2009). As a symbol of fertility, the shell was thought to empower re-birth and hence their prevalence on gravestones (Eliade, 2009). The symbolism of the shell implying re-birth and immortality probably stemmed from shells, although dead and inanimate, contained life (Kopaliński, 2007).

In many cultures people used to bury valuables into graves with the corpse, including shells. In Africa the bottom of a grave is often covered with shells. In a cave in Laugérie in Dordonya (France) archaeologists found the shells of *Cypraea pyrum* and *C. luria* on a human skeleton. Similarly, in Cro-Magnon there were over 300 perforated shells of *Littorina littorea* (Eliade, 2009). Archaeological discoveries in the Dian cemetery in China revealed tombs with large numbers of bronze weapons and farming implements. There were also ritual items such as bronze drums and cowry shell containers. Moreover, on the lids of the cowry shell containers the casts of activity scenes, narrating Dian's victory in a battle (Yao, 2005) were discovered. In some parts of India people put shells into the mouths of the dead and similar funeral customs have been observed in Borneo (Eliade, 2009). The number of shells depended on the

wealth of the deceased and the mouths of the poor were filled with rice. On the islands near the coast of Venezuela, shells of *Strombus gigas* (the queen conch) were used in the production of personal ornaments and funerary offerings (Antczak and Antczak, 2005).

In many vanitas paintings, which basically present allegorical still life illustrating the transient nature of human life and inevitability of death (Gibson, 2010). Snail and mollusc shells as remnants of an animal represent the end of life and the passing of time. A similar account can be found in Siegel (2011), who suggested that shells in vanitas paintings signified "exploration, power and wealth, scientific discovery and that time is fleeting". Finally, snails, just like reptiles, were also the symbol of the deadly sin of laziness. Samples of vanitas paintings, immortalising shells are shown in fig. 1 and 2.

Human characteristics: vulnerability, royalty, power, money, mind, jealousy

As part of it, people found and still find not only a source of beauty and inspiration in nature, but they also sought reflections of their own characteristics to confirm their social status. In various cultures and regions, shells were used as symbols of the ideas mentioned above.

Shells of *Muricidae* snails signified royalty. One reason being that some species were used by the ancient Phoenicians to produce purple dye (Kopaliński, 2007; Samek, 1992). The shells of *Strombus costatus* were frequently used by the Olmec people to craft sceptres – symbols of power (Taube, 2004). Also in India, the shells were a symbol of social status and great pride (Appukuttan and Ramadoss, 2000). In the Solomon Islands the village leader still wears *Cypraea aurantium* shells to demonstrate tribal domination, holding the most important office and the support of their most important deity, i.e., Fini, who endows wisdom and infallibility. Shells are also perceived as talismans which make becoming rich or wise and speaking publicly much easier (Dworczyk and Dworczyk, 1997). In India *Turbinella pyrum* is the symbol representing success, peace and prosperity (Lakshmi, 2011). The same can be said about Nautilus cups. Even today obtaining a *Nautilida* shell and transporting it to any place in the world presents no problem. However, due to the considerable depth at which these animals live, fishing for this snail in ancient times was extremely hard. For this reason most shells found in the past were empty (Tax, 1995). Shells of this snail were frequently used by goldsmiths and sculptors. Interestingly, the most beautiful designs of jewellery and other artistic handiworks are from the 16th and 17th century. For example, there are the famous Nautilus cups made out of *Nautilida* shells (Zieliński, 2001). Sometimes, artists did not use shells but, inspired by their shape and beauty, imitated them in the artwork they produced, e.g., the golden footless bull's head bowl of the Treasurer of Nagysztentmiklós, Vienna (Tax, 1995). Also storage containers for perfumes or medicines were made out of Nautilus or larger bivalve shells (Lakshmi, 2011).

Shells are also present in heraldry. The coat of arms of Tuvalu (formerly known as the Ellice Islands, a Polynesian country located in the Pacific Ocean, midway between Hawaii and Australia) has eight shells and eight banana leaves on a golden shield, a traditional cottage on green grass under a blue sky, and at the bottom a sketch of waves, representing the Pacific Ocean. The coat of arms of the British Indian Ocean Territory, besides a shield held by two sea turtles standing on a beach, also shows the shells of three sea snails and one mollusc. The crest of the Northern Mariana Islands (the northern part of the Mariana Islands Archipelago located in Micronesia in the south-western part of the Pacific Ocean)

Fig. 1. Juan de Espinoza, *Still-Life with Grapes, Flowers and Shells*, 1640.

has a wreath of shells and flowers. The foreground of the emblem of New Caledonia shows a *Nautilida* shell. The coat of arms of the Turks and Caicos Islands (southeast of Mayaguana in the Bahamas island chain and north of the island of Hispaniola) has a queen conch shell (i.e., *Strombus gigas*), as a symbol of the local fauna. The queen conch shell is an enduring symbol for the USVI, as it is for the whole Caribbean (Toller and Lewis, 2003).

Owning jewellery was a symbol of prosperity and wealth. The first inhabitants of the Caribbean (Arawak, Taino and Caribe Indians) used the shells of *Strombus gigas* to make jewellery and tools, e.g., knives and even parts of their buildings (Toller and Lewis, 2003). Shells also were used as the raw material for bracelets, lamps, cutlery as well as cameos – due to the changing colour of layers. Raw materials for everyday objects are not only derived from *Strombus* shells, but other molluscs such as conch shells presented in phot. 3.

A snail in a shell can also represent a recluse, hermit or misanthrope (Kopaliński, 2007), as evident in some expressions, for example, Polish one "Sitting like a snail in its shell" or the Greek "To live the life of a snail". Similar examples can be found in literature, e.g., "He has closed himself into his house like a snail in its shell" (*Alkhadar* I, 12 Edmund Chojecki).

Due to the complex spiral shape of the mollusc shell, it also is considered a symbol of laborious, difficult and unnecessary thinking (Kopaliński, 2007). Such a type of introspection might in particular be a feature of jealous people and probably for this reason the shell in the foreground of the painting by Giovanni Bellini *Allegory of Malicious Slander or Jealousy* (1490) is purported to signify the complex nature of human jealousy and the misunderstanding it can cause (Battistini, 2006). Finally, Biedermann (2001) rightly points out that snails carry their shells, which serve as homes, suggesting modesty since the snail carries all its property with it on its back.

Fig. 2. Adriaen van Utrecht, *Still Life with Bouquet and Skull*, near 1642

Conclusion

While reflecting on the rich symbolism attached to shells, their cultural and esthetical aspects should not be neglected. Not without significance is the fact that man is much more attracted by the shells of sea snails, not only larger but with few exceptions, more colourful than the land varieties. The most popular seem to be the genera *Cyprea sp.*, *Strombus sp.*, *Spondylus sp.*, and *Pecten sp.* Symbolic meanings are rarely attached to species such as *Littorina littorea*, *Turbinella pyrum* or *Tridacna gigas*. An indisputable place in history and culture is occupied by *Bolinus brandaris* as a source for purple dye.

The beauty of objects crafted from molluscs have repeatedly been the cause of great pleasure to people. The English word "shell" and a stylised clam has for

over a century been registered as the trademark of the oil company, Royal Dutch Shell. The origin of the company dates back to 1833. Its founder, Marcus Samuel, then in London, had a shop selling antique and oriental shells. Attracted by the shape of the clam shell he used the symbol and the name for the company.

We should not ignore the adaptation of shells by the applied arts. Nautilius Cups were originally manufactured in Augsburg and Nuremberg (hence the popular name "Nuremberg Cups") as early as the sixteenth century (Tax, 1995). The first jewellery – beads from 82 000 years ago, discovered in a limestone cave in the Grotte des Pigeons (Taforalt, Morocco), were hand-made shell beads of perforated *Nassarius gibbosulus* (Bouzouggar et al., 2007).

The author hopes that the article will serve as an example of an integrated approach to biology teaching with the humanities. Enthusiastic teachers might be encouraged to connect subjects that they are interested in in similar ways to prepare stimulating lesson materials to meet the challenge of the modern curriculum.

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OECD PISA methodology and the interpretation of Polish students' results in the area of science

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Summary:

The article presents the results and methodology of OECD PISA – the largest and most prestigious contemporary international study on pupils' competence. The main methodological assumptions of sample surveys and their comparison with the analysis of data from the examination system are discussed. The article presents procedures for the creation of test items, with a particular focus on the tasks in the area of science and the rules of interpretation of the test results, with particular emphasis on the principles of statistical inference. Also discussed is the importance of the effect of the incomplete sample and subsequent attempts to interpret the results.

Key words: OECD PISA, methodology, tasks, natural science, 15-years-olds

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Introduction

The OECD PISA results for the 2012 edition were announced in December 2013. PISA is considered the most important and prestigious international students' competence study. Since 2000 every three years, in dozens of countries, the skills of fifteen-years old students are measured in reading, mathematics, and sciences. PISA results are regarded as the most authoritative source of international comparisons on students' competence and the observed trends in the results – improving or deteriorating over time – are regarded as an important indicator of the effectiveness of the educational systems of individual countries: improving results confirm the relevance of educational policy and their deterioration indicates serious problems with which the educational system cannot cope.

Results of the OECD PISA study in 2012 has been implemented and interpreted, both in Poland and in the rest of the world, with great interest. Among the biggest positive heroes for 2012 were Polish students who have obtained one of the highest growth performance compared with PISA 2009 (especially in the area of sciences), and throughout the period of research, since 2000, moved from the position which was clearly below average among the leading European.

Let us look at the results of reasoning in the natural sciences. We can observe a significant improvement of Polish students in comparison with 2006 and 2009 results. In the 2006 study, when the reasoning in the natural sciences was the main area of measurement, the average score of our students was almost equal to the average for OECD countries (498 points) and in 2012 Poland with a score of 526 points was in the forefront of countries, the results of which are statistically significantly better than the average for OECD countries (table 1).

Among all the countries and regions participating in the study the best results were obtained in Shanghai, Hong Kong and Singapore, and among European countries, Finland, Estonia and Poland. It is also noteworthy to compare the results from the years 2012 and 2006 with respect to the mean change score attributable to the year. Poland is among the countries with the highest value of this parameter. Only those countries whose average were significantly lower than the OECD average (Kazakhstan, Turkey, Qatar and the United Arab Emirates) showed a higher rate of change then the Polish one.

The international report[1] and the preliminary Polish report[2] on OECD PISA study in 2012 was announced in December 2013; The Polish full report will be published in the spring 2014. It is worth examining the methodological aspects of research – both in order to know the rules to be followed when interpreting the results, as well as to know its limitations, and factors that in some areas require special care. Introduction to the methodology of the study will also assess the appropriateness of a variety of opinions about the PISA study and its results, published in the media – usually by people who do not know the methodology of the study or do not understand it.

OECD PISA studies are representative, i.e., **they are conducted on a representative random sample of the population of scientific research competence**, the aim is to provide precise information about the level and diversity in the population identified by the researchers skills). To the same category belongs also a number of other educational research projects conducted in Poland, such as "Laboratory of Thinking"[3] or "School of

1 See: http://oecd.org/pisa/keyfindings/pisa-2012-results.htm.
2 See: http://www.ifispan.waw.pl/pliki/wyniki_pisa.pdf.
3 See: http://eduentuzjasci.pl/pl/badania/110-badanie/409-laboratorium-myslenia-diagnoza-nauczania-przedmiotow-przyrodniczych-w-polsce.html.

PISA 2006	
Country or Region	Average score
Finland	563
Hong Kong (China)	542
Canada	534
Taiwan	532
Estonia	531
Japan	531
New Zealand	530
Australia	527
The Netherlands	525
Liechtenstein	522
Korea	522
Slovenia	519
Germany	516
Great Britain	515
Czech Republic	513
Switzerland	512
Macao (China)	511
Austria	511
Belgium	510
Ireland	508
Hungary	504
Sweden	503
Poland	**498**
Denmark	496
France	495
Croatia	493
Iceland	491
Latvia	490
United States	489
Slovakia	488
Spain	488
Lithuania	488
Norway	487

PISA 2009	
Country or Region	Average score
Shanghai (China)	575
Finland	554
Hong Kong (China)	549
Singapore	542
Japan	539
Korea	538
New Zealand	532
Canada	529
Estonia	528
Australia	527
The Netherlands	522
Taiwan	520
Germany	520
Liechtenstein	520
Switzerland	517
Great Britain	514
Slovenia	512
Macao (China)	511
Poland	**508**
Ireland	508
Belgium	507
Hungary	503
United States	502
Czech Republic	500
Norway	500
Denmark	499
France	498
Iceland	496
Sweden	495
Austria	494
Latvia	494
Portugal	493
Lithuania	491

PISA 2012	
Country or Region	Average score
Shanghai (China)	580
Hong Kong (China)	555
Singapore	551
Japan	547
Finland	545
Estonia	541
Korea	538
Vietnam	528
Poland	**526**
Canada	525
Liechtenstein	525
Germany	524
Taiwan	523
The Netherlands	522
Ireland	522
Australia	521
Macao (China)	521
New Zealand	516
Switzerland	515
Slovenia	514
Great Britain	514
Czech Republic	508
Austria	506
Belgium	505
Latvia	502
France	499
Denmark	498
United States	497
Spain	496
Lithuania	496
Norway	495
Hungary	494
Italy	494

PISA 2006	
Country or Region	Average score
Luxembourg	486
Russia	479
Italy	475
Portugal	474
Greece	473
Israel	454
Chile	438
Serbia	436
Bulgaria	434
Uruguay	428
Turkey	424
Jordan	422
Thailand	421
Romania	418
Montenegro	412
Mexico	410
Indonesia	393
Argentina	391
Brazil	390
Colombia	388
Tunisia	386
Azerbaijan	382
Qatar	349
Kyrgyzstan	322

PISA 2009	
Country or Region	Average score
Slovakia	490
Italy	489
Spain	488
Croatia	486
Luxembourg	484
Russia	478
Greece	470
Dubai (UAE)	466
Israel	455
Turkey	454
Chile	447
Serbia	443
Bulgaria	439
Romania	428
Uruguay	427
Thailand	425
Mexico	416
Jordan	415
Trinidad and Tobago	410
Brazil	405
Colombia	402
Montenegro	401
Argentina	401
Tunisia	401
Kazakhstan	400
Albania	391
Indonesia	383
Qatar	379
Panama	376
Azerbaijan	373
Peru	369
Kyrgyzstan	330

PISA 2012	
Country or Region	Average score
Croatia	491
Luxembourg	491
Portugal	489
Russia	486
Sweden	485
Iceland	478
Dubai (UAE)	474
Slovakia	471
Israel	470
Greece	467
Turkey	463
Bulgaria	446
Chile	445
Serbia	445
Thailand	444
United Arab Emirates (except Dubai)	439
Romania	439
Costa Rica	429
Kazakhstan	425
Malaysia	420
Uruguay	416
Mexico	415
Montenegro	410
Jordan	409
Argentina	406
Brazil	405
Colombia	399
Tunisia	398
Albania	397
Qatar	384
Indonesia	382
Peru	373

Table 1. Average results of students of measuring reasoning skills in the natural sciences in the study of the years 2006, 2009 and 2012 of measuring reasoning skills in the natural sciences in the study of the years 2006, 2009 and 2012

White background indicates the countries whose outcome was not significantly different from the average in OECD countries, the light green color highlights countries with better results, and the light blue – worse than average.

Independent Thinking"[4], drawing from PISA also many other elements. Therefore we shall start the discussion on PISA methodology with the presentation of this type of research, in particular by comparing them with the alternative source of knowledge about the students' competence level: external examinations system which, unlike studies such as PISA, include the entire population; what is more, their purpose is primarily to provide a specific assessment of students' knowledge and skills across the content of the curriculum and examination requirements. In the later part of this article we will focus on specific solutions used in PISA, in terms of sampling, the creation of test items process, evaluation of test items performance and scaling of the results.

Scientific research competencies in the classroom and examination system

In the Polish educational system external examinations have been conducted since 2002 (a test after the primary school for 13-years old and a gymnasium exam for 16-years-old pupils) and since 2005 the maturity exam has been also conducted as an external exam. The results of external examinations are valuable material for the study over the level of competences of Polish students and sources of their diversity. Is it worth spending the extra money for research based on random sampling?

External examinations, as a source of knowledge about the level of competence of the students, have a number of limitations comparing to sample surveys:

- **Scope and procedures of developing tests.** Authors of tests used in examinations system are restricted by the content of the curriculum for a given stage of education. The tasks posed to students in the research on scientific abilities do not have such restrictions – you can explore the students' skills in the field defined by the investigator.
  At the same time, due to the requirements of confidentiality, exam has to be developed by a narrow circle of people, and the possibility of a pilot test or calibration tasks are very limited. Although in the case of scientific research in the development of the tasks some principles of confidentiality apply, the rigor of secrecy does not limit the number of specialists involved in the preparation of tests and, what is more, assignments are subject to thorough verification of the pilot studies, so tasks may be selected and developed much more effectively.
- **Number of items used in the test.** The main aim of the exam is to provide individual student assessment, comparable with assessments of other students who have passed the same exam. For this reason, all students solve, in principle, the same set of tasks, and consequently: the number of test items is limited by the period of time the student has to write the exam.
  The number of test items used in the students' assessment is essential for precision of the results. First, a larger number of tasks allows the inclusion of more aspects of skills or sub-fields. Second, each particular item brings to a task "error" associated with its specificity (e.g. a student may not be able to solve it, because he does not know the meaning of the specific words used in the task, and not for the fact that he does not have a skill to be tested by the task); the greater number of test tasks can compensate for errors of this kind. Scientific research competence are focused not on the result of a single student, but on providing information about the entire population or subpopulations. It is thus possible to use, in one study, different test sets (usually in the form of "tasks' block" juxtaposed in several ways – so that each two "blocks" are simultaneously taken by a part of the students). As a result, all of the tasks used in the study may correspond to the test, the solution of which would take a single student many hours. The result of such a procedure may in fact be somewhat higher load random errors when we look at the assessment of a single student, but gives much more accurate assessment of the average level of skills in the population.
- **Accessibility of the contextual information.** When we analyze the results of external examinations the only available data on the student who has written the exam are information about the gender, age and the school where he learns. We do not known anything about his family circumstances, education of parents, cultural possession, etc., and even the place of residence (e.g. urban/rural) can be inferred only indirectly (with the school location), and therefore not always accurately. This means that the analysis of the results of external examinations cannot provide knowledge about the number of potentially important factors which diversify the skill level of the students.
  In scientific research students, and often their parents, fill in addition to the tests a detailed questionnaire regarding issues such as parents' education, socio-economic position of the family, household equipment in good cultural or educational aids, etc., as well as attitudes towards school and learning[5].

4 See: http://eduentuzjasci.pl/pl/badania/110-badanie/420-szkola-samodzielnego-myslenia-2.html.

5 In the Polish educational research environment for years were discussed the need to supplement the examination results of a range of contextual information; at the moment the collection of such data is not possible for legal reasons. The authors of this paper, as a researchera, would obviously be very interested in such a data, but as a citizens would have serious doubts: the collection

- **Scaling of the results.** Results of Polish exams are administered as a simple sum of the points awarded for each task. The results of the student's achievement surveys are determined on the basis of complex statistical procedures of scaling, usually referring to the models of the Item Response Theory. Consequently, for example in the final result may be omitted test items that have a poor psychometric properties. Processed in this way results are much more valuable base for statistical analysis and inference about the factors of differentiation achievements of students. It should be noted, however, that in the case of use of the results of examination for scientific purposes we may (instead of relying on "raw results") subject them to the same procedures scale (however, their effectiveness will be less good for the reasons listed earlier, mainly due to the smaller number of questions used in examination tests). In some systems outside the Polish one individual examination results also tend to be determined using statistical scaling procedures.
- **Comparability of the results over time.** The aim of the examination system is to provide a comparable assessment of student's skills with assessments of skills of other students participating in the exam. Being able to compare the results obtained in the different editions of the exams is therefore of secondary importance. In surveys, such as the OECD PISA, the possibility of comparing the results of different editions of the test is crucial. It is achieved through the use of "linking tasks" – tasks repeated in subsequent editions of the study; through statistical scaling procedures can be followed by an assessment of difficulty remaining tasks, used only in one edition of the survey, on a common scale. The ability to use "linking tasks" on exams is virtually non-existent due to the requirements of secrecy[6]. Procedures of "equating" the results of the examinations are carried out for research purposes, and therefore require recourse to intermediate data and are burdened with a much higher uncertainty level.

External examinations, however, have its advantages over representative studies and for some applications are still an irreplaceable source of data:

- **No limitations due to sample size.** Although educational representative studies are usually performed on very large samples, for much analyzes sample sizes are still too small. In particular, on the basis of national surveys it is usually not possible to analyze the regional differences, e.g. on the basis of the PISA survey, we are not able to assess whether in the Opole province students have better or worse results than in Lower Silesia. Analysis of exam data allows us to make comparisons even at the level of county, municipality, or a single school.
- **No problems of non-responses.** The weak point of all sample surveys are problems of response rate. In most educational research the response rate (the percent of students selected to the sample that actually take part in the research) is about 80% (this is anyway an excellent result compared to e.g. opinion polls, which rarely get a share of more than 40% of the original sample). The exams involved virtually all students.[7] Examination data are not burdened with the problem of incompleteness of the sample. It allows us to use them to assess what is the impact of this phenomenon on sample surveys. In particular, by comparing the examination results of students participating in PISA and students selected for the PISA sample but not participating in the survey we know that although the students who did not participated in the study have (probably) slightly lower skill levels, the influence of their absence on the outcome of the PISA survey was ultimately very small.

Methodology of the OECD PISA[8]

The OECD PISA is an international study of 15-year-old students' skills in reading, mathematics and reasoning in the natural sciences. What does it mean?

The study population are "15-year-olds". The term "15-year-olds" is, in the case of this study, fairly conventional: the participants were students born in 1996, so at the time of the study (March 2012), some of them were already 16-year-olds. It is important, however, that it was a group defined by age, and not e.g. grade in the school.

The study population is students – and so the study is not intended to include young people outside the school system. In countries participating in the study

of data about the family situation or of the views or attitudes under the state exam would be a serious interference of the state in the privacy of the students. It should also be noted that the basis of all social research, including educational research, is voluntary participation in them, and this is difficult to say if the collection of contextual data, needed for research purposes only, was connected with the obligatory exam.

6 This problem could be, however, solved, had to create exam tests using publically available, but very large databases of tasks with known measurement characteristics.

7 When analyzing the results of examinations a bigger issue, than non-participation of students in the exam, may be the fact that some tasks can be omitted by some students (ie the student does not provide a solution, not because he cannot find it, but he/she did not try to find). The same problem applies to scientific research competence – furthermore, the nature of the examination participation in it strongly motivates students than in the case of a voluntary, anonymous survey research.

8 A brief description of the survey methodology can be found in the report of the next edition of the Polish PISA study, and in a most complete version in Technical Reports. The technical report of the PISA 2012 at the time of writing this text has not yet been announced.

children at this age are generally subject to compulsory education (it was indeed a selection criterion for testing that particular age group), however, the actual level of schooling may vary, to some extent, among the countries-participants of the study. This has no significance for the comparison of results for OECD countries, however, may be important for the interpretation of some of the other study participants. For example, a very high level of performance of the students in Shanghai is attributed by some critics to policies of local authorities, not allowing into the local school system children of immigrants from other regions of China (Loveless, 2013).

PISA is an international study: its purpose, in addition to allowing comparison over time, is to allow international comparisons. The international nature of the study enforces such a procedure for creating and verifying the quality of test items, based on the ability to solve the tasks without being dependent on the cultural specificity of each country. For example – from the set of questions related to thinking in life sciences an item concerning the process of baking bread had to be rejected, after a preliminary verification. This is due to the fact that in some of the countries participating in the study, bread is not an everyday dish and students could have difficulty in solving the task not because they would not have the appropriate skills for this, but because they would use them in a way which is incomprehensible for them.

Hence, there is a need to consider cultural factors during creation and selection of tasks and to check them by statistical methods to know whether individual tasks are not culturally burdened. It is one of the main reasons for which the final announcement of PISA results take places many months after completing the fieldwork. At the same time, fully effective release of the PISA results from the impact of cultural diversity is never fully possible. The question whether this is achieved to a satisfactory standard is also the subject of lively discussion (Kreiner and Christensen, 2013).

Year of study	2000	2003	2006	2009	2012	2015
Skills to be tested	**Reading** Mathematics Natural science	Reading **Mathematics** Natural science	Reading Mathematics **Natural science**	**Reading** Mathematics Natural science	Reading **Mathematics** Natural science	Reading Mathematics **Natural science**

Table 2. The distribution areas leading in PISA from 2000 to 2012

The international character of the PISA survey is important for another reason: it enables the involvement of teams of experts which could not be gathered in most individual participants countries. Polish representatives in the bodies of control or in analytical teams of OECD PISA as prof. Zbigniew Marciniak and dr. Maciej Jakubowski played an important role on PISA, however, it would be practically impossible throughout the country to gather a team of professionals who would be able to carry out this type of study independently and competently from the beginning to the end.

On the other hand, if we are now in the position to conduct a large (though not as large as PISA) educational research, we should remember that a significant part of Polish specialists have been educated, to a greater or lesser degree, during the implementation of the previous PISA editions (since 2000).

PISA is a survey of skills in mathematics, reading-interpretation and reasoning in natural sciences. In the following cycles an enhanced measurement of skills for other area called the leading study is applied (see table 2).

In particular, the range of skills in the tested subject does not have to coincide with a set of core curriculum subjects in school, *especially when* considering that participation of students from dozens countries makes the assignation of a common curricula quite difficult.

The starting point for the creation of test items was not what students should know and be able to do, because this is already taught at school, but what skills they will need to be able to act in the modern world or to gain the qualifications needed on the job market in the economies based on developed technologies.

Competencies tested in the OECD PISA are essentially: independent reasoning and interpretation (among issues natural sciences, math problems, information texts). To a much lesser extent PISA checks "knowledge" possessed by the student. The scope of PISA results also from the international nature of the study. It is obvious that 15-year-old students should have adequate knowledge of literature, history and geography – in the case of Polish students it should be, in particular, Polish literature, history and geography; obviously, an international study cannot, check anything that is specific for a particular country. Demanding this from OECD PISA is absurd because this would assume that school should teach only what can be measured in international tests.

Selection of the sample

PISA is a sample survey and therefore carried out on a representative random sample. The sample is selected in all the countries participating in the study according to similar principles[9]:

- The method of sampling is designed to ensure the representativeness of the target population for the study. It is the population of 15-year-old students, with the exception of students with intellectual disabilities or with other disabilities that might prevent them (or make it difficult for them) to complete standardized tests (and thus would make the measurement unreliable) and students lagging in school for more than two years with respect to the country learning cycle. Due to technical difficulties or excessive costs other small categories of students can also be excluded from the test (i.e. pupils from very small schools, students studying in a minority language), but such exemptions may not exceed a total of 0.5% of the population (except the ones due to language of instruction), and this must be settled with the international consortium carrying out the test.
- The study should include at least 4500 students. Therefore due to the expected prospect of partial test realization the sample drawn should be at least 5500 students in each of the countries participating in the survey, and, if a given country wants to analyze the results separately for different sub-populations (regions or language groups), in each of these sub-populations. If that given country implements optional components of the study, or in parallel with the international research or the country implements its own additional testing, the sample size can be increased accordingly.
- The sample is of a two-stage type: first we randomly select schools, and next from these schools we randomly select 15-year-old students (35 students from each school). To achieve the required sample size of students, schools sample must be of at least 150-160 schools, as a rule, however, this number is even higher due to the existence of small schools that do not have 35 15-year-old students.
- In order to improve the variability of students selected, the sample of schools is stratified. Characteristics that are taken into account as stratifying variables are subjected to an agreement between the international consortium and the institution carrying out the research in a given country. After settling this issue with the consortium it is also possible to use over-representation of certain groups of students, in order to enable more detailed analysis in specific subpopulations (due to data weighting procedures, it does not affect the representativeness of the sample to the entire population).
- The sampling process (selection of schools) is carried out by a company which belongs to the international consortium. However, the selection of students is conducted in each country separately, but using the software provided by the consortium. Thus, in effect, the institution carrying out the research in a given country cannot affect the results of the sampling. Its first task, however, is to provide the consortium with a complete list of the schools (along with the necessary data) with representative samples of 15-year-old students, and then to obtain from those schools a list with all the students selected for the second stage of study.

In the Polish study the OECD PISA 2012 PISA sample consisted of 5545 students, of whom 4607 (the response rate 83%) participated in the study. The subjects attended 183 schools (176 *gymnasium*: middle schools, six secondary schools and two technical ones).

In addition to PISA tests, some non-compulsory international components were conducted, so the sample was extended by an additional 1266 students (of whom 1055 participated in the study) and a Polish competence tests for pupils in 1st grade of post- middle schools on a separate sample of 5758 randomly selected students (of whom 4637 participated in the study).

The Polish PISA survey, practically speaking, is the research study of *gymnasium* students. In 2012 among the participants only 13 students attended secondary schools, but since the definition of population in the OECD PISA refers to age, not the grade or type of school, the sampling procedure had also to include secondary schools: *licea*, technical and even vocational schools. Even though, in the whole country, less than a hundred 15-year-old students attend the latter type of school. In effect, it is hardly surprising that none of those schools were selected for the sample. Fortunately, we did not have to take into account primary schools, where more 15-year-old students attend than to vocational schools; they are, however, excluded from the study population because of the criterion related to lagging in school for more than two years with respect to the country learning cycle. Would the organizational effort required to implement the PISA study in secondary schools and the very fact of participation of these thirteen students raise the quality of PISA study in Poland? Probably not, but this situation is an illustration of the methodological standards that apply to the study. And, although in this case they probably did not bring immediate benefits, in many other respects they do not allow to "take a shortcut", at the expense of the quality of research.

9 The only exceptions are very small countries (eg, Lichtenstein), in which the study involved the entire population of fifteen-years-old pupils, so the survey is exhaustive, and not representative.

Creating tasks and assessment of student performance

The basic element used in PISA test tasks are of varying themes and designs. In 2006, 103 task concerning natural sciences were utilized, 53 of them were included in the study in 2012 (this fact allowed comparison of results between research cycles). Reasoning in natural sciences covers topics such as: health, natural resources, protection of the environment, locally and global, as well as the limits of science and technology. Tasks were collected in three groups, **each one of which** measures a different component of the scientific reasoning:

- recognition of scientific issues,
- explanation of natural phenomena in a scientific manner,
- interpretation and use of results and scientific evidence.

Linking tasks are varied due to diagnosed content and skills as well as their relationships with the Polish science core curriculum.

Tasks checked:		Number of tasks used in the study in 2006–2012
knowledge and skills that can be applied to the core curriculum of:	biology	25
	chemistry	6
	physics	6
	geography	6
knowledge of research methodology		11
technical knowledge and skills		2
Total[1]		56

Table 3. Classification and number of each category of tasks used in the natural part of the PISA survey in 2006

As you can see most of the tasks (25) can be related to the content and learning objectives of the biology curriculum. This implies that among science courses taught in high school, the one that has the greatest influence on student achievement in PISA can be biology and the way it is implemented in the classroom.

Creating a task

Tasks that are the basis for measurement in PISA are created specifically to be used by a specific area in the test. Some of the tasks operate in each cycle to ensure comparability of results over time. Creating tasks is a long process. The same counts for the procedures for preparing the tasks of individual areas. New tasks to measure skills in the PISA study are prepared for the leading field.

In the first phase of the operation, a group of international experts draw up the theoretical basis for each of the tested areas. Then the test tasks are prepared. The tasks are prepared both by experts and teams from countries participating in the study. Proposals tasks are repeatedly consulted with external experts, up to the creation of the first pilot version and code keys. These tasks are tested on a group of several dozen students. Also, interviews with students are carried out. After applying the necessary corrections the tasks are re-evaluated by international experts. As a result of the recommendations of the expert group the tasks can still be improved in the new version. The result of the above activities is a broad pool of tasks, including all described theoretical assumptions of the test areas.

In the next phase, all tasks are subjected to an international assessment by the national teams participating in PISA. Each task is evaluated in terms of:

- a reference to the curriculum in the country;
- authenticity: i.e. whether the task and issues present are real and understandable for 15-year-olds;
- whether the task are of interest for students;
- cultural references;
- any difficulties with the translation into a language;
- clarity of intention of the questions;
- consistency and adequacy of key code

Rating task is done using a computer score sheet.

Based on analysis of ratings and comments submitted by the countries participating in PISA, the tasks are improved and the group of international experts selects some of the tasks for testing trial, which involved all the countries participating in the main study. At least twice the number of tasks that ultimately will be on the test, undergo a trial study. Tasks are prepared in two languages: English and French, they are treated as source versions.

The results of the test are analyzed in terms of content and also statistical, based on qualitative and quantitative data. Based on these results, the task is improved as well as the key codes. Then a pool of the best tasks that meet the criteria described in the theoretical assumptions of the study is selected.

Adaptation of domestic tasks

Due to the large variety of countries participating in the study, it is essential to provide the most similar versions of the national tasks. During preparation of the national versions tasks it should be taken into account not only the accuracy of the translation versions of the source but also a form of presentation of the task. The aim is to ensure that students in each country fulfill the task, in their own language, that most accurate reflects the source version.

The adaptation of tasks is carried out by teams of individual countries, in cooperation with the international consortium. The availability of two versions of the source helps to determine the degree of freedom in

developing the national language version. The method of adapting a domestic test material is well defined by test procedures.

Adaptation of test tasks is as follows:

- double translation of test materials with both versions of the source (two independent professional translators);
- development of the first, a single Polish version based on the two translations, with a view to the version of the source (person with at least a passive knowledge of both the source language) – a key step in adapting the content of the tasks to national conditions;
- national verification language: based on a unified national version, without any insight into the earlier translations and versions of the source, checking of the quality of the language used in the task for its wide acceptance and application of amendments (a person with editorial qualifications);
- assessment of the level of difficulty of the task in the Polish national version: based on the revised editorially version and at least one version of the source comparing the degree of difficulty of the task and incorporate the necessary corrections (a person with expertise in the field and an excellent knowledge of at least one of the source language);
- an independent review of a specific national experts outside of the research team, based on the latest version of Polish, with the possibility of insight into both versions of the source;
- international revision (translator employed by the international consortium);
- final acceptance or rejection of foreign verifier comments by the national team;
- preparation of the final version of the task also checked at an angle uniformity of appearance of the version of the source;
- the final acceptance of the material sent by the International Centre for Validation.

Evaluation of the results of students – coding

PISA includes a variety of tasks: multiple choice tasks, tasks that require individual responses and tasks that require complex answers. Most of the short and extended responses require coding based on the key code to the task containing the method to assess the task, tips and examples of student responses. Powerful and multifaceted key codes are the most important elements of tasks in PISA. During preparation of the tests for the cognitive part of the research, it is worthy not only the development of the same tasks, but also meticulous and the most accurate preparation of instructions for interpreting (assessment) the student responses. This is particularly important in the case of open-ended questions where you expect a variety of answers implying discrepancy ratings. For this reason, it is an important stage during both the creation and testing of key codes.

The encoding process consists of the following steps:

- International Training Coordinators encoding;
- preparation of the national version of the encryption/code keys;
- preparation of training materials for coders based on authentic student responses in Poland;
- developing a coding scheme and code forms;
- coding organization and training of coders based on the examples of a particular material;
- coding the next batches along with applying the symbols on the cards, current control of the encoded material; launch of each new batch of material preceded by the re-training coding based on relevant examples of the response;
- re-training of coders;
- multiple encoding selected by the consortium along with application of the symbols on the cards;
- sending a randomly selected notebooks to the consortium in order to verify the international quality coding.

Scaling results: interpretation and comparability of point values

Unlike external exams, the final score assigned to any given student is not a mere sum of points awarded for each task. "Raw" test results are subjected to a statistical scaling procedure, referring to a model with specific assumptions. In the case of PISA it refers to models of Item Response Theory, and more specifically – the generalized Rasch model. Student's skill level is treated as a "latent variable": the aim of the procedure is to estimate its value for each student, on the base of values of "observable variables", which are given by the (correct or incorrect) answers to the test items. The IRT model is based on the following assumptions:

- Whether the student correctly solving the task is a random event, the probability of this event depends on two parameters: the student's skill level and the level of difficulty of the task. The essence of the Rasch model is to assume that this dependence can be expressed as a specific function (some variants of a logistic function). Traditionally, both parameters (level of student skills and level of difficulty of the task) locates on the same scale, assuming that the student with skills of x has a 50% chance of solving the problem of the difficulty of x.
- Local independence: For the student (or more precisely – for students with the equal skills level) events based on correct termination of two different tasks are independent events: in other words,

if a student has a 40% chance of solving the problem *a* and 50% chance of solving the problem *b*, it has a 20% chance of giving the correct answer of the both of them. It should be emphasized that it is about independence for an individual student or group of students of the same skill level. If these events have considered the entire population, of course, we do not assume their independence – they are correlated, because students with higher levels of skills are likely to know how to solve each of these tasks. Important assumption, however, lies in the fact that this correlation we can explain by referring to one characteristic, that is, the level of student skills. However, this means that we assume that (1) the examined "skills" to be "one-dimensional", and (2) there is no variation relative difficulty of tasks due to the characteristics other than the level of skill, e.g. that the task is easier for girls than boys, or for the Poles than the Hungarians[10].

Of course, both of these assumptions are optimal or ideal – there are no tests that would satisfy these assumptions completely[11]. Hence, the first phase of work on the results is the assessment of psychometric properties of individual tasks, to check to what extent answers distributions indicate a possible violation of assumptions of the model. At this stage it may be decided not to use the results of some of the tasks in the further analysis (in practice, the decision to remove "bad" tasks is usually taken after a pilot study – so that only those items that meet the needed quality criteria goes into the main study.

In particular, the elimination of items culturally biased is a prerequisite to be able to interpret the differences in the results obtained by the students in different countries. On the other hand, complete removal of cultural burdens is never possible – as a result, comparison of results in different countries always involves some uncertainty.

The process of scaling the results can be further conducted in either of the next two ways:

- If the difficulty of tasks is not known, both the difficulty of the task, and the skill level of individual students are treated as "latent variables". The scaling process then consists in determining the combinations of these values, for which the acquisition of such test results would be most probable.
- If the difficulty of each task is known, then scaling is only applied to the performance of students (each student can be assigned a skill level at which it is the most likely that he/she solves as many tasks as a given student was able to solve). Similarly, it is possible to estimate the difficulty of tasks in a situation where the skill level of students is known.

Since scaling is a probabilistic process, all estimates (both task difficulty and skill levels of students) are subject to the risk of random errors, with known characteristics (but, of course, unknown values).

A special property of the Rasch model is that it is possible to make estimates of students' skills on the same scale even if they partially solved different sets of tasks. It is also possible to asses on the same scale of students who performed a shorter or a longer version of the test – provided, however, that the estimation of the "latent variable" value is biased with the random error, which is the greater, the shorter was the test used[12].

These features of Rasch model allow comparison of different editions of the PISA survey, through the use of "linking items": the same tasks used in different editions of the test. When scaling, the results of the next cycle is then used already known, designated in the earlier cycle difficulty levels of "linking tasks", and the difficulty levels estimated for new tasks are related to the "linking items" difficulty level.

However, for the "linking" to be really effective, that is, not associated with a risk of random error; it must be based on a sufficiently large base of "linking tasks". Therefore in PISA is assuming that a reliable comparison of results over time are possible only from this year's survey, on which the area was an area leader – in the case of sciences from the PISA 2006. Of course, the results of studies in this area have also been reported for PISA 2000 and 2003, while efforts were made to preserve comparability over time, however, a direct comparison of the results of the 2000–2003 PISA cycles may result in large errors.

When assigning scaled results of individual pupils in the PISA study, a method known as plausible values is applied. It involves assigning a student a random value of "hidden characteristics", based on the conditional probability distribution of the feature value in the population provided a set of responses for a given task.

This procedure may seem surprising (as a result, any given two disciples who gave exactly the same answer can be assigned different values on the scale of skills, what is more, the same student is assigned a number of different plausible values which are "predicting" the level of the same skills). However it should be noted that, due to the probabilistic nature of the measurement, students of the same skill level can correctly solve a different number of test tasks. If the objective of the study was

10 Of course, it is possible that the girls (or Polish) generally have a higher average level of the skills – but if this applies to only one task, this means that it does not meet the assumptions of the model.

11 It should be added that IRT is only one (although the most developed and widely used) test theory – alternative theories focus on the cumulative aspect eg skills, so that without acquisition of some knowledge it is not possible to acquisite other.

12 Note that it is also possibility to assess on the same scale of students who solved completely different sets of tasks – for example, if one group solved subtests A and B, the second B and C, and the third C and D, we can compare the skill levels of students from the first and the third group, although this comparison may be loaded with a high random error.

to determine the individual performance of students, the method of plausible values would not be appropriate (in this case would indicate for each student, the most likely level of skill at a given configuration of responses). In the case when the aim is to determine the distribution of skill levels in the population, the use of plausible values, however, turns out to have some advantages (it leads to more accurate assessment of diversity of skills among the students, and most of all, thanks to a comparison of several plausible values assigned to the same student, to assess size of the random errors associated with the probabilistic nature of the IRT model).[13]

PISA test results are given in points, and the scales are constructed in such a way that the 500 points corresponded to the OECD average in 2000, while the 100 points difference corresponded to the standard deviation in 2000 – so this is a completely arbitrary scale. It is *the interval scale*, which means that it is possible to interpret the size of a difference between the two results, but not *the proportion* of two results. It can therefore be concluded that the increase in the average result of Polish students between 2009 (508 points) and 2012 (526 points) – 18 points, was greater than 10 points of increase between 2006 (498 score points) and 2009, but there is no sense in saying that the results of Polish students between 2009 and 2012 improved by 3.5%, despite the fact that, indeed, 526/508 = 1.035. This is due to the fact that the interval scale has no objective "zero". If the OECD average in PISA 2000 was set to 400 points instead of 500, the same results as in 2012 and 2009 would be represented as points 426 and 408, and the ratio would not be 1.035, but 1.044.

13 A broader introduction to the methods of plausible values can be found in articles: Wu M (2005), Role of Plausible Values in Large-Scale Surveys. *Studies in Educational Evaluation*, 31:114-128; Wu W (2004). Plausible Values. *Rasch Measurement*, 18(2):976-978.

The fact that the scale has been referenced to the average performance of students in the OECD in 2000, means that the number of points could not be directly interpreted in terms of high or low skills: they indicate only the level of skills compared to the skills of other students from OECD countries. To facilitate interpretation of the results, PISA experts defined six "skill levels", from the first, covering only the most elementary skills and insufficient to operate effectively in the modern world, to the sixth, including skills, the mastery of which gives pupil a good chance of becoming part of future intellectual or economical elite of his society. The division of point scale into "skill levels" is based on the analysis of tasks (and skills required to solve them) which typically students can solve with specific test results.

Interesting to note is the dynamic of the percentage of students for different levels of skills in reasoning in the natural sciences in Poland. In subsequent test cycles the percentage of students at levels 2, 1 and less than 1 decreases, while gradually increasing levels 3, 4, 5 and 6 (fig. 1).

Depending on the individual measurement results, each student is assigned a certain level of skill.

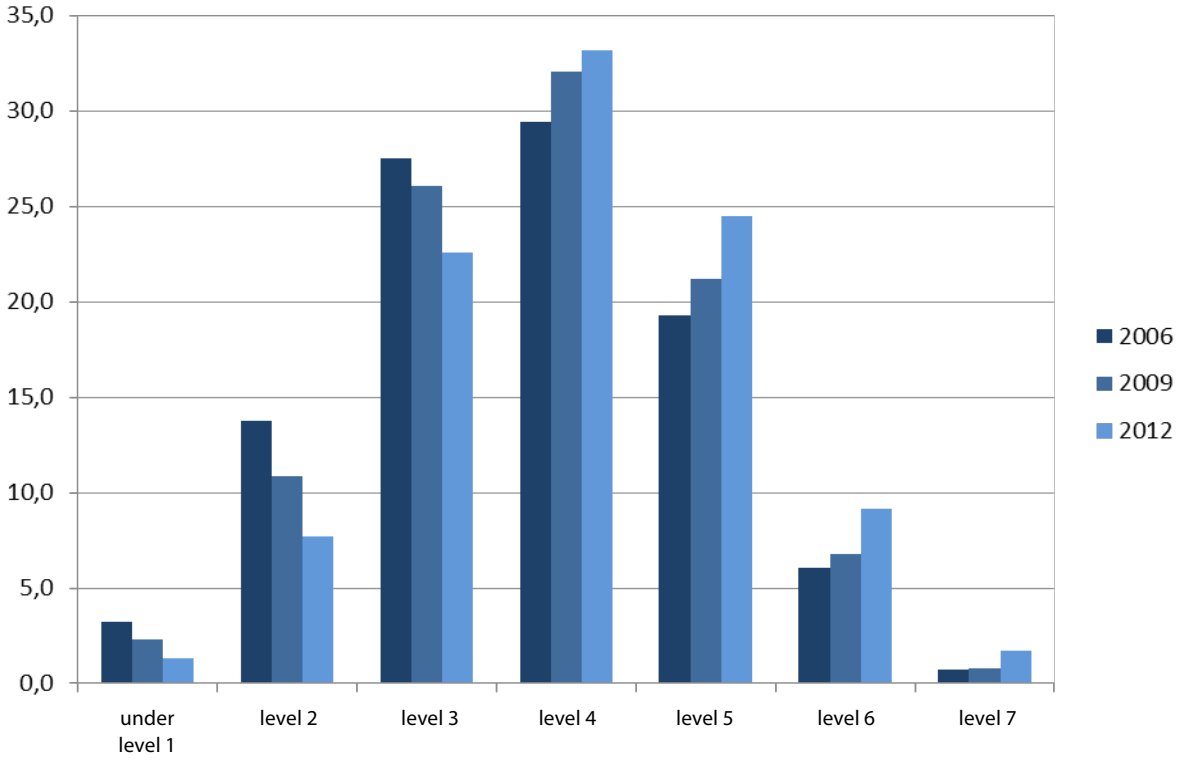

Fig. 1. The percentage of students at different skill levels in the years 2006, 2009 and 2012

In the case of reasoning in natural sciences it is assumed that a student who has reached the lowest levels of skills is able to apply the knowledge in a well-known situation or context. A student usually can interpret test results, provide a simple cause and effect relationships and solve simple technical problems.

In turn, students at the highest levels of skills are able to identify, explain and apply scientific knowledge and reasoning in complex situations in life. They are able to solve a scientific problem, describe or interpret natural phenomenon, combine knowledge from different fields and different sources, refer to the results of research as a basis for formulating credible judgments and identify the essence of scientific research.

Interpretation of test results: the rules of statistical inference

Comparing the results of the PISA survey, for different countries, on different subpopulations, or for different survey's edition, it should be always considered that they are burdened with random errors. These errors have two sources: the representative nature of the study, and the probabilistic nature of the measurement (including linking error when comparing different edition of the survey).[14]

In properly methodologically conducted surveys the size of random errors are not known. However, there are known characteristics of the random error; in particular, it is considered that with a certain probability (typically 95%) the error does not exceed a certain size. For example, Polish students participating in PISA 2012 obtained a mean score of 526 points – but we do not know the exact average score that would be obtained if the study consisted of all students in Poland, and not just the random sample. However, given the results in the sample (mean and standard deviation) it could be calculated that the adopted procedure in 95% of cases lead to the designation of a mean not different from the "true" mean in population of more than 6 points, so the "confidence interval" for the result of a population can be determined from 520 to 532 points .

By analogy, the average score of Dutch students was 522 points, and so was 4 points lower than the average obtained in the Polish sample. Do we allow it to claim that Polish students are on average better than the Dutch? We can calculate that if, in fact, the average score of students of Polish and Dutch were the same, the likelihood that a random sample of Polish students would has 4 points better average than the sample of Dutch students amounted nearly 20%. In this situation, you have to accept that the results obtained on random samples did not allow us to conclude that the average skill level of Polish students is higher than the Netherlands: too high is the risk that better result of Poles was obtained only "by chance".[15]

Basic methods of calculating confidence intervals and verification of statistical hypotheses based on the results of sample surveys are taught to students at all socio-economic and science university faculties. In the of case PISA studies (as well as other educational research) calculations are, however, much more complicated due to the use of complex sampling schemes and the need to take account of errors associated with the test tool. In the analysis of PISA results, to take into account the effects of sampling scheme, replication techniques are used, and the method of plausible values is used to take into account the effects of probabilistic test tool. Researchers interested in analysis of publicly available PISA data sets should use statistical software allows to use both of these types of analyzes; many calculations can be performed also using already calculated "standard errors", published for many parameters in PISA international report or reports prepared by PISA teams from particular countries.

When formulating conclusions from the results of the PISA we should also avoid making mistakes in the opposite direction: although the results of the study do not allow us to conclude that the Polish students represent a higher level of skills than their Dutch colleagues, but we cannot argue that the PISA study shows that students in Poland and the Netherlands have obtained the same results. The only thing we can say is that the result of the two groups of students were so similar that it is impossible to determine with the appropriate level of confidence the group, the results are actually higher: although the results of the study provide some evidence to conclude that this Polish students are slightly better, this claim, however is too weak, statistically speaking.

The effect of incomplete sample realization to the results and their interpretation

PISA results are loaded not only with random errors. Often a more serious problem is the systematic errors, so those whose characteristics cannot be predicted by reference to the theory of statistics. Their source may be, for example, non-compliance by the tests of assumptions used to scale the results (and, as mentioned, these assumptions are always fulfilled at most approximately) fall into this category also called coverage errors, result-

14 A more detailed discussion of sources of random errors (both related to the measurement procedure and the representative nature of the study) in educational research can be found in articles: Wu M (2010), Measurement, Sampling, and Equating Errors in Large-Scale Assessments. *Educational Measurement: Issues and Practice*, 29(4):15–27; Wu M, *Issues in Large-scale Assessments*, Availabe at: http://www.edmeasurement.com.au/_publications/margaret/Issues_in_large_scale_assessments.pdf.

15 In the common practice the results are considered "statistically significant" if the probability of obtaining them "by accident" is less than 5%.

ing in an incomplete representativeness of the sample, including, in particular, the errors associated with the incomplete implementation of the random sample. Errors of this kind can never be completely eliminated and, unlike random errors, cannot be theoretically predict their rational scale. In some cases, however, you can – on the basis of, for example, appeal to some external criterion available – try to estimate the size of some errors of the non-random type.

In the Polish PISA 2012 only about 83% of the students selected for the sample take part in the test. On the one hand, this situation is better than the typical surveys (such as opinion polls, pre-election survey, marketing research), which today (the phenomenon of declining levels of implementation of sampling – and thus increasing the percentage of refusals to participate in the study increases, both in Poland and in Western Europe, since the nineties) rarely get the response rate of more than 40%, and much better than even the best of academic research, where a response rate level of 60-65% is virtually impossible to overcome. On the other hand, it is reasonable to question whether the results would be the same if the test were completed by all sampled students. In other words, whether the decision to participate or not to participate in the test (or simply the fact of absence from school on the day of the survey) is or is not correlated with a result that students would receive on PISA test.

There is some evidence, that there is indeed such a correlation, and that the weaker students are more likely to not participate in the study. This is indicated not only intuitively, but also by PISA results and, indirectly, the results of post-*gymnasium* schools students' competence test, carried out simultaneously with PISA. In PISA, it can be observed that the response rate of students of grades I and II of *gymnasium* (and therefore students who have in their educational career once or twice repeated a grade – so we may expect a lower skills) was only 60%, so it was more than 20 points lower than among third graders. Also, in the study of post-gymnasium schools, the response rate of secondary school students (85%) was nearly 20 points higher than among students of basic vocational schools (66%).

It should be noted that the particular differences in response rates presented above were taken into account when in analyzing results, and theirs effect was combated by procedures of data weighing. But this represents only a partial solution to the problem – in fact, it is possible that also in the case of students of the same school and the same grade and sex (and therefore "undistinguishable" for data weighting procedures) there is also similar correlation between the skill level and willingness to participate in the test.

In PISA, it is possible – at least partly – to check whether such a phenomenon occurs and how – approximately – may be its effect on the test results. We can compare students participating taking, and not participating in the study due to the results obtained by them in the test after he primary school, which are quite strongly correlated with subsequent performance on the PISA tests. The analyzes performed[16], support the hypothesis that sampled students who do not participate in the study, are on average slightly weaker – but also shows that the effect of "enhancement" the Polish average does not exceed about 4-5 points, which value goes down to about 3 points due to the weighing procedures.

Does this mean that the average score of PISA test in science obtained by Polish students – 526 points – should be on these 3 points lower? Let us remember that the score is referenced to the OECD average – meanwhile the problem of incomplete response rate applies to all countries participating in the study. There is no reason to believe that the "real" score of Polish students should be a fewer number of points, unless studies showing that non-participation in other countries is not correlated with the expected result of the test (which seems very unlikely) arise.

One of the main objectives of the PISA study is to make comparisons over time and determining the direction of trends. Taking this into account, the question of the impact of incomplete sample realization on its outcomes should focus not so much on the average number of points, but on whether the impact was different in the study in 2009 or 2006 than in the 2012. In other words, even if the effect were much bigger than we think it was, but it would be fixed in time, would have no relevance to the conclusions as to whether the results of the Polish students are improving or worsening. It should be clearly stated that the parameters of the sample realization – both the response rates in general, of response rates among different categories of students – are all over the PISA study period (i.e. since 2000) very stable. It gives us a good reason to assume that the impact of incomplete implementation of the research sample on the resulting level of performance in the entire period was more or less the same, and therefore it does affect estimates of results changes between editions of the study.

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The basis of international studies is the careful preparation of research materials that ensure the comparability of the results. It seems that developed by the consortium procedures that are presented in this publication provide a meaningful basis for measuring the

16 Detailed calculations and motivation are given in Polish reports of PISA 2006 and 2009 (see page PISA Poland, http://www.ifispan.waw.pl/index.php?lang=pl&m=page&pg_id=98), and for PISA 2012 edition it will be included in a full drawn Polish report PISA 2012.

assumptions. All countries adhere to the strict rules of conducting studies. Failure of these rules entails exclusion of results for the country of study. Full survey methodology, data, and the results are publicly available at the OECD PISA.

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Developing students' critical thinking during biology lessons in junior high school with the use of IT

Izabela Szot

Summary:

Critical thinking is one of the main skills of modern human. In the age of overwhelming amount of information available on the Internet, one of the most important aims of school teaching is developing the ability of selecting and evaluating information found on the Internet by students. Therefore, the aim of my research was to examine how junior high school students' critical thinking can develop while using the Internet as a source of information.

A group of second year students of junior high school (age 14–15) were asked to complete some WebQuests. Their WebQuest task was to prepare, using given Internet sources, a paper with information required for the next biology lesson. WebQuest topics concerned human anatomy and physiology (e.g.: digestive, circulatory and respiratory system). Apart from the Internet sources, students were also given a presentation, which was later on used, by the teacher during the lesson. An experimental group included 46 students who accomplished minimum three of five assigned papers. It is 75% of all population of second year students. Completed papers were analyzed. Content selection was taken into consideration, as well as the form of presenting it by the students during the class.

Results show that:

- 32% of students prepared all or almost all papers on a high level of accuracy,
- 35% of students improved their papers during the experiment,
- 20% of students did not complete correctly any of their papers.

Well-prepared papers were those which were not copied from website articles. They showed deep level of subject understanding and proper source selection. Also, the form of paper allowed quick and easy access to the information. The research will be continued.

Key words: students' critical thinking, WebQuest, IT

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Introduction

Nowadays, critical thinking and using the Internet as a source of information are considered very important skills. Therefore, it is crucial to include them in the curriculum. This paper aims at showing how critical thinking can be developed while browsing the Internet sources.

Critical thinking means skeptical judgment of information and sources (Bartz, 2002). Modern people are overwhelmed with information coming from the Internet which should have been evaluated properly by the users. The method of learning called CRITIC shows how to select proper sources and how to choose the most significant problem solutions. In this teaching technique, students must know the source of information, evaluate its credibility, find backup sources, test it, verify it and in the end evaluate all findings (Matthies, 2005). In addition, critical thinking is not only an academic consideration, but it also means activity, discussions and looking for new solutions (Mogensen, 1997).

WebQuest, defined by Dodge (1995), is: "an inquiry-oriented activity in which some or all of the information that learners interact with comes from resources on the internet". WebQuest became one of the most important method of using network as source of information. It allows students to develop their cognitive processes, create more effective learning strategies, learn to use different sources and work in groups (March, 2003/2004). WebQuest contains following elements:

- introduction, in which the teacher presents the background of the specific topic,
- an interesting task students should complete,
- sources needed for solving the task,
- process description that leads students to accomplishing of the task,
- conclusion that recapitulates the task.

Not only using the Internet sources but also critical thinking are crucial skills that ought to be taught according to the new Polish curriculum introduced to schools in 2009/2010. Therefore, in my research I try to use WebQuest method to develop junior high school students' critical thinking.

Research aims

The main aim of the research was to develop students' critical thinking while browsing the Internet. The participants of this project should:

- improve their ability of evaluating information and credibility of sources,
- learn how to select information and sources,
- increase creativity,
- raise learning ability,
- create useful learning materials.

Research description

The participants of the research were students from three groups of junior high school – teenagers aged 14 – 15. The students' task was to complete five WebQuest assignments during the school year. All WebQuest topics were concerned with human biology, and they included: the role of nutritional ingredients, the structure and physiology of the digestive system, the constituents and the role of blood, the structure and physiology of the respiratory system, the biological stages of the human life. WebQuests were presented uploaded onto school website as a PowerPoint presentation, which students could download.

- WebQuest presentations contained:
- Introduction,
- Detailed instruction of the task students should accomplish,
- Process description in the form of presentation used during the classes,
- Sources – websites, where students couldt find useful information needed for this task.

The students were supposed to prepare a paper for their next biology lesson using the given website sources. The paper was to contain information they might use during the class. Final presentation of the WebQuest took place in the classroom during biology lesson, where students exchanged information and evaluated its importance.

Sources

There were various website sources suggested to be used. Students could choose between popular sources like Wikipedia or cheat sheet websites, but also medical or science websites and academic teachers' papers. Students could use one or more from the given sources. They could also find and use other websites, not listed in the teacher's presentation.Students were not allowed to use biology school books.

Papers

Papers could have any form according to students' preferences, but they should have made the access to needed information quick and easy. Students could copy fragments of texts from websites but were not allowed to copy a full article. Paper could include photos, drawings, slides from presentation or just text. It could be typed or handwritten. There were no limits in paper length.

Discussion in the classroom

The students brought their papers as a source of information. During the class, they presented the information they had selected, discussed and evaluated its importance.

Evaluation of the paper

All papers were graded and the following factors were taken into consideration:

- correct facts selection,
- accuracy when it comes to chosen information and the paper topic,
- the amount of information – whether too much or not enough information is given,
- the style of presenting the information – whether the student can quickly access needed information,
- the selection of sources,

After having submitted each paper, the students were given a grade and a written feedback which included advantages and disadvantages of the work.

Results

In this research, the experimental group included 46 students which constituted 75% of all second year students (fig. 1). Those were students who accomplished at least three of five papers. Among these students almost half of them completed all five tasks (46%), 35% students have completed four papers, one fifth only three (19,6%) (fig. 2).

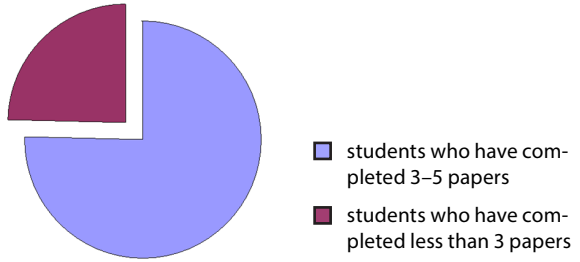

Fig. 1. Students participation in the research

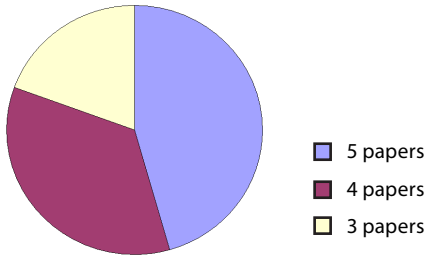

Fig. 2. Number of papers prepared by students

There were 196 papers evaluated in this research. Among them, 3% of papers, prepared by five different students (11%), weren't related to the topic, and 7% of papers, prepared by eight students (17%), were too general. The rest of the papers (90%) were generally acceptable.

The most common way of presenting information in papers was copying some passages or whole websites articles. The students were told not to copy whole sources, and it became very clear that it was the main difficulty for them.

Ten students (22% of all students in experimental group) submitted papers which were entirely copied from the Internet sources. Among them:

- three students (7%) copied information only in the first paper,
- four students (9%) copied information in other papers apart from the first one,
- three students (7%) copied information in all their papers.

What is more 11% of all evaluated papers were co pied from the Internet sources.

Thirty one students (67%) selected information and copied only parts of sources. 37% of papers were prepared this way. Only five students (11%) prepared all of their papers without copying even paragraphs from the sources (fig. 3).

In WebQuest assignment the students were given teacher's PowerPoint presentation used during the class. Some of the students came up with an idea to use it in their paper. Nineteen students (41%) in 34 papers (17% of all papers) used slides from presentation to demonstrate required knowledge. The students created their own mind maps, sign drawings, illustrated their knowledge with correct diagrams. Seven students (15%) used this method once, twelve (26%) used it more than once (two or three times).

In summary, the research shows that:

- Fifteen students (32%) prepared all or almost all papers at a high level – selection of information was good, papers were not just mindless copies of sources and it seemed that students understood the task.
- Sixteen students (35%) improved their papers during experiment – at the beginning their papers were weak and were not sufficient, but they became better. By better I mean the students tried to evaluate given sources: they stopped using cheat sheet websites, used more than one source to prepare the paper. They also tried to select information – they chose the ones they believed were significant and included the most important ones in the paper, explained new phrases, illustrated them with diagrams and pictures. It seems that the students spent more time and energy on studying and understanding information.
- Six students (13%) prepared papers of different quality – some of them were really good, others much worse. There were no patterns indicating students' attitude towards prepared papers.

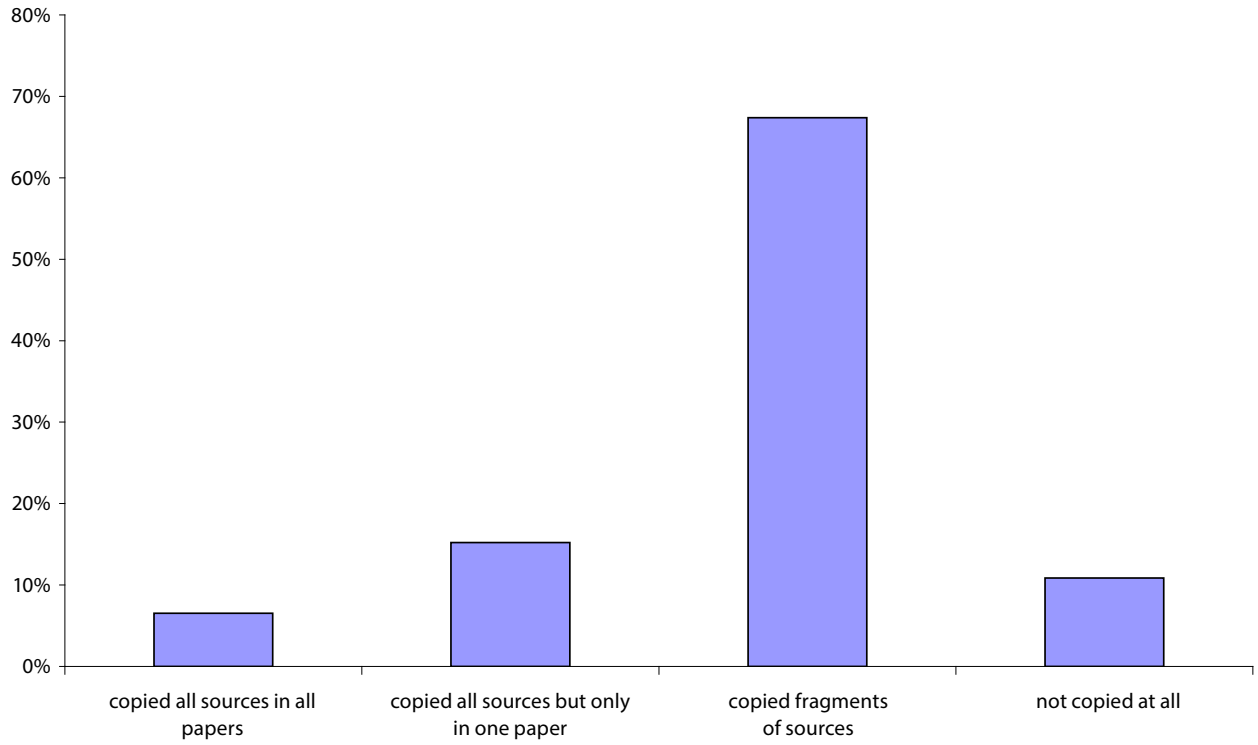

Fig. 3. Copied content from different sources in the students' papers

- Nine students (20%) did not complete correctly their task in any of the papers – they did not spend enough time and energy on preparing to the lessons, all their papers were weak, mostly copied from sources without any consideration (fig. 4).

Over half (56%) of students who improved their papers had low biology grades. Improvement of papers quality does not mean that the papers were really good. The students, mainly tried to select information, not just copy all sources, with better or worse results. They also tried to show facts in more approachable way – emphasize more important words, explain them, illustrate information with pictures and diagrams. Student who score the best biology results prepared the papers of very different quality. Almost three quarter (73%) of students, whose papers were at the high level were those with average biology grades.

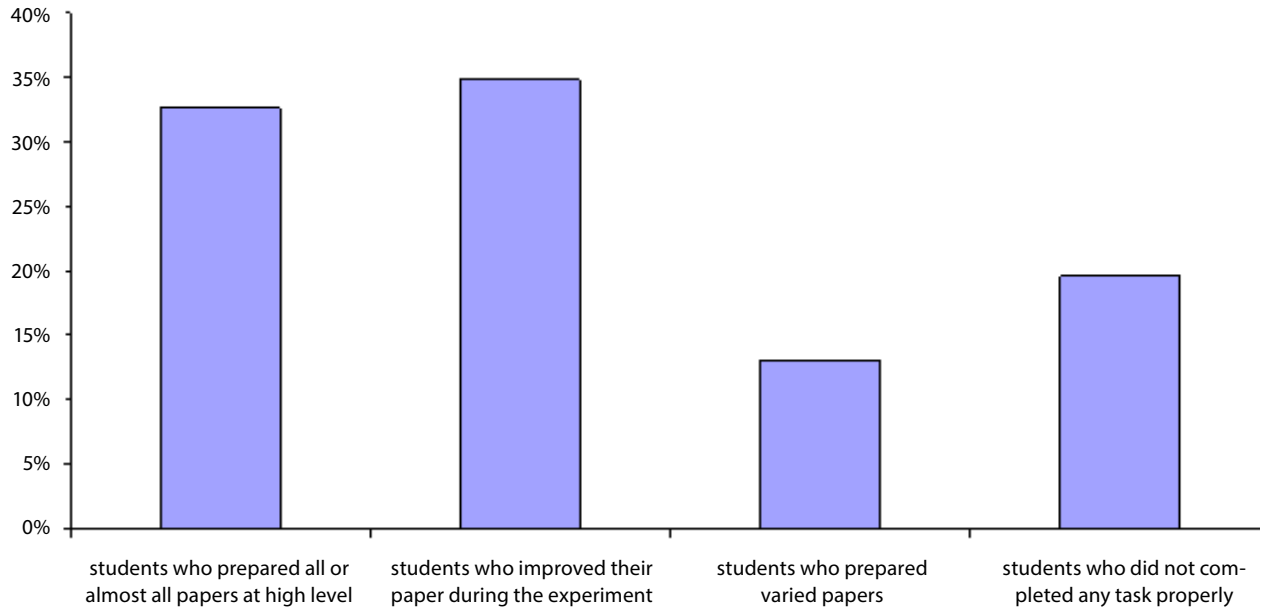

Fig. 4. Evaluation of students papers in research

Discussion

Results of the study show that almost 70% of students had difficulties with using the Internet websites as a help for studying. They have to be taught how to use them, because their skills of selecting information are poor. Students are used to copying websites sources without evaluating them. In my opinion, students believe that the Internet is an easy way to do schoolwork and teachers will not realize that students' effort was limited to copying.

Only 5% of study participants were able to write information using mostly their own words. One third of students were able to select information in the first paper and another 35% increased their ability to evaluate facts during the research. When those students were obligated to evaluate information they started trying to do that. They practiced choosing important words, facts, illustrating them with diagrams and pictures. This had to develop their critical thinking.

Over 30% of students did not increase their evaluation abilities at all – their papers remained on the same level. 13% of them prepared worse or better papers probably depending on the amount of time they had. Almost 20% of students were not even interested in developing these skills. They were given guidelines on how to prepare the paper, but they did not take the information into consideration. Another 25% did not participate in the research at all.

Using WebQest makes it possible for students to do all required work online let me transfer all students preparation process into network. WebQuest structure gave the students a list of sources to be used. It also made it possible to confront information the students found on the Internet with the teacher's presentation prepared for lessons. 41% of the students considered the presentation an extra source which might be used in their papers. They tried to link information they found on the Internet with presentation slides. It encouraged them to create diagrams or mind maps that improved their understanding of the given topic.

These results show that the students are not aware of the possibilities of using the Internet for education. What is significant, students achieving average grades learnt using the Internet more willingly than those with the highest grades. These results are consistent with the UK research from 2004 which showed that children use the Internet mostly for fun or to communicate with people. Children and young people need and want to be showed how to use websites for learning because they

do not know how to benefit from IT (Livingston&Bober 2004). My research also show that Polish students use the Internet with an unconditional trust to its content – they copy everything, without selecting or even checking unknown words. They find it really difficult to do something more than copying. It is an intensive process to teach students how to select website information. It should be guided by all teachers, and there is a group of students who are not ready for that kind of effort. These studies are going to be continued.

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The formative role of media and social transformation on attitudes to sex education

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Summary:

Issues regarding sexuality should be considered against their biological and social context. Trends in educational change result from new understanding and social and cultural transformation. Questions have arisen about a new model for sex education in view of social transformation and the increasing role of media in attitude formation (Chomczyńska-Miliszkiewicz, 2002; Giddens, 2007; Izdebski, Wąż, 2011). The hypothesis is that informal sources of information on human sexuality significantly influence formal education in this respect through shaping teacher and student attitudes and popularisation of specific knowledge and behaviour models. The verification of this hypothesis was attempted in the study reported here, involving 101 teachers and student biology teachers. This educational experiment included a diagnostic survey and a focused interview. Thurston's scale was applied. Conclusions from the study suggested recommendations regarding sex education at various stages of education and revealed new areas for research on the educational role of social transformation.

Key words: formal and non-formal education, media, sex education, social transformation, teacher and student attitudes

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Introduction

Human social transformation shapes behaviour and responses, including those related to sexuality. Sexual behaviour in societies constituting modern civilization is not only connected with procreation, but also the formation of the personality and identity of individuals. Cultural factors contribute to the idea of the human body such as: femininity, masculinity, sexuality, and give biological characteristics meaning. Modelled by the biology of sexuality these may be disordered and succumb to anomalies or simply change meaning and their perception through the influence of changing cultural factors, depending on the requirements of society. According to many biologists and educators (Giddens, 2007; Giordan, 2010; Kurzępa, 2007; Luciano, 2001; Melosik, 2010; Raisky, 2003) sexuality combines the biology of the human body, human identity and systems of social norms. Moreover, according to Chomczyńska-Miliszkiewicz (2002), parental ignorance and lack of psychosexual knowledge create a situation in which peers and the media are the main sources for sex education.

Social contexts are now strongly associated with the contexts of the content transmitted mainly through informal sources. Social factors must be taken into account when the attitudes of respondents to concepts such as gender and human biology are considered. The share of accidental education through TV advertisements and its impact on attitudes towards sexuality were considered in the context of the development of biological knowledge by consumers of mass culture. The starting point was the view of Melosik (2006, 2010) who claimed that in modern culture, people were perceived through the prism of their bodies and that TV commercials shape an almost unrealistic idea about it. Therefore, iconic media coverage can influence the level of sexual education in a society. Rams (2011) argues that contemporary media are an integral part of life and a carrier of basic social values. Recipients are free to choose a media's message and interpret it for themselves.

There is a risk that the school cannot keep pace with educational and social needs. For this reason the attitudes of human biology teachers were examined to improve the teaching model. This is the knowledge that should be offered by schools and colleges to educate future teachers in order to appropriately impact the sexual education of their students and meet the needs of knowledge-based society.

Methodology of research

The aims of the study were to:

1. examine the attitudes of teachers and students in terms of media information concerning human sexuality and its influence on social attitudes and the model for school sex education;
2. investigate whether social transformation in the perception of the body and human gender identity influence changes in the biology curriculum and attitudes of different social groups;
3. investigate the progress in science education on human biology, transformation of psycho-pedagogical beliefs on public perception of gender and influence on the attitudes of students, i.e., future teachers.

The research questions addressed were as follows:

What is the role of the media and social transformation in shaping the attitudes of teachers and students to human sexuality and how does education influence the attitudes of future teachers considering scientific progress in the human biology of gender identity and transformation of psycho-pedagogical views on the public perception of gender identity?

The following hypothesis was proposed:

Informal sources of information about human sexuality have a significant impact on formal education by shaping the attitudes of teachers and students and promoting specific knowledge and models of behaviour which are subject to verification when confronted by current knowledge.

Table 1 shows the methods and tools used in the study.

Research methods	Research tools
analysis of documents (and subject-methodological literature)	guide to the analysis of documents and literature
pedagogical experiment (study of attitudes)	pre-test and post-test (Thurstone's attitude scale)
diagnostic survey	Questionnaire
	interview questionnaire (focus interviews)

Table 1. Research methods and tools

Science curricula, 13 from elementary schools, 10 from junior high schools and ten from high schools were reviewed in terms of their human biology content and 135 scientific articles and lesson plans published in the journal "Biology in the School", an educational and scientific journal published since 1944. The articles were analyzed in terms of issues relating to sex education and human biology with particular emphasis on sexuality. The journal only printed materials in accordance with the curriculum of the time. The articles are a reflection of trends in curriculum reform. The guidebook which was prepared for the analysis of the curriculum and school textbooks included issues about human biology relating to gender identity and sexuality divided into 10 thematic categories. Each category contained biological keywords. The school curriculum was compared with the student biology curriculum for the "Sexology" course at the Pedagogical University of Cracow.

The experiment observed the influence of experimental factors, applied as an intervention, on attitude changes of 40 future biology teachers (students) to sex education. Students took part in a series of classes and discussions about gender identity which constituted the intervention.

The materials used in this experiment were developed by the authors and adopted recommendations from national and international publications and those for professional development available to students during their biology course. Included were articles from scientific journals, chapters from recent monographs, professional web pages and chapters from up-to-date textbooks. Additional sources of knowledge were in the form of television programmes, reports, a conference concerning sexuality and the activities of civic society organizations to combat xenophobia.

In the experiment, students were pre- and post-tested using Thurstone's scale of attitudes concerning interdependence of sex education and the media. It was assumed that the test would cover the attitudes of respondents in relation to traditional media such as television, magazines, signs / advertising posters and billboards in the form of new media: digital images (advertisements) and the Internet (sites, blogs and social networking sites relating to gender identity).

Verification of the hypothesis was also based on a diagnostic survey (the focus interview), which initially involved two groups of second year biology students (the first group included four and the other, eight students) and a diagnostic survey, carried out on 101 respondents (27 biology teachers and 74 biology students from the Pedagogical University of Cracow).

Results of research

Review of literature

Analysis of magazine articles showed that topics related to sexuality were not discussed in the 1940s, as if human sexuality did not exist then. Furthermore, the curriculum hardly touched on human reproduction. One of the first articles relating to sexual education emerged in the 1950s and was focused on reproduction, the curriculum itself and other issues in the human sciences. However, for decades, the number of curriculum items relating to gender issues has increased. In addition, over the past 70 years, Polish curriculum reform and changes to the biology curriculum have considerably expanded the number of gender related issues featured. With time a new subject – sexuality – was introduced, which in Poland over decades has changed both in name and status at school, from optional to compulsory. Every time a new program or curriculum reform was introduced the curricula for human biology were extended. The increasing number of keywords concerning gender identity is marked. A definite change is visible in the subject itself and its relation to education. There are numerous descriptions of the structure and function of the reproductive system, puberty, pregnancy, marriage and family. The issue of contraception is repeatedly raised. There was always an emphasis on responsibility in sexual life. In the 1980s and 90s many

handouts and articles on AIDS and sexually transmitted diseases were distributed. Currently, the curriculum focuses mainly on issues concerning human anatomy, physiology, pregnancy and foetal development. Hygiene and its relationship with human health, development of the individual as well as problems associated with puberty are also emphasized. Only a few of the curricula published in the years 1995–2012 included entries on: psychosexual development during puberty, accepting sexuality, the menstrual cycle, AIDS, the anatomical gender differences and the correct vocabulary applied to sexuality. Keywords associated with rape, sexual extortion, prostitution and pornography appear one by one. Comparative analysis of the education of student teachers according to the "Sexology" subject and curriculum revealed that, included among the topics discussed in school science classes, there were hardly any touching on sexuality. At elementary school there are topics concerning physiology of the menstrual cycle, natural methods of birth control, sexually transmitted diseases: syphilis, gonorrhoea, herpes, AIDS, and their prevention, sexual desire and the need for love and the importance of emotional bonds with parents. In junior high school and high school the same issues are covered and hormonal contraception, i.e., the two-component pill, the progesterone only "mini-pill". Sexual desire in the biological, mental and social dimensions is also mentioned.

Analysis of responses to the questionnaire

With regard to the impact of media on the sexual education of young people, more than 50% of students felt that the messages of opinion-forming media on sexuality, appearing mostly on the Internet, are often not in keeping with their age and stage of mental development. Moreover, film magazines contain too many sex scenes which stimulate the imagination and encourage students towards early sexual initiation and pornography. About 20% of respondents felt that a lot of the media information on sexuality is taken out of context, resulting in gaps in the knowledge of pupils who often believe that they know everything about sexuality. According to 25% of the student teachers studied, young learners often use social networks and information, instant messaging, fora, advice sites for young people about varying sexuality issues not included in school sex education courses. According to almost 20% of student teachers, pupils visit pornographic websites on a regular basis.

Analysis of the focus interview

Impact of the media on student attitudes to sexuality

According to the students interviewed, media (advertising, online fora, television, billboards) have a major impact on young learners, since people tend to imitate some of the behaviour they are exposed to. Students did not support the introduction of sexual education into kindergarten. Also, the students clearly expressed negative opinions about the toys which have recently been introduced into Swiss kindergartens as part of sex education there.

Feedback from participants interviewed on the programs of sexual education

Most of the students stated that Poland should adopt the "Tutoring sex" program which is popular in the UK. Implementing this should include, for example, photos presenting symptoms of sexually transmitted diseases to educate pupils to the effects of making irresponsible sexual contact. In the opinion of all student respondents, in Poland, such a program would not be easy to implement since "in most Polish homes sex is taboo and it always will be, which is a shame, because thanks to it you can learn many interesting things."

The experiment

Almost all maintained their view that in the media (both new and traditional), action should be taken against prostitution, which increases the risk of AIDS and facilitates satisfying sexual desire without emotional involvement. About 80% consistently argued that the media should educate parents not to adopt a hostile attitude towards contraception for their children, because it did not discourage young people from sexual contact. Teachers were perceived as an untrustworthy and unreliable source of information on sexual abuse. About 70% of respondents said that pupils often ask about sexual education topics and were willing to express their opinions and pose moral questions about sexuality which was not only present in commercials, but about how it was used for commercial purposes.

Just over half of the sample in both the pre-and post-test found that media (especially television advertising, Internet images and film), frequently presented negative sexual behaviour associated with perversion and violence. Post-test showed that 15% changed their attitudes towards raising awareness regarding intersexualism. They considered it necessary to mention and underline that intersexualism was not a threat, and was not the result of a mental disorder, although in the pre-test, it was perceived that way (table 2).

The post-test showed that 27.5% changed their attitudes towards social campaigns (happenings, promotional advertising, public service advertising – PSA), overcoming feelings that intersexual people were inferior. Moreover the students considered that this should be organized using media messages on television and online social networking sites (table 3).

Post-test results showed that 15% of respondents changed their attitudes towards films and television commercials. They perceived them as not only as

a source for negative role models for young people. Previously this type of media coverage was perceived as a hazard (table 4).

Post-test showed that 15% of respondents had changed their attitude towards the TV program about sexuality for young people which they had previously opposed (table 5).

Discussion

According to Chomczyńska-Miliszkiewicz (2002), sex education should cover all sexual problems in the contexts of the individual, culture and progress in the life sciences, which were included in the experiment. The experimental results showed that student biology teachers changed their attitudes to problems concerning human sexual biology and sex education. It seems reasonable, therefore, to publicise the latest research results on problems in human biology, which impact on the improvement of public awareness in this regard.

People interviewed stated that pupils treated the matter of sexuality in a highly objectified manner and very often use banned websites, which means that they have inappropriate views on issues concerning sexual behaviour. Giddens (2007) argues that advertising is based on generating the sexual pleasure associated with pervasive sexual imagination in a market which itself stimulates sexual behaviour in the context of magazines, films and media products. Sykała (2010) suggests that the media are a threat to the formation of young people's identity and sexuality, mainly through the process of sexualisation. As a consequence, disruption of gender identity, adolescent self-esteem and dissatisfaction with body appearance present themselves. According to McDowell (2000), media distort the reality of the sexual sphere. Sex represented in the movies, pop music, newspapers and advertisements is a mere fiction and has nothing to do with reality. Particularly disturbing, is the fact that reports published in the United States claimed that the media ranks third (after peers and parents) among factors shaping values and standards of behaviour fully accepted by young people. A slightly different view on the impact of media on sexual attitudes of young people is presented by Izdebski (2006), who states that the Internet is often the only source of knowledge about sexuality, even though most European countries offer lessons on the subject in school. In Poland 92% of adults declared that sex education should even be compulsory at school. Pozdał (2008) also suggests that the Internet has a positive role when it comes to sex education for young people since most of the answers to their questions are available. Skowronek (2011), however, strongly emphasizes that in the context of filmmaking, the concept of liberation of cultural discourse is practically a metaphor, because filmmakers are not really "free" or autonomous enough in creating their works. They tackle subjects that interest recipients. This results from controversial issues of social phenomena, often taboo subjects such as identity crisis, transgender or prostitution. These considerations tend to emphasize the educational function of the media. An important role is played by the mediation of teaching, and thus collabo-

	Post-test	
Pre-test	No	Yes
No	1	6
% whole	2,5%	15,0%
Yes	0	33
% whole	0,0%	82,5%
	χ2 McNemar	
Test	4,17	p=0,04123

Table 2. Changing attitudes in terms of awareness about intersexualism

	Post-test	
Pre-test	No	Yes
no	9	11
% whole	22,5%	27,5%
yes	0	20
% whole	0,0%	50,0%
	χ2 McNemar	
test	9,09	p=0,00257

Table 3. Changing attitudes about the campaign concerning intersexual people

	Post-test	
Pre-test	No	Yes
No	4	0
% whole	10,0%	0,0%
Yes	6	30
% whole	15,0%	75,0%
	χ2 McNemar	
Test	4,17	p=0,04123

Table 4. Changing attitudes to films and television advertising as a source for negative role models for young people

	Post-test	
Pre-test	No	Yes
No	4	6
% whole	10,0%	15,0%
Yes	0	30
% whole	0,0%	75,0%
	χ2 McNemar	
Test	4,17	p=0,04123

Table 5. Changing attitudes towards the sex education TV programme

ration of biologists and educators in shaping attitudes towards issues concerning human biology and ways to present them in the media.

Television often shapes negative forms of behaviour saturated with eroticism or a stereotyped approach to the issue of equality (Ejsmont and Kosmalska, 2009). This is confirmed by the teachers and biology students participating in this survey and experiment. Models of behaviour suggested by TV commercials and on billboards have a very strong influence on the attitudes of young people (Parafiniuk-Soińska, 2005). Respondents related to the promotion of false and inappropriate role models in the same way, especially in the context of the presentation of the "ideal body" using the bodies of models and persuasion that it is an essential requirement to the realisation of all needs and desires, even in the area of sexuality. Young people indicated that external characteristics (biological): a slim and neat body and youthful appearance were the most attractive to them (Parafiniuk-Soińska, 2005). This creation of an image of the human body raises concern for biology teachers, who consider it a reason for the formation of complexes and dissatisfaction with one's own sexuality, especially for young people. Kurzępa (2007) reports that while growing up, young people are in constant contact with the media, advertising, nudity and eroticism. These communications are particularly dangerous for, even shaping, adolescent sexuality, biological maturation and the formation of attitudes towards sex. In particular, respondents believed that adults possessed the ability to interpret diverse content, while children received items presented within the "image culture" as a literal message. However, it should be pointed out that modern society exists in the so-called "Instant culture". One of its features is the so-called principle of "Quick sex" – instant sexual satisfaction without obligation or emotional involvement. This can result in "infection with HIV then AIDS and death" (Melosik, 2006). In this context a positive role for advertising has been revealed. It can actually assist in the education of young people to teach critical thinking. This in turn may result in greater class participation and consequently cause an improvement in the functioning of society (Mitas, 2003). In addition, 70% of respondents shared the view that moral concerns did not apply to the presence of sexual motives in advertising, but rather to the manner of their commercial use.

Based on the results it should be emphasized that one of the functions of the media should be to educate for the expanding public awareness of problems associated with human sexual biology. Respondents influenced by the educational materials for use in sex education claimed that films and TV commercials, billboards and blogs were not solely a source to young people for negative role models. Furthermore, 15% changed their opinions about TV programs on sexuality aimed at adolescents. They agreed that this form of sex education should appear on Polish television.

Conclusions

In view of the rapid development of the new media and their impact on social transformation in terms of sexualisation, there is an urgent need to address the challenges facing biological education through an interdisciplinary approach to the problems of human biology. The dynamics and increasing range of content and influence of traditional and new media renders teachers' knowledge insufficient to teach sexual education. Their preparation for the task is inappropriate and they are not trained for class discussion. There is a need to change the model for teacher education in this area. In addition, there is a need to modify and to modernise the curricula for sex education to cope with the increasingly strong influence of the media in the form of advertising, social networking, social transformation and progress in the biological sciences, which demand a new look at educational and training models for human biology. The teaching objectives for human biology on gender identity should account for skills allowing critical reception of information on the structure and function of the human body that are broadcast by traditional and new media. Sex education should be an integral part of education and besides subject knowledge it should shape attitudes towards responsibility for the lives of pupils and other people. What is more, tolerance for diversity and biodiversity needs to be promoted in the education of the teachers themselves, especially to face the deluge of information from online forms of communication such as fora, blogs and images.

In connection with the development of the media and their increasing influence on the development of young people, greater emphasis should be placed on discussion of the consequences of risky sexual behaviour.

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Laboratory under microscope

From sociology of science to the STEM education

Marcin Zaród

Summary:

Science and technology studies examined various aspects of everyday scientific practice by application of various social sciences. In result they discovered many mechanisms responsible for successful scientific training. This article presents selected major concepts and approaches in this program, especially within the field of sociology. State of empirical and theoretical knowledge is applied in various proposals for enriching science, technology, engineering or mathematical education on a high school level.

Key words: science and technology studies, STEM education, sociology of science, history of science

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Classical philosophical approaches to science in early twentieth century Europe lead to development of logical positivism and falsificationism. First was connected with Vienna Circle and emphasized inductive method of reasoning (extrapolation of empirical data into theories). Former (created by Karl Popper) focused on importance of verification of hypothesis. Despite criticisms, both of those approaches still remain the philosophical background for science, technology, engineering or mathematics teachers' training (Sismondo, 2011). Development of those theories was heavily influenced by the success of Einstein's physics. Those theories were based on historical analysis or remained purely philosophical speculations.

But those philosophical concepts did not sufficiently cover recent scientific breakthroughs done in more complex social groups (e.g. Manhattan Program or genome sequencing). They were also less useful in applied sciences, computer modeling technologies or scientific controversies. This paper will provide guidelines to explore those issues and to include them into regular education practices. Due to rising complexity of social role of scientist or engineer, philosophical or ethical approach needs to be supplemented with broader sociological perspective.

Prehistory of science and technology studies

In the shadow of those theories, interwar Polish physician Ludwik Fleck published various papers that reported everyday life of microbiological / medical laboratory. These papers were published in Polish medical press from 1927 to 1936[1], and provided baseline for further book (*Entstehung und Entwicklung einer wissenschaftlichen Tatsach*). At first this book was published in German (common language for sociological discourse in interwar Europe), English translation (published in 1979) was entitled: *The Genesis and Development of a Scientific Fact*. Fleck's writings (in German) heavily influenced Thomas Kuhn's *Structure of Scientific Revolutions* (Kuhn, 1962). Both of those works emphasized role of social factors in scientific work: education provides background, career track promotes certain characters more than others, division of work and group behaviors also have different effects on laboratory occupations. All of those factors create certain "thought collectives", unique for particular science period (in Kuhn's approach) or even single school or branch of science (in terms of Fleck).

Those sociological findings proposed different vision of science than those proposed by philosophers. Resulting dispute is still important in the contemporary philosophical literature. But Kuhn and Fleck started a whole new branch of sociology, known as Science and Technology Studies (STS). Less concerned about epistemological theories, that approach concentrated rather on participant observation, interviews and other empirical methods of social sciences. After nearly fifty years of sociological and anthropological work in various scientific societies, this work developed various concepts that could be easily used in science, technology, engineering or mathematics (STEM) education. The empirical value of those works is useful for education regardless of the philosophical details.

Strong program in the sociology of knowledge

STS was divided in three intermeshing stages (Hackett and Society for Social Studies of Science, 2008). At first (from Kuhn to early nineties) it focused on ethnographical accounts of various laboratories. Second stage marked shift of interest on the developing countries

1 Papers are available in Polish on this web archive: http://hint.org.pl/itd=n18 [access: 17.01.2014].

research and development history. Third stage emphasizes public engagement of scientific problems in wider social context (e.g. climate changes). Neither of those stages definitely ended, they should be considered as growing branches rather than closed periods.

During the first stage, social scientists ventured to "hard science" laboratories, to describe everyday practices of "tribes in labcoats". By application of qualitative methods of sociology and anthropology (especially symbolic interactionism or grounded theory), researchers spent years observing laboratories, conducting interviews and eventually becoming life-scientists themselves. One of the most important accounts is *Laboratory Life* (Latour and Woolgar, 1986), describing protein research in Jonas Salk Institute. Authors shown that standardization of results was more common than formal hypothesis verification. This account is especially interesting for older students interested in careers in life sciences.

Another research motivation (important especially in Poland) was research on scientific productivity and engineering ergonomics (Pełka-Pelińska, 1973; Cichomski, 1976). Studies conducted in Eastern Europe were outside of the scope of STS, due to Cold War politics. They had simpler theoretical goals (practical reporting rather than answering classical epistemological questions), but remain important source of reference, because scientific practice should be analyzed in historical context.

Important guidance for western STS was Strong Program of Sociology of Knowledge, created within University of Edinburgh. Major guidelines for this program were (Sismondo, 2011):

- **Causality.** Program was concentrated on conditions of creation of knowledge or beliefs.
- **Impartiality.** "It would be impartial with respect to truth and falsity, rationality or irrationality, success or failure. Both sides of those dichotomies will require explanation" (Sismondo, 2011).
- **Symmetry.** Falsified theories would be examined by same tools as true counterparts.
- **Reflexivity.** All guidelines will also apply to the sociological inquiries made within the program.

Edinburgh program was crafted and employed in various studies conducted by David Bloor, Barry Barnes or Donald MacKenzie (Bloor, 1991; Barnes, Bloor et al., 1996). Perhaps one of the most interesting (in terms of student's interest) works is history of statistics in Britain from 1865 to 1930, analyzed by MacKenzie (MacKenzie, 1981). It shows how mathematical concept became issue of state, politics and other social structures.

The Strong Program was put under criticism by various sides, accusing it of rejecting reality, rationality or truth. Similar criticism were formed against other theoretical frameworks done within STS. Resolving philosophical issues connected with Strong Program or STS is outside of the scope of this article, especially that theoretical disputes do not undermine value of empirical observations.

Visualizations and tinkering

By criticisms and rebuttals on the Strong Program Bruno Latour, John Law and Michael Callon developed supplementary theoretical approach called Actor-Network Theory. Major theoretical assumption for this approach that effectiveness of a discovery depends on the ability to connect human and non-human actors of discovery process (Abriszewski, 2012). For example: analysis of Louis Pasteur research shown how the exact definition of bacteria gradually emerged from ongoing experiments (Latour, 1988).

Another important issue was study of visualization of scientific data – examining importance of imagining, schematics and patterns: e.g. electricity circuits diagrams, chemical graphs (Latour, 1986). Due to clarity of thought and practicality of examples, this essay might be used as introductory reading, especially for classes connecting arts and sciences (Polish translation is also publicly available (Latour, 2012)).

Practical or manual side of scientific discovery was also emphasized in works of Karin Knorr-Cetina, who compared laboratory work in particle physics and microbiology laboratory (Knorr-Cetina, 1999). Major concept was "epistemic culture", which covers attitudes to various types knowledge (textbook, simulations, empirical data, theoretical concepts), division of labor in laboratory or self-perception of scientists from different sciences. This work provides account on work in CERN and Max Planck Institute, so selected fragments might be interesting for students considering careers in science.

Another important concept pinpointed in this study was "tinkering", or the importance of manual capabilities in knowledge development. This finding is in agreement with latest cognitive sciences discoveries (or progressive pedagogies): e.g. manual operations (with a solder or pipette) involves different procedures of thinking and analysis (Afeltowicz, 2012). Sometimes manual operations provide additional approaches to inquiry, also in social context (e.g. exchange of opinions between staff specialized in operating different equipment).

Controversies and catastrophes

One of the most important methodological guidelines of STS was call to study scientific controversies. "Normal science" operations too often become "black boxes", that operate within stable social configurations. Stability and regularity of social interactions makes observations difficult, because many factors are consid-

ered "obvious" or "natural", whereas they are result of underlining historical or local processes. Scientific controversy (frauds, public scientific cases or involvement in political disputes) often leads to new perspectives and reconfigurations of roles of scientists or citizens (Latour, 2005; Bińczyk, 2012).

Medicine and life sciences are among one of the most publicly disputed science fields. Public medicine issues (e.g. vaccines politics, definitions of medical deaths and biotechnology / medicine / society middle grounds) were studied by various researchers (Martin, 1996; Burri and Dumit, 2007; Fisher, 2011), often supplied with feminist critique sociological approach. Most of those studies are too complex for ordinary student, but introductory STS courses often use popular science-journalism books. For example: Ben Goldacre (British physician) critically highlighted various issues connected with process of drug testing. That kind of reading might be used as a case for building critical thinking in the field of medicine (Goldacre, 2010). Another example might be study by Naomi Oreskes and Erik Conway, that shows how climate change denial traces its roots to cold war nuclear physics and various industrial lobbies (Oreskes and Conway, 2010). Polish sociologists (declaring themselves as outside of the STS) provided important contribution, focusing on the trans-national mobility of scientists and intercultural issues (Wagner, 2011).

Similar approach might be also applied to technological sciences. Starting from seemingly trivial issues, Wiebe Bijeker shown how different aspects of the society (elegant dress, cost, public opinion, social changes etc.) shaped development of bikes (Bijker, 1995). Louis Bucciarelli and Dariusz Jemielniak analyzed work in various high-tech companies (Bucciarelli, 1994; Jemielniak, 2012). Critical errors in technology are also examined: e.g. Challenger launch decision was described in terms of social mechanisms (Vaughan, 1996), which could be easily suggested as a follow-up to a popular Richard Feynmann desrciption (Feynman, 1988). Ethical issues of engineering researchers was also examined in more classical sociological approaches in Poland (Mucha, 2009).

In field of physics, STS research on controversies highlighted ethical dilemmas of nuclear physicists (Gusterson, 1996) and disputes on cold fusion (Collins and Pinch, 1993). Important contribution is Michael Polanyi's concept of "tacit knowledge", characterized by the fact that in cannot be described in textbook or lecture form (Polanyi, 1958). Gaining such knowledge requires personal, hands-on approach. This concept was used to analyze how laser development was hindered by cross-cultural perspective (Collins, 1974).

STS in general education

Education remains one of the most important social factors determining science practice. Important contribution in field of STS was made by John Ziman (Ziman, 1980), who provided outline for integrating STS into STEM education, suggesting 4 approaches for such application:

Within the **vocational approach**, the curriculum focuses on providing additional context on typical issues of scientific, engineering or medical practice. STS provides excellent accounts of such workplaces, which might be used as a background for presentation for careers days, vocational councils etc. Complex, high-profile scientific project often involves compromises between needs of various social groups. For students interested in medical career, Ben Goldacre might provide excellent introductory reading (Goldacre, 2010). For ones more interested in technology, other books might be more suitable (Bucciarelli, 1994; Vinck, 2003).

Interdisciplinary approach suggests to built up the curriculum around the one concept (e.g. energy) rather than on one scientific field. Similar propositions were made possible by recent reforms of STEM education in various countries (Bybee, 2013). STS works might provide social background for science concepts. Perhaps best examples from various disciplines might be found in one of the Bruno Latour's books (Latour, 1999): it shows cases from soil sciences, biotechnology and nuclear physics.

Historical approach is already a part of science education (in form of biographies of role models). John Ziman proposes more subtle version, focusing on the social conditions that collaborated to creation of discovery. That kind of analysis might build both scientific self-reflection and better understanding of historical processes. History of cholera and sanitation engineering by Steven Johnson is an excellent example on linking historical and scientific imagination (Johnson, 2006). (Polish readers might benefit from Polish paper on similar case (Nowak, 2013). Intermeshing of biology and civilization might be also observed in Jared Diamond's book on native cultures (Diamond, 2005). Important source are also works on social history: classes on nineteenth century Industrial Revolution or agriculture are easily connected with STEM education (Kopczyński, 2009; Hobhouse, 2010).

Philosophical approach should also include reference to STS. Student thinking about humanities track should have basic grasp of current ontological disputes connected with STS or cognitive sciences. Ian Hacking provides accessible example on such class, analyzing geological discoveries from various philosophical perspectives (Hacking, 1999). Another approach (more recognized in philosophy but less accessible) was developed by classical works on philosophy of technology by Lewis Mumford (Mumford, 1967).

Sociological approach could be connected with group projects. It might involve the notion of "epistemic culture", as students try to characterize differences between research groups (Knorr-Cetina, 1999). These approach is seen also in scientific competitions: e.g. international contest in synthetic biology includes part "human practice", that covers ethical and sociological aspects of research work (Roosth, 2010; Miścicka, 2013).

Due to its importance to science, STEM education became object of interest for various STS researchers. This field often involves textbook content analysis and other methods from historical perspective. For example: Karl Hall analyzed importance of Landau-Lifschitz's *Course of Theoretical Physics* for development of Soviet theoretical physics (Hall, 2005). Other examples involve rise of mathematical methods in electrical engineering (Gooday, 2005).

Current status of research

Science and technology studies became important approach in social sciences. Classes on this approach are taught in all major universities, both as a major track or additional specialization. Both European and global associations for STS organize bi-annual congresses focusing on this discipline. In 2014 European congress will be held in Toruń, Poland.

For those interested in career in STEM occupations, STS provides insight into their future disciplines and provides basic socialization to various occupational or ethical issues. For other students, STS might be used as a way of overcoming "technophobia" an understanding public importance of science debates. For STEM teachers, STS could be a way o maintaining the contact with their discipline.

Due to interdisciplinary and empirical status, STS provides valuable contribution to disputes on science and technology issues in modern societies. Using this legacy in the general education might provide different viewpoints, beneficial for various groups of students.

Closing remarks

I had deliberately avoided discussion between realism and constructivism that lead into "science wars" (Mooney and Kirshenbaum, 2009). They could be easily found in literature (Hacking, 1999; Yearley, 2005; Hackett and Society for Social Studies of Science, 2008). Those detailed inquires might be interesting for teachers and students interested in philosophy or theoretical sociology, but due to higher complexity they are less accessible for wider audience. My choice was rather to present different empirical approaches in educational context, as that kind of data could be used or read without previous philosophical preparation. Therefore theoretical sources presented in this paper are limited only to major works, necessary to understanding key concepts in this field.

Another factor is classification issue. Being diverse and interdisciplinary, this field is not easy to contain. While not every cited author would subscribe to all of approaches of STS, some of them became "unwilling classics" or classical examples of STS academic courses.

Most of the works were published in English, so their accessibility is limited to high-school or college students with higher language proficiency, however some books are more accessible than others – they are marked in blue text in bibliography.

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Connection of biology and ecology with mathematics

Ilona Horychová, Milada Švecová

Summary:

Natural sciences have achieved rapid growth of knowledge and come up to new approaches of studying organisms. One of the approaches is integrating the disciplines and their mutual permeability. The integrative disciplines, such as ecology, can be an example of such procedure.

Developing the connection between mathematics and ecology becomes possible with the help of mathematical models that are used to solve biological problems. Showing examples of interactive disciplines at school can encourage pupils' creativity and inspire them to look out for information not only in an individual field of study, but in other disciplines. Numeric data is convincing for pupils and helps them to put compelling and plausible arguments.

Key words: natural sciences, interdisciplinary subjects education, ecology, biology, mathematics)

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Introduction

Interdisciplinary relations are a didactic modification of the relations that normally exist in nature as well as in the society, and are demonstrated in scientific disciplines. The teaching methods, that are usually used at school, seem to be a collection of isolated and static facts and very often lead to narrow knowledge without any connections between the disciplines. Effective interdisciplinary teaching, with the use of interdisciplinary relations, shows more clearness, dynamics and a comprehensive approach. A general tendency towards coordination and integration in teaching natural sciences at school is another notable characteristic. The application of interdisciplinary relations shows importance especially in the case of the distant disciplines when the relations and connections of these subjects can be shown (for example, between natural and social sciences). These relations are shown not only in the content and extend of the teaching, but also in the application of teaching methods, means of teaching and the evaluation of the results of the teaching. The aim of these relations is the interconnection of natural sciences, such as biology, chemistry and ecology, with mathematics and the main intention is to show the students the connection between the phenomena and processes taking place in nature.

No less important aim of interdisciplinary relations' application is to teach students to use the acquired knowledge in various contexts and relations. The creation of interdisciplinary relations leads to a long-term retention of knowledge and develops critical thinking among students.

Connections and relations can be deduced:

- from universal studies and understanding of phenomena, subjects and objects;
- from perfect knowledge and practical use of a scientific method, procedure or working technique (the ability to measure, experiment, analyse the results, etc.);
- from understanding the nature and way of using a theory when explaining various phenomena, without regard to the studied discipline;
- from applying and comparing knowledge and activities received from one or more subjects.

A principal didactic rule for effective application and observance of interdisciplinary relations is the creation of knowledge structures consisting of biological and other natural sciences terms and use of the structures everywhere where the terms appear in related natural sciences (in method, theory, law, piece of knowledge, working procedure, etc.) (Švecová et al., 2001; Švecová et al., 2001; Hodgson et al., 2005).

Theoretical starting points for the application of interdisciplinary relations

The name itself – interdisciplinary relations – reflects the informative, formative, growing as well as the practical value of mediated knowledge. It is becoming apparent that every piece of knowledge is valuable on condition that its understanding concerns as many connections and relations as possible, including the knowledge of a concrete scientific discipline in the form of a school subject. At the same time, connections with the other scientific disciplines, close to the field of the studied subject are created.

As a result, by interdisciplinary relations we can understand their recognition as well as the way of expressing these relations and connections, understanding the meanings of basic terms, theories, axioms, laws and regularities about facts, objects and systems or phenomena in nature as well as in the society. It means the

identification and the way of formulating the relations of natural and social character, transformed into corresponding school subjects in the teaching process.

Natural sciences have criteria that allow them to be used in the interdisciplinary relations because they study the same objects and systems, although from the different points of view.

The current need for the growing use of interdisciplinary relations arises from the gradual surpassing of the borders between individual scientific disciplines, which has obviously led to the creation of borderline disciplines (in connection with mathematics, biostatistics can be mentioned as an example). After the previous phase of differentiation of natural sciences, another phase is currently starting – their integration.

The concrete manifestation and realisation of interdisciplinary relations in teaching, particularly of the natural sciences, proves that the more details and particulars are known within one particular science, the more credible the generalisation can be. This observation is based on the systematic control of the actual thinking processes of students. When such conditions are created, with a minimum of facts, a maximum amount of information of theoretical as well as practical significance can be achieved. If a student has to explain or give reasons for a particular theoretical or practically evoked and problem-oriented situation, it is also necessary for them to apply knowledge from another school subject in order to come to the solution, especially from a related subject. Looking for the optimum solution of a problem is very closely related to the content of education as well as to the looking for possibilities of creating unity in it, not only at the level of its selection and organisation but also as the optimisation of its didactic structure.

In a broader context, the application of interdisciplinary relations in teaching can be seen as a matter of integration of knowledge. The need for this arises from the significant increase of knowledge of nature and society. This is the fact that creates new quality and, at the same time, increased requirements to the area of education in pedagogical theories as well as in teaching practice. It leads to an integrated knowledge about nature.

The application of interdisciplinary relations and the subsequent process of integration are certain prevention against encyclopedism and the overtaxation of students by an excessive amount of factual information; it contributes to the deeper understanding of the structure's nature of the studied objects. Moreover, it leads to the explanation of the value of the studied objects.

On the one hand, in the situation when students need to give reasons, to deduce, to compare or to make a generalisation, it is impossible for them to do it by just reproducing what they have been taught. On the other hand, remembering certain facts, such as a definition or a law is the first and very important condition for the application of interdisciplinary relations, and it requires from the student the development of more complex thinking processes (abstraction, generalisation, analysis, synthesis, etc.).

The matter of interdisciplinary relations has led to the creation of integrated disciplines. The following examples can be given: getting to know nature, Man and nature, Man and society.

Model examples of interdisciplinary relations between mathematics and ecology

Mathematics, as the gate and the key to the sciences, has a very specific position and due to the creation of borderline disciplines, which have an interdisciplinary character, its importance becomes even greater. As an example of such a borderline discipline, we can mention ecology (a biological scientific discipline) and environmental sciences (a comprehensive science about the environment). Mathematical approaches can also be used in simple statistical methods, for example, as a tool for analysing school experiments. A graphical presentation of new data is one of the skills that are required from pupils in the lessons of mathematics. Mathematics also plays an important role when solving calculation problems, for example, population change statistics.

Mathematicians derive mathematical models that govern what we observe, and then compare the results predicted by their models with the actual measurements. The agreement is often remarkably good but that does not mean that the nature necessarily has to follow the model. A simple reason for this is that an event can be modelled in several ways. Moreover, each model is always based on simplified assumptions. On the other hand, mathematical models help us to gain better insight into the behaviour of modelled systems. It is important to warn students not to regard the models as being strict or exact description of the reality. Our goal in this section is to inspire students to develop and apply modelling skills. In particular, a familiar mathematical model will be used in a variety of disciplines and in this way we illustrate how mathematics can be used (Agnew, 1983; Davis et al., 1994; Purmová, 1999).

Resolved Tasks

While differential equations are widely used in this context, here we have chosen models based on the difference equations since the secondary school students can solve them geometrically, with the help of a calculator or computer. Let us start with the first simple problem.

1. Evaporation. A mothball is in the shape of a sphere and starts with the radius *1/2 inch*. The material

in the mothball evaporates. After *6 months* the radius is *1/4 inch*. How the radius of the ball changes with time?

In the first place, we try to analyze the task by making a physical assumption. Only molecules on the surface can leave the mothball. A layer of molecules leaves the ball in a short time *t*; two layers – in time *2t*. Thus, during one month the radius of the ball decreases by *k* units. Let us introduce *t*, the time measured in months, and R_t, the radius of the mothball at the time *t*. A layer of molecules leaves the ball in a short time *t*; two layers – in time *2t*. Therefore, we derive the equation:

$$R_{t+1} = R_t - k$$

The model can be solved for R_t. Starting with the time *t* and using bach substitution, we derive the equation:

$$R_t = R_{t-1} - k = (R_{t-2} - k) - k = \ldots = R_0 - kt$$

that is

$$R_t = R_0 - kt$$

The ball starts with the radius *1/2 inch* (R = 1/2) at time $t = 0$: $R_0 = 1/2$; $R_6 = 1/4 = 1/2 - 6k$. Therefore $k = 1/24$; consequently, we derive $R_t = 1/2 - (1/24)t$ to complete the problem. Students can sketch the graph of the solution and discuss how the radius changes with the passing of time. Here questions whether $R_{24} = -1/2$ or not and whether $R_{-12} = 1$ or not should arise.

The next problem is similar to the previous one and requires some physical assumption as well.

2. Absorption of Light. A slab of a glass *1 inch* thick absorbs one-quarter of the light which passes through it. How thin must a pane be made to absorb only *1%* of the light?

Let *n* be an index representing the thicknesses of panes of glass in inches, and let X_n denote the fractional part of the light that passes through a pane of thickness *n*. Then obviously X_n is a decreasing sequence. A pane of thickness *0* means that there is not any pane and any absorption of light, consequently, we derive $X_0 = 1$. According to the task, $X_1 = 3/4$. We need to find *n* such that $X_n = 99/100$. The method used in the problem of evaporation leads to the solution of this problem:

$$X_n = 1 - (1/4)n$$

The model is nonsense for $n > 4$. One of the reasons for that are our considerations that were not precise enough. We suppose that a pane of thickness *1 unit* absorbs *k* percent of the light which passes through it. By adding another pane of thickness *1 unit* we obtain the pane of thickness *2 units*. It is not true that the pane composed of two layers absorbs *2k* percent of entering light, when the thickness of each of the layers is *1 unit*. In fact, the first pane absorbs *k* percent of light entering the pane and the second absorbs only *k* percent of light entering the second layer of the pane. This observation brings us to the equation:

$$X_{n+1} = X_n - X_n k$$

Applying the same process as in the first task we complete the problem:

$$X_n = X_0(1-k)^n$$

Since $X_0 = 1$ and $X_1 = 3/4$ we derive $k = 1/4$. Calculating from the equation $99/100 = (3/4)^n$ gives $n \approx 0.035$ *inch*. Students can compare their results with the answer which they work out from the formula $x(n) = x(0)\, e^{-kn}$. This formula is a solution of the equivalent differential equation. The high school students should be able to formulate the continuous model of the problem and solve a simple differential equation which they create. Apparently, it is interesting to discuss the differences between the continuous and discrete models.

Third problem refers to microbiology (ecology). In this subsection we show how a statistical method can be used in mathematical modelling.

3. Growth of Bacterial Culture. A jar containing growth media was inoculated with bacterial culture, the bacterial growth is controlled every hour through cell density. After one hour, there are $1.9x10^8$ *cells/ml*, after the second hour $3.6x10^8$, and consequently $6.9x10^8$, $1.3x10^9$, $2.5x10^9$, $4.7x10^9$, $8.5x10^9$, $1.4x10^{10}$. We propose to create a mathematical model to explain these data.

Let B_n denote the cell quantity observed at the n^{th} sampling time: B_0 is the initial cell concentration, $B_1 = 1.9x10^8$, etc. We expect that during the log phase, which is characterized by cell doubling, growth of the population continues at a constant rate so that the number of cells increases doubles with each following time period. Thus, we create the equation:

$$B_{n+1} = rB_n$$

The constant *r* is called the *growth rate*. If the cells divide every hour and we take samples every hour, then we should observe that $r = 2$. Now, we determine *r* from the observations. As it has already been mentioned, it is sufficient to know two values of measurements. According to the task, we take eight measurements, and we do not know which two we should choose. One of the approaches is using a statistical method called the *method of least-squares estimation* in order to estimate *r* from the data. The derivation and workings of this method are described in the Hoppensteadt's book. We solve the difference equation for B_n. Substituting backwards the equation we derive:

$$B_n = r^n B_0$$

This formula shows that the population grows geometrically. As far as the method of least squares is concerned, we need a linear relation between B_n and n. Taking natural logarithms of both sides, we have:

$$\log B_n = n \log r + \log B_0$$

Teachers should give students insight into the difficulty of the least-squares method and instructions how to ease the work by using a calculator or computer. In this case, numbers $\log r$ and $\log B_0$ are estimated. After certain calculations we have: $\log r = 0.642$, that is $r = 1.9$. As a result, we derive the equation:

$$B_{n+1} = 1.9^n B_n$$

Students can solve the equation by starting with B_1 and marching forward, thereby predicting the population dynamics during *8 hours*. It is reasonable to arrange the results and actually observed values in a table and compare them. One way of comparing the values is to compute percent errors.

$$\% \text{ error} = 100 \text{ (observed} - \text{predicted)} / \text{predicted}$$

Finally, this model gives remarkably good predictions of Sweden's population numbers for nearly a century. On the other hand, the estimation in the distant future gives unreasonable results. The model seems to be acceptable only during the log phase of growth, but it has to become invalid as the population reaches the stationary phase. The age structure of the population can be the reason for this phenomenon.

The following example introduces the basic idea of age structure in a simple way. This factor plays an important role in demographics.

4. Fibonacci's Rabbit Population. Fibonacci proposed a model for population growth based on an imaginary rabbit population. Starting with one pair of rabbits (one female and one male) that matures to reproductive age, say, *N*-days-old. At that time they give birth to a new pair, one female and one male. The original pair will survive to the next reproductive time (*N* days later) and again produce a pair. Each pair of rabbits will reproduce twice, at intervals separated by N days, and at each reproduction each new pair will go on in a similar fashion. All reproduction is synchronized. We will create a model of Fibonacci's population.

Let R_n be the number of pairs born during the n^{th} reproduction time. Then the first pair appears at $n = 0$ and bears one pair at $n = 1$, so that $R_0 = 1$, $R_1 = 1$ and for all later times:

$$R_n = R_{n-1} + R_{n-2} \qquad \text{for } n = 2, 3, 4, \ldots$$

The fact that each pair reproduces twice (after *N* and *2N* days) is reflected in the two-step difference equation for the sequence of numbers Rn where the number of births now depends on both the population sizes *N* and *2N* days ago.

It is possible to find an appropriate solution for this problem. The experience with the growth of a bacterial culture suggests that we should look for the term R_n as a power of an unknown constant *r*. Thus, suppose $R_n = r^n$. Substituting this into the equation, we see that *r* must satisfy the equation:

$$r^2 - r - 1 = 0$$

which has two solutions

$$r_{1,2} = (1 \pm \sqrt{5}) / 2.$$

It follows that the terms in the sequence are given by the formula:

$$R_n = A r_1^n + B r_2^n \qquad \text{where } A = (1 + \sqrt{5}) / 2\sqrt{5},\ B = (1 - \sqrt{5}) / 2\sqrt{5}$$

The constants *A* and *B* are determined from the first two terms of the sequence. A surprising result of this formula is that, although complicated, this expression for Rn always gives an integer. Even though Fibonacci's model is artificial, it nicely illustrates important methods used to study more realistic age-structured problems.

The idea of the fifth problem can be used for the dating of paintings and other materials such as rocks and fossils, and can uncover some fakes. In 1967, it helped to prove that Disciples at Emmaus, which was thought to be a painting by the famed 17th century Dutch painter Jan Vermeer, was forged by Van Meegeren. You can find a detailed description of the discovery in the Braun's book. To prove that Disciples at Emmaus is a modern forgery and not a 17th century painting, the numbers of disintegration of the radioactive elements lead-210 and radium-226 were evaluated. For simplicity we will consider radioactive decay of radium.

5. Radioactive Decay. At the end of the 19th century it was shown that the atoms of certain radioactive elements are unstable and that within a given time period a fixed number of atoms spontaneously disintegrates and atoms of new elements are created. Let *n* denote time measured in years and let X_n be the weight of radium in grams in a given portion of matter at the time *n*. Supposing that alpha particles are radiated from the matter containing radium and the amount of radium decreases with time passing. Let X_0 represent the weight of the radium at the time $n = 0$. It is necessary to know how X_n depends on *n*.

It is reasonable to repeat the physical assumption that has been mentioned in the Light Absorption Problem. According to the assumption, the quantity of ra-

dium in a given portion of matter decreases by *k* percent within a year. This statement is expressed in mathematical terms below:

$$X_{n+1} = X_n - X_n k$$

The constant *k* is known as the decay constant, and its value has been computed from results of different observations. Its value turns out to be approximately $4.3x10^{-4}$ / year. Setting $k = 4.3x10^{-4}$ and solving gives

$$X_n = X_0 (1 - 4.3x10^{-4})^n$$

It is closely connected with the half-life of radium which is defined as the amount of time required for the amount of radium in a portion of matter to decrease its value for a half. Students can calculate the half-life of radium and compare it with the table value 1602 years. In a book of Davis there is a description of how to date a fossil in terms of measuring the amount of radioactive isotope carbon-14 and not radioactive carbon which is present in the fossil.

The sixth problem is really helpful and practical, while it can give instructions how to control money.

6. Bank Investment. First, let us introduce two basic definitions. Simple interest is the amount of interest paid only on the original amount of money (principal) that you invested, and not on interest that has already been accumulated. Further, compound interest is interest that is paid both on the principal saved and on the interest that has been added to it. On the basis of the above information we can write the formula for simple and compound interest.

Let P_n denote the amount of money (balance) in the untouched account gained after passing *n* years and let P_0 be the principal. Supposing P_0 dollars earn interest at an annual rate *k*. After *n* years the total amount of principal and simple interest, which is proportional to the principal and to number of passed years, will be:

$$P_n = P_0 + k P_0 n$$

and the total amount composed of principal and compound interest will be

$$P_n = P_{n-1} + k P_{n-1}$$

that is

$$P_n = P_0 (1 + k)^n$$

If the money is loaned at an annual rate *k* compounded monthly, then the total amount of principal and compounded interest is $P_0 (1 + k/12)$ at the end of the first month, and at the end of nth year is:

$$P_n = P_0 (1 + k/12)^{12n}$$

In general, when banks announce an interest rate of *k* per year compounded *m* times a year, then you calculate the balance (the total amount of the principal and compound interest) in your account *n* years after the initial deposit P_0 by using the formula

$$P_n = P_0 (1 + k/m)^{mn}$$

Assuming simple interest. Is there any difference between the interest at the rate compounded monthly and annually? Let $k = 0.04$ and $m = 12$. How much money do you need to put into an account today in order to achieve your goal in a specified time? What is more beneficial: to deposit money at a bank that pays simple interest or at a bank that pays compound interest, if an annual interest rate *k* is compounded monthly? Give a graphical explanation. Notice what happens if you deposit the money for less than *12 months*.

Conclusions

To sum it up, the geometrical progression can be used to model a lot of other problems. As we have seen on the example of bacterial growth, this model is not always perfect. It seems that more difficult model agrees more precisely with the behavior of systems. For instance the difference equation

$$C_{n+1} = (2 / (1 + (C_n/K))) C_n$$

where *K* is called the saturation constant, describes a strain of bacteria that are histidine auxotrophs. When such bacteria are cultured in growth media containing sufficient histidine, they and divide every 40 minutes. When the population of the cells becomes large, competition for the limited amount of histidine follows, and the bacteria get an inadequate supply to sustain division every 40 minutes. However, the growth rate is no longer a constant. Please notice that the population growth rate $(2 / (1 + (C_n / K)))$ decreases with the increase of the cell population while we suppose $Cn < K$. Unfortunately, better agreement with the nature is the price for that this model is not as easy to solve as the earlier ones were.

Finally, all the problems mentioned here can be solved by means of differential equations. It could be an interesting topic for another activities referred to the high school students. From the point of view of mathematical modelling it is remarkable that a relatively simple difference equation can have solutions that have to be described using the theory of probability.

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Environmental awareness and attitudes of farmers with environmental commitments

Adam Kowalak

Summary:

Environmental education for adults living in rural areas can be considered both from a theoretical point of view and practical-learning. The article describes a study to identify ecological awareness of farmers on agri-environment schemes. Activities of Selected Agricultural Advisory Centres were presented as an example of training for adults in the countryside. An attempt was made to assess activities in terms of the shaping of farmers' pro-environmental attitudes. The results obtained will be used to determine the educational needs for local farming communities. The results highlight the poor environmental awareness of the farmers researched. The shaping of adult attitudes towards the environment is founded in school. Deficiencies in education do not foster later development of favourable habits towards the natural environment. While conducting lively educational activities, Agricultural Advisory Centres aim mainly at vocational training. Education about the natural environment is not an objective in itself but is focussed towards economic goals. Lack of cooperation between AACs and schools makes it difficult to introduce the concept of lifelong education.

Key words: sustainable development, rural areas, farmers, agri-environment scheme, education

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Introduction

Stimulating adult interest in the environment with various out-of-school courses was long delayed compared to schools. Internationally, the theme of sustainable development was introduced at the V UNESCO Conference of Education for Adults, in Hamburg, 1996. Issues discussed at this Conference included: Education for Adults r.e., Environmental Protection, Concern about Health, Ecology and Health Education (UNESCO, 1999). The balance of development was seen mainly at two levels – social and economic, according to documented records. Also a controversial statement was made from an ecological point of view: "(...) the only development in the direction of putting the human at the centre and active society based on total respect for human rights leads to continuous and sustainable development." This begs the question of whether we can discuss the matter of sustainable development away from the existence of mankind. Environmental problems were one of the main guiding ideas behind the next VI International Conference on Adult Education (CONFINTEA VI) UNESCO, held on 1–4 December 2009, Belem (Brazil), under the title "Live and Learn for a Sustainable Future". The importance of adult participation in education for sustainable development has been emphasised (Frąckowiak and Półturzycki, 2010). A worrying fact was that at this Conference the balance of development was seen mainly on the social and economic plane. The environmental dimension – human contact with the environment – though represented, remained on the second agenda (UNESCO, 2010).

Before the 1990s, adult education was treated in isolation from schools. Under the chairmanship of J. Delors, a change in approach was initiated by the report of the International Commission on Education in the 21st century, developed for UNESCO in 1996 (Delors, 1996). This highlighted the role of continuing education throughout life in the shaping of knowledge for the development of skills and abilities to assess situations to take action. After the Second World War (1947–1956), the education of adults in rural areas in Poland was aimed against illiteracy and towards politically motivated collectivisation of agriculture. Later, in the 1980s, it was focused on vocational training for farmers (Maziarz 1984). The problems of protection of host ecosystems only started to feature in adult education programmes for farmers towards the end of the eighties.

Environmental protection in agriculture

The relationship between agriculture and environmental protection today seems obvious.

On the world forum it was formally articulated in the UN report from the Secretary General, U. Thant in 1969. However, this document mainly concerned the negative impact of agriculture on the environment. The concept of sustainable agriculture only emerged in international publications immediately preceding the UN Rio de Janeiro Conference in 1992, referred to here as the "Earth Summit".

In 1991 at the conference organised by the World Organisation for the Food and Agriculture Organization (FAO) and the Dutch government in Den Bosch, a declaration and action plan for sustainable agriculture and rural development SARD (Sustainable Agriculture and Rural Development) was forged. The SARD plan included maintenance and management of natural resources and the orientation of technological change satisfy the needs of present and future generations. This concept was incorporated into the programme for the Conference in Rio de Janeiro (Sołtysiak 1993). Rules for its implementation are detailed in chapter 14 of Agenda 21 (MRRW, 2009). At a world level for the

first time, the roles of the non-productive functions of agriculture and rural areas, such environmental protection, landscaping, local traditions and materials and spiritual culture were indicated. The urgent need to take new initiatives in education was highlighted (Kozłowski 1993). The modern concept of the European model of agriculture was defined in the 1999 package of reforms, Agenda 2000. It was based on the assumption that the agricultural sector, in addition to agricultural production generates other benefits, jobs and services, which together guarantee increase of the income to rural communities, shape rural areas and preserve natural values. With the entry into force of Agenda 2000, the redevelopment of the Common Agricultural Policy to promote multifunctional development in the rural economy and environmental protection with the simultaneous liberalisation of market instruments has become a challenge for the European Union. The Common Agricultural Policy for the period 2007–2013 "Agenda 2007" was a continuation of earlier reform. In Agenda 2007 it was considered that implementation of the principles for sustainable development was a precondition for the achievement of the objectives concerning economic growth in agriculture. It was stated in this document that apart from primary production, rural areas were important in environmental protection, including management of water resources and soils, shaping landscape, the protection and conservation of habitats and biodiversity.

Today, most politicians and economists generally do not dispute that sustainable development of the agricultural sector in addition to forestry, water, fishing and land resources, protects the genetic resources of plants and animals, does not degrade the environment, is technically viable, competent and socially appropriate. But still, numerous concepts and programmes for "sustainable agriculture" remain declaration objectives – it is known what is to be achieved, but there is no effective action to achieve these objectives. Sustainable development in rural areas is often a screen, often concealing other quite contradictory purposes. Agri-environment schemes are the primary instrument for protection of ecosystems containing host plants of outstanding natural suitability, as stated in the EU Common Agricultural Policy for 2007–2013 (Agenda 2000). It is a financial instrument that allows farmers to supplement their income by their action to protect of particularly valuable host ecosystems. Motivation for the development and implementation of these programmes was growing awareness among EU politicians of the need to counteract negative developments in rural areas of developed countries resulting from intensification of production. In the framework of the Rural Development Programme for the period 2007–2013, farmers could apply for the following packets of agro-environmental subsidy:

- sustainable agriculture,
- organic farming,
- extensive permanent grasslands,
- protection of endangered species of birds and natural habitats outside NATURA 2000 areas,
- protection of endangered species of birds and natural habitats in NATURA 2000 areas,
- the preservation of the endangered plant genetic resources in agriculture,
- soil and water protection,
- buffer zones.

The individual packages were divided into variants. Agri-environment schemes allowed financial support for farmers for commitment to the following objectives:

- development of environmentally friendly farming, diversification of agricultural production, the use of local varieties and breeds for the protection of genetic resources in agriculture;
- development of organic farming or integrated management methods, beneficial to the environment and the conservation of biological diversity;
- continuation of extensive production methods, especially extensive animal rearing with the maintenance of grazing on grassland;
- active protection of habitats and protected species in agricultural areas, in particular, those in or near Natura 2000 areas;
- counteracting the negative effects of agriculture in relation to water, soil and air according to the rules of the Code of Good Agricultural Practice and the principle of cross-compliance;
- long-term planning to protect the environment and biodiversity on farms.

Financial compensation was only for farmers who agreed to continue the agro-environment commitments over five years. Measures provided for in the framework had to exceed those set out in the Code of Good Agricultural Practice, to significantly contribute to the improvement of the natural environment and preserve cultural resources in rural areas.

Intensive use of natural resources as in many European countries, does not generally feature in Poland, where the model for agriculture combines a modest higher capital-intensity in agriculture production combined with relatively high labour demands. Biological diversity in Poland is among the best preserved in Europe as a consequence of both the prevailing conditions and the nature of human impact (including traditional agriculture preserved in large areas and extensive and historically sustainable forest).

Poland has a wide variety of habitats, which in many regions create a mosaic of natural features, but are there sufficient measures to in place protect this wealth?

Environmental education for the countryside

As the Programme for the Development of Education in Rural Areas by the Ministry of Education (MEN) points out "The Polish village is the unique cultural and natural heritage of Europe. Attention to these values provides a chance for sustainable rural development. The healthy condition of the Polish countryside and good quality soils provide an opportunity for the development of organic farming and farm and eco-tourism". This document states the need for young people, well prepared for the assessment and valuation of the natural and cultural resources on non-urban terrain (MEN, 2008).

The question is whether rural schools, on the basis of the current programme, are able to deliver this requirement. The fact that the Programme for the Development of Education in Rural Areas was drawn up by MEN without visible participation of Ministry of Agriculture and Rural Development is symptomatic. Despite the transfer of responsibility for the majority of agricultural schools to local authorities, this Ministry in fact, should feel responsible for the training of future farmers. Conclusions from analysis of the recently introduced bases for the training programme for professions (MEN, 2012) are far from optimistic. It is indicative that in the first part of the base titled: "Effects of Training Common to All Occupations", reference to the protection of the environment is only mentioned in the section on health and safety at work BHP[1]. The results of training mainly include knowledge and skills. A student:

- makes a distinction between "tasks and powers of institutions and departments acting in the field of work and the protection of the environment in Poland;
- provides for risks to the health and human life and property and the environment related to the performance of professional tasks;
- organises the work place in compliance with the requirements for ergonomics safety and health at work, fire protection and protection of the environment".

Shaping attitudes can be attributed only to the last point in this Section: student "adheres to the principles of health and safety at work and the provisions of the law relating to fire protection and protection of the environment". Classification of environmental matters as issues of HEALTH and SAFETY at WORK is puzzling, because in all textbooks issued so far in this area, only described is how to safely use the environment, rather than how to protect it (Kowalak and Tuszyńska, 2003).

Vocations have been organized by type of school: basic vocational, technical and post-secondary. The effects of education described in the second part of the document, common to each area of training, are far from the assumptions of the holistic education model – there is a lack of coherence even within one area. There is a lack of reference to lifelong learning for the vast majority of vocations, specified on the basis, for example in the form of the requirement that an apprentice has an awareness of the need for constant updating and supplementing his/her knowledge. Also, there is no suggestion of an institution or organization to help with continuous knowledge updates. The exception is a provision setting out the requirements for farm and garden technicians: "uses the services of institutions and organisations acting on behalf of the village and agriculture". Agricultural school graduates are considered to be familiar with institutions that may help them to continue training. Also, there is no coordination of educational activities between schools and the agricultural advice centres, which are the responsibility of the Ministry of Agriculture. It is therefore hard to define the existence of a lifelong learning programme in rural areas. The state of adult education in rural areas raises serious concerns.

The diagnosis reported in the Programme for the Development of Education in Rural Areas in the years 2008 to 2013 described low rural uptake for lifelong learning in the age group 25–64 years. In 2006, only 0.61% of trainees in the continuous system of learning lived in the countryside. There are also serious deficiencies in adult ecological education. In Poland, as in other EU countries, agri-environment schemes perform an important role in environmental protection. This financial instrument is used to subsidise actions to protect host ecosystems. This raises the question whether it is adequate to ensure the sustainability and effectiveness of protective action? Whether or not investing in the form agri-environment payments should not go hand in hand with educational activities aimed at the development of pro-environmental attitudes? Analysis of the Common Agricultural Policy (CAP) of the European Union and the Polish Rural Development Programme for the period 2007–2013 indicated that the creators of those documents did not account for the fact that attitudes are understood to be emotional relationships with any object, person or the natural environment. As such, it is impossible to "buy" and must be shaped by education. Only ad hoc actions carrying out the task can be paid for. The purchase of or payment for financial compensation for the commitments does not guarantee sustainability of patterns of behaviour. Only the activities aimed to improve the awareness and ecological culture of farmers can ensure the continuation of environmental protection even after EU funding. Improving the people's qualifications in rural areas related to protection of host ecosystems is a key element for the sustainable development in these areas. To this aim it is nec-

1 BHP – Bezpieczeństwo i Higiena Pracy (Health and Safety at Work).

essary to establish close links between education at all stages of training. This implies the need to take effective action for the continuing, lifelong education of adults.

The purpose and methods of research

In the years 2010–2011 research was carried out to identify the state of ecological awareness of farmers participating in the agro-environmental schemes. The conclusions were applied to assess the role of the EU Common Agricultural Policy, Rural Development Plan for the years 2004–2006 and the Rural Development Programme for the period 2007–2013 in the shaping the pro-ecological attitudes of the farmers. These results will be used to identify the educational needs of local communities for education for sustainable development.

Research problems:

1. What is the level of environmental awareness of farmers participating in agro-environmental schemes?
2. What is the motivation for farmers to make agro-environmental commitments?
3. How does participation in agro-environmental schemes influence farmers' attitudes and behaviour?
4. Are there close links between education in school and farmers education (carried out by the agricultural advisory centres) that make up the continuing education system?

These problems correspond to the following research hypotheses:

1. Environmental awareness of farmers on agro-environmental schemes is low.
2. The main motivation to make agro-environmental commitments is to obtain higher additional payment.
3. Agri-environment schemes do little to shape environmentally friendly attitudes.
4. Agri-environment schemes necessitate certain actions to protect the environment.
5. There is a lack of links between schools and instructional programmes for the continuing education of farmers.

400 farmers in five regions were the sample for the study. After the elimination of incomplete surveys, 378 qualified farms (207 in Pomerania, 33 in Kuyava-Pomerania, 30 in Łódź, 33 in Silesia and 75 in the Subcarpatian Region). Training programmes organised by agricultural advisory centres and interviews with 120 farmers and 47 agricultural advisers and experts in agriculture and rural development were also analysed. Since most farms researched were in Pomerania, the effect of the agri-environment schemes in the region was compared with the other four regions (Kuyava-Pomerania, Łódź, Silesia and the Subcarpatian Region). In the farmer study, 25 questions including 7 open, 5 semi-structured and 13 closed were used in the research questionnaire. Open questions concerned the characteristics of the research sample and general characteristics of farms; semi-structures enquired about the principles of cross-compliance, the natural qualities of the area and problems in Natura 2000 areas. Farmers were free to provide their own answer or choose an available option in response to the semi-structured questions. Farmers were asked to justify their answers to some questions. The closed questions collected information about agri-environment schemes, ecological knowledge and the educational needs of respondents.

Agri-environment schemes – implementation in Poland

In Poland by more than 7% of farms benefit from environmental subsidies. On a national scale farmers complete tens of thousands of new applications every year. Table 1 shows the number of applications in the regions covered by the survey in 2009.

Region	Total applications	Amount claimed
Kuyava-Pomerania	3448	36 484 625,45
Subcarpatian Region	2849	27 699 883,41
Pomerania	2001	26 253 527,82
Łódź	1380	6 756 203,77
Silesia	469	3 920 159,60

Table 1. The number of applications lodged in the regions surveyed in 2009

Source: MRRW 2009 (the newsletter of Ministry of Agriculture and Rural Development and ARiMR, p. 22).

Applications for agri-environmental subsidies are lodged at the area offices of the Agency for Restructuring and Modernisation of Agriculture (ARiMR). The administrative decision to accept and grant payment is issued by the manager of District Office of ARiMR between the 1st October to 1st March the following year. At a country level, between 2005 and 2009 more than 100,000 applications were made for environmental subsidies. In 2009, farmers submitted 37,184 claims for 56,407 packets – on average 1.52 packages per farm.

The results of implementation of the agri-environment scheme in Pomerania

More than 7% of farms in Poland participated in the schemes. Pomerania is in second place in the country in terms of the number of farmers agri-environmental commitments (15,49% farmers applying for direct payments in year 2009). The leaders are the farmers from the Leborski, Bytowski, and Czluchowski areas (poviats), in which the agri-environment scheme encompassed 25% of farms. By 2008, the most popular package in Pomerania was for "Protection of Soil and Water", with3814 applications. In second place were the natural packages, mainly the variant, "Semi-natural Meadows, Twice Mown", with 847 applications. The changes to the detailed conditions of implementation for the environmental scheme in 2008 resulted in a clear weakening of interest in the "Soil and Water Protection Package" and dynamic growth in the number implementing the packages: "Extensive Permanent Pasture" and "Ecological Agriculture" (Radke 2010).The number of farms implementing the agri-environment scheme in Pomerania in relation to farms applying for direct payments in 2009 was in the areas (poviats): Słupski 27,28%, Lęborski 28,78%, Bytowski 27,28%, Człuchowski 26,01%, Wejherowski 21,96%, Chojnicki 16,56%, Kościerski 16,68%, Pucki 14,05%, Starogardzki 11,91%, Kartuski 9,89%, Gdański 6,69%, Malborski 9,04%, Tczewski 6,37%, Kwidzyński 10,04%, Sztumski 8,11% and Nowodworski 6,12%. Subsidies paid to farmers by the end of year 2010 exceeded 200 million zloty[2]. The question is about whether spending this amount significantly improved ecological consciousness and pro-environmental culture of farmers, or did it lead to change in their attitudes to the environment.

This research only partially answers these questions.

2 The data made available by the ARMiR District Branch in Gdynia.

Educational activities of the Pomeranian Agricultural Advisory Centre

Educational activities at the Pomeranian Agricultural Advisory Centre concerning the environmental measure covered two periods. The first was during the implementation of the Rural Development Plan for 2004–2006 (RDP 2004–2006) and the second implementation 2007–2013 (RDP 2007–2013).

In the first three years, 282 training, seminars and conferences concerning the issues concerned were organised with 6064 farmers participating.

The dynamics of training are shown in fig. 1.

From fig. 1 it appears that the activity of the national training advisory service showed a clear upward trend, both in terms of quantity and diversity.

During the implementation of the Rural Development Programme between years 2007 and 2013 (up to 2010) 685 different types of training and conferences were organized, in which a total of 17,649 people participated. Dynamics of the training are shown in fig. 2.

The number of training sessions were dependent on the implementation period of the Rural Development Programme between the years 2007–2013. Requirements of farmers were also taken into account. In addition to training as shown 1175 people also attended 13 regional conferences. The extensive training offer is evidence of serious commitment by the Pomeranian Agricultural Advisory Centre to prepare farmers for participation in agri-environment schemes.

The subjects of activities included:

- rules for qualification to participate on agri-environment schemes,
- requirements for individual packages,

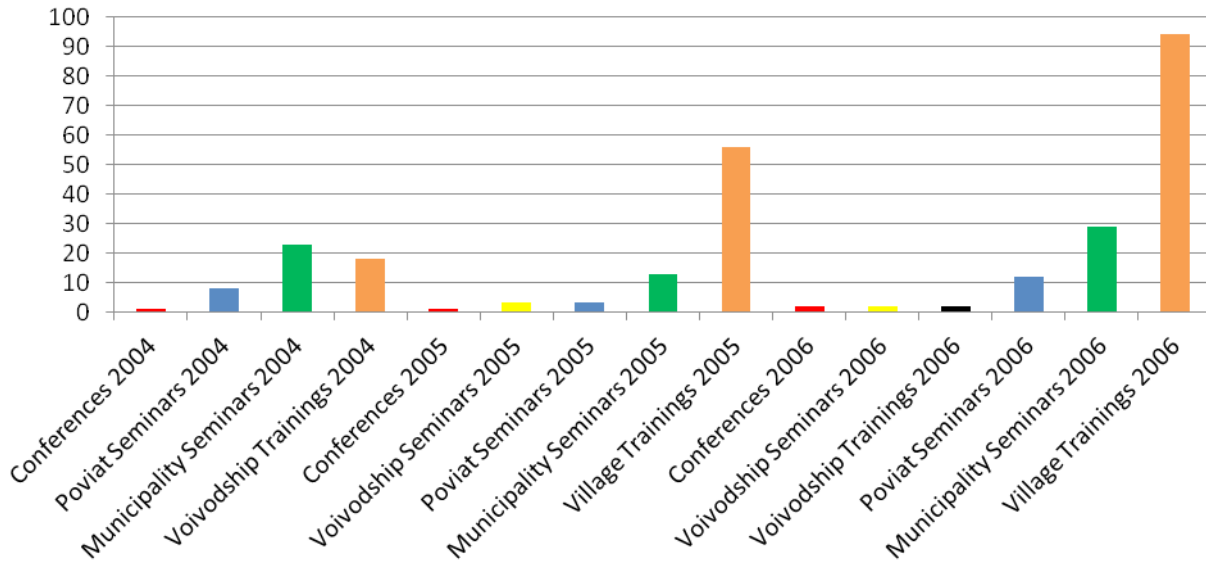

Fig. 1. Agri-environmental Training during RDP 2004–2006

- form and deadlines for submitting applications,
- rules for the preparation and preparation of agri--environmental documentation (plan for activities, fertilisation plan, records of agri-environmental activities),
- calculation of payments for the implementation of the programme on the farm,
- farm controls by the Restructuring and Modernisation of Agriculture Agency on the implementation of agri-environment schemes,
- qualification rules for meadows, habitats and land in the scheme,
- practical issues on the farm related to the implementation,
- environmental, ecological and economic benefits from involvement on the schemes.

Between 2004–2011 this centre also carried out dozens of training sessions on cross-compliance rules, organic farming and principles of good agricultural practice.

As is clear from the previous statement, training for the most part concerned technical and organizational problems for the agro-environmental scheme (the application process, actions to take to qualify).

Marginal attention was paid during activities to the relationship between implementation and the importance of commitments to environmental protection. The creators of the training did not account for the concept of ecological andragogy (Turos, 2004). It should be stressed shaping attitudes is a long-term goal. The development of adult attitudes should be founded in the formal educational system. Information obtained during the course of interviews with AAC management and agricultural advisers revealed no formal cooperation between advice centres and rural schools at different levels. Such cooperation had been previously successfully implemented in the 90s by Centers of Agricultural Advisory in Krosno and Toruń (Kowalak, 1994). The realisation of the concept of lifelong education requires such cooperation.

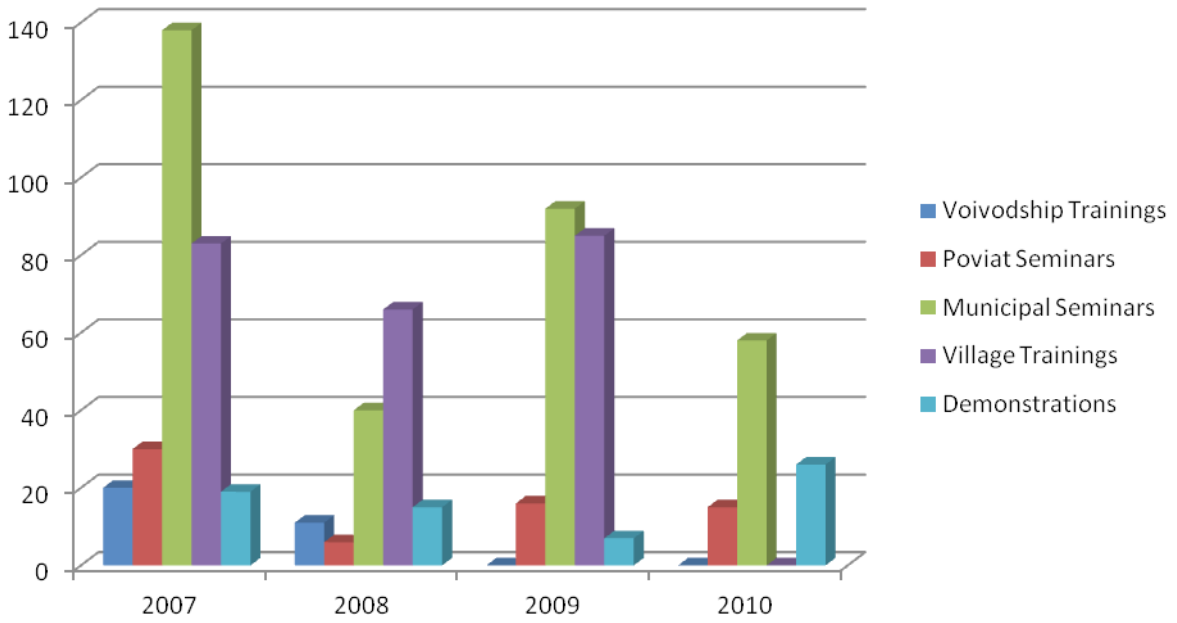

Fig. 2. Training for agri-environment schemes within the framework of the RDP 2007–2014

Activities of other centres

Wide-ranging training for environmental protection and agri-environment schemes had been conducted by all centres surveyed. According to the obtained but incomplete data, up to the end of 2010 the total number of training sessions carried out in the four regions surveyed under RDP 2004–2006 and during the RDP exceeded 2900.

The most training sessions were run in the Subcarpatian (Podkarpackie) Region and the least in Silesia (Śląskie) (this largely results from the extent participation in the agri-environment schemes). As an example, in the 2010-2011 training season in the Subcarpatian region most (over 50%) training was entirely related to environmental problems including environment schemes or indirectly associated with related issues. Altogether, 364 training sessions were on to these topics including a regional conference, 2 local (poviat) level training sessions, 121 municipal training sessions and 240 in villages[3]. Training topics in the Subcarpatian Region are shown in table 4.

This shows the high commitment of the centre to environmental protection issues.

3 The data obtained from the web site of Subcarpatian Agricultural Advisory Centre in Boguchwała. Access on 10.01.2011.

Subject	Training sessions
Agricultural Production vs. the Requirements of the Environment	80
Minimum Requirements for Farms Relating to Cross-Compliance	44
Support for Agri-Environmental Ventures	84
Natura 2000 in Agriculture	3
Organic Production	25
The Implementation of the Principles of Good Agricultural Practice	31
Other Matters Associated with environmental protection	97

Table 4. Subject of training sessions in the Subcarpatian region in season 2010/2011

Selected results of questionnaire survey for farmers

In five regions, 378 interviewees farms accounted for a total of 597 packages on agro-environmental schemes (mean, 1,58). Farms had made up to three types of commitments. In Pomerania 207 farms were participating in 286 packets (mean, 1.35 per farm). One of the important criteria for assessing the state of farmers' ecological awareness was the analysis of their answers to the question concerning motivation for agro-environmental schemes and commitments.

While completing the questionnaire, farmers could choose from two given justifications or provide their own. The results obtained suggested that the main motivation to the undertaking was for the financial benefit. A higher subsidy payment was the reason for signing the environmental contract in 73,37% of cases with a slightly higher rate in Pomerania – 76,57%. Some remaining farms reported the rate of payment as an additional reason for commitment. Only 2.9% of respondents did not report financial motivation for any packages, which was seen as symptomatic. It may be concluded that as many as 97% of farmers enter agri-environment schemes mainly because they receive increased additional payments. This is a confirmation of hypothesis No 2. Such willingness to protect nature and the landscape is demonstrated by farmers in choosing 177 packages (29,65% of respondents), including most of organic agriculture (and mostly in conjunction with a high rate of payments). In Pomerania the result is higher and accounts for 45,10% of respondents.

Natura 2000 has an important role in the territories to which it applies. These locations determine the possibilities and methods for agricultural production to a large extent. Knowledge of the purpose for which these areas were chosen and their specificity is one of the important policy issues for sustainable development in rural areas. Respondents had either to choose from three answers or they could provide their own. Figure 3 shows respondents' knowledge about purposes for designation of Natura 2000 areas.

The results indicated that 73% of Pomeranian and 81% of the other respondents were aware of the purposes for designation of Natura 2000 status to areas. In Pomerania 27% and in the remaining regions 19% of respondents were not able to identify these purposes. It can therefore be assumed that the vast majority of farmers were familiar with the objectives of the establishment of Natura 2000 areas.

The question about personal impact on the location of Natura 2000 posed far greater difficulty. Only documented scientific and natural factors are taken into account for the designation of Natura 2000 status and the site owner had no influence on the matter. The results are shown in fig. 4.

The question of whether the farmer had influence on the designation of Natura 2000 status to sites, as many as 41% of the Pomeranian respondents and 34%

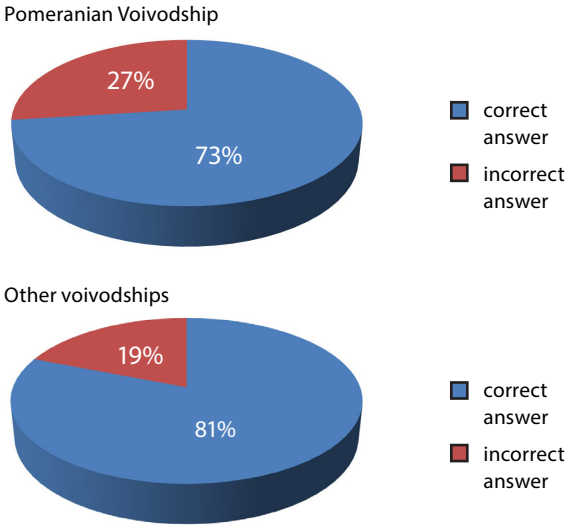

Fig. 3. Knowledge of purpose of the designation of Natura 2000 areas (% of respondents)

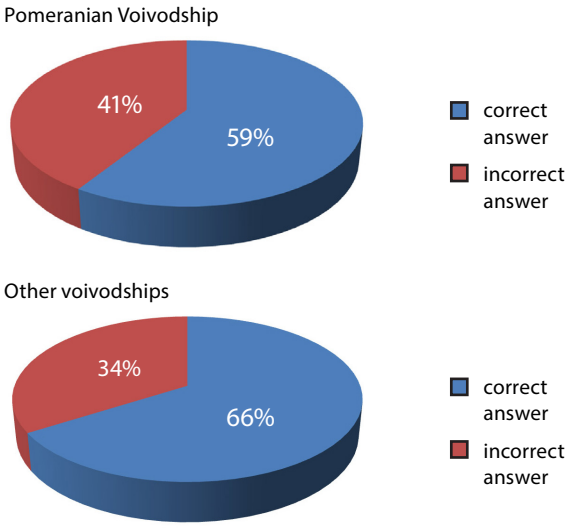

Fig. 4. Reported farmer influence on designation of Natura 2000 status (% of respondents)

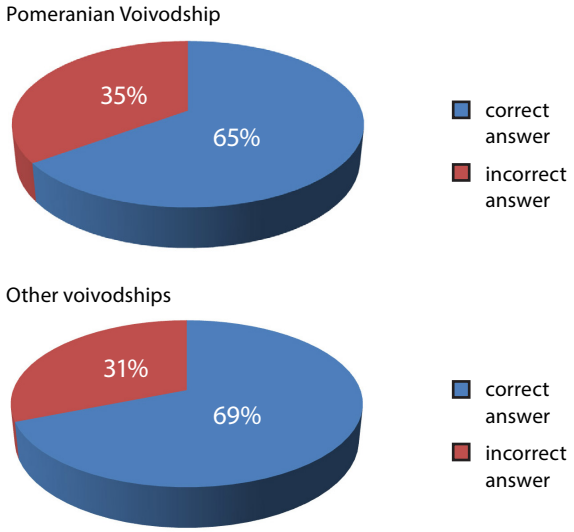

Fig. 5. Awareness of the definition of sustainable development (% of respondents)

of the remaining regions responded in the affirmative. A farmer on Natura 2000 sites should be aware that he is required to comply with strict regulations – which he is not able to change. Nearly 40% of respondents lacked such awareness.

The closed question regarding the definition of sustainable development offered three choices of which only one was correct. In answering this question 35% of Pomeranian farmers and 31% from the other regions offered wrong answers. They considered that this was a development in which nature protection overrode the interests of human civilization (respectively 18 and 17%), a system that enforced the protection of the environment (9 and 9%), and even "the development of a market economy in which the increasing production and consumption of material goods only allowed slight deterioration of the state of the environment" (3 and 2%). Remaining respondents indicated "I don't know" (4 and 3%). The results are shown in fig. 5.

Farmers showed relatively high awareness about the principles of cross-compliance. In the five regions, only 15% answers about this were incorrect. This mainly resulted from the fact that meeting the conditions for cross compliance is the requirement for receiving agro-environmental payments. In all the researched centres, many of the training sessions were devoted to this subject.

Self-evaluation of self interest in the problems of protection of the host ecosystems is an important finding about attitudes of farmers in their approach to the environment. In terms environmental protection, in Pomerania, 15,46% of respondents in Pomerania declared little interest, 62,7% average interest and only 22,3% were very interested. In the other Regions 33.4% were strongly interested in the issue, 49% moderately and 17.6% weren't very interested. It can therefore be assumed that about 25% of farmers are genuinely interested in nature conservation. This is a confirmation of hypotheses 1 and 3.

Since most respondents cited agricultural advisory centres as the main source of information on agri-environment schemes and for the environment in general (46.4%), it was asked why the extensive training on offer did not translate itself into pro-ecological attitudes of farmers. Here, one can identify at least three reasons.

The main purpose of training is to instruct farmers about how best to obtain financial rewards. The development of environment-friendly attitudes or empathy towards the natural environment is treated as a matter of secondary importance.

The attitude of farmers towards the environment, based on knowledge of relationships, knowledge of and respect for nature and accountability, has not been shaped by schools (in formal education). This is confirmed by interviews conducted with farmers.

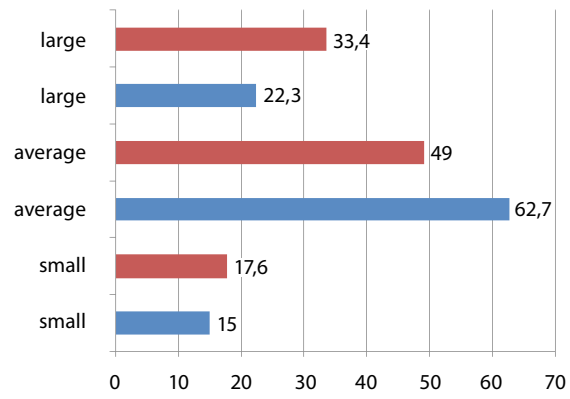

Fig. 6. The results of self-evaluation of self interest in environmental protection (% of respondents)

Pomerania marked blue, others red.

Lack of proper preparation of farmers by schools at different levels to participate in the process of lifelong learning (including in nature conservation). Formal education in schools builds a foundation for adult education.

Interviews with farmers were important to supplement and refine the data from the questionnaire survey. One motivation was for an assessment of the aesthetics and certain aspects of biodiversity in the farmyard and its immediate surroundings (including the presence of old trees amongst the old varieties of fruit trees and alien species such as conifers). Information obtained indicated that the overwhelming majority treated the natural environment as a subject. A positive attitude towards the environment and an understanding of its reciprocal system of connections was observed in relatively few households (19%) – mainly organic farmers.

Unfortunately, even organic farmers included people whose main motivation for environmental commitment was financial.

Puzzling was the fact that more than 60% of farmer respondents reported that their main source of knowledge about nature in the surrounding environment (knowledge of crops and flora and fauna, including birds) was from home, not school. The family home also formed their patterns of behaviour towards the environment. This referred primarily to people raised on farms.

Nevertheless, interviews with agricultural advisers and farmers revealed positive environmental benefits from involvement with agro-environmental commitments. These schemes require actions which improve environmental status such as: compliance with the principles of good agricultural practice and the principle of cross-compliance, proper management of waste water, appropriate management of manure and arrangements for the disposal and sorting of waste.

According to agricultural advisers, visible improvements to the environment are also made by reduced fertilization, introduction of appropriate cover crops, effective rotation systems to maintain permanent pasture and some of the other activities. This confirms hypothesis 4.

From interviews with consultants and experts dealing with agriculture in Local Government, it appears that there is an absence of the concept of lifelong education, including links between schools and adult education.

The full results of the study will be published in a monograph.

Conclusions

Agri-environment schemes contribute to improvement to the environment in rural areas, however, it is an effect induced by the system of additional payments. Financial reward is subject to compliance with specific environmental criteria. These programs only contribute to a small degree to raise farmers' environmental awareness.

The results confirmed that farmers' main motivation for agro-environmental commitments was to obtain higher payments.

The implementation of agri-environment schemes should not only benefit ad hoc environmental improvement, but also shape farmers' attitudes to ensure a stable implementation of environmental objectives in the future.

Educational activities performed by the agricultural advisory system consist mainly of perfecting methods of production and farm organization for better economic results. Shaping pro-environmental awareness and attitudes is of secondary importance.

Authors of the common agricultural policy should realize that pro-environmental attitudes, understood to be a relatively stable behavioural disposition featuring an emotional relationship with the natural environment, cannot be 'bought' but need to be formed in the process of upbringing and education. Additional payment is a form of compensation for a reduction in profits from agricultural production.

High activity of agricultural advisory centres in the organization of training activities for the protection of agricultural ecosystems in combination with a constant low state of environmental awareness, necessitates changes in the preparation and training of agricultural advisers, change to the objectives of seminars and training and the development of better adult teaching (to reach the adult consciousness).

It is necessary to develop a model for life-long learning, including formal education and adult education for the rural population to shape enduring pro-environmental attitudes.

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Stem cells lesson

Classroom learning scenario

Ilona Żeber-Dzikowska, Aleksandra Szydłowska

Subject: The Accused – stem cells

Audience: high school or technical college students, pursuing an extended biology programme

Duration of course: 2 x 45 mins

Reference to the core curriculum:

Learning outcomes/aims:

II. Developing knowledge in the area of the construction and functioning of human's body. Student explains the functioning of the human body at different levels of complexity (...).

IV. Searching for, using and creating information. Student reads, sorts, compares and processes information from variety of sources, including ICT.

V. Reasoning and arguing. Student explains and comments on the information, critically evaluates presented information, distinguishes facts from opinions, provides opinions related to discussed topics, chooses reasonable arguments (...) Understands the importance of modern biology in human life.

VI. The attitudes towards nature and the environment. Student (...) presents an attitude of respect towards each other and all living things (...)

Learning content:

VI. Genetics and Biotechnology. 8. Molecular Biotechnology, genetic engineering and molecular medicine. Student:

6) presents methods and purpose of obtaining stem cells

8) discusses the ethical problems associated with the development of genetic engineering and biotechnology, including the present controversy related to research on human therapeutic cloning; formulates his/her own opinion on the subject.

Type of activity: Introduction of new material

Form of teaching: learning activities in the classroom.

Classroom organization: individual work, group work

Strategies: operational, emotional.

Teaching methods:

- observational: observation of surrogate measure – movie
- verbal: discussion, staging of the courtroom

Teaching resources: learning handouts, movie

Reference:

- The article: Archacka K (2013). Stem Cells. Part 1 – Introduction. *Biological and Environmental Education*, 1(45):3-7. Available at: http://ebis.ibe.edu.pl/index.php?l=english&d=numery&rok=2013&nr=1
- The article: Bauer D, Neska J, Archacka K (2013). Stem Cells. Part III – adult stem cells of organisms. *Biological and Environmental Education*, 4(48): 3-10; Available at: http://ebis.ibe.edu.pl/index.php?l=english&d=numery&rok=2013&nr=4
- The movie, a piece of news program "Facts". Avaalable at: http://www.youtube.com/watch?v=g5j--eBzQpns [Date accessed: 11.01.14]

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Translation into English: **Maria Nowacka**

I. The preparatory stage

The teacher asks the students what they think are the stem cells. Together, using the brainstorming method, they produce the definition. It is written down on the board. At the end of the course, students will evaluate its accuracy.

II. The realization stage

Presentation of the piece of information service 'The Facts' (Fakty) – the video report on stem cells. Students work independently on handouts, given by the teacher, using source texts no 1 and 2 – the articles *Stem Cells, Part 1 – Introduction* and *Stem Cells. Part III – stem cells of adult organisms*.

Checking together the answers given in handouts, discussion of any unclear or questionable issues.

Presentation by the teacher regarding recent discoveries in the field of genetic engineering:

- 2005 – Nobel Prize for Martin Evans in Physiology or Medicine for obtaining embryonic stem cells.
- 2007 – obtaining for the first time human stem cell lines from unfertilized oocytes, These lines were later transferred into liver cells.
- 2010 – formation of working neurons from mouse fibroblasts by the introduction of three genes. In August 2011 it was also conducted a similar procedure to human cells. At later stages mouse fibroblasts were transformed into liver cells and heart muscles, while human fibroblasts into hematopoietic cells..
- July 2011 – the magazine 'Science' announced that there were identified markers helping to find blood stem cells.
- October 2011 – obtained the first human stem cells from a cloned human embryo. The same month the Court of Justice of the European Union banned using the methods of obtaining the ESC, if it leads to death of the embryo.
- January 2012 – South Korean Medicines Agency was the first in the world committed to the sale of the drug with human stem cells. In February 2012 it was found that breast cancer cells after exposure to radiation transform into cancer stem cells which are much more resistant and malignant.

Source: http://pl.wikipedia.org/wiki/Kom% C3% B3rki_macierzyste

Divide/split the class into two groups according to their opinion on stem cells. Before splitting into groups teacher chooses (or students apply for the position of) the judge. The judge must remain neutral and therefore does not participate in the group work. He/she can prepare for the role by reading additional literature on stem cells (for example, Part II of the series in 'Biological and Environmental Education').

Note. If it turns out that the entire class is for or against the acquisition and application of stem cells in medicine, the actual class division becomes invalid. (You can not put students in a situation where they will perform against their beliefs.) In such situation possible solution is that the teacher will play the role of an opponent.

- Group I – Proponents; out of this group will be chosen a lawyer, defending stem cells.
- Group II – Opponents; out of this group will be elected a prosecutor, accusing stem cells.

Groups prepare arguments to support their positions and present them to the whole class in the form of a final speech delivered by previously selected prosecutor and lawyer. After the presentation of all the 'For' and 'Against' the court announces verdict.

Example of the course

The prosecutor's submissions: Stem cells offer great opportunities for the treatment of various diseases – it was cited in many research studies and articles. This was confirmed by tests carried out not only on animals, but also on humans, what we absolutely do not support. In most cases the tests are carried out on fetuses, which is another source of moral disputes. We also read that some of the stem cells are totipotent, which means that they are able to convert into all types of tissues and organs. This raises the question whether it is the first step to human cloning? Knowledge of the subject located in the wrong hands may lead to serious consequences.

Huge interest is placed on stem cells taken from umbilical cord blood. They have a greater capacity to divide themselves and are more easily transformed into specialized cells. So they can be collected at birth and use in situations where the child will need medical intervention. However, it is unethical to conceive the child for the purpose of obtaining stem cells for the treatment of older siblings. Can one human being be treated at the cost of another?

Additionally, cord blood can be stored in a special bank, in case of future illness or accident. However, it is very expensive, so only the wealthiest people will have opportunity to use this service. Usually, couples who are expecting a child, are informed about possibility to store the cord blood, because their effort to secure the future of the child is paramount. However, it is unethical to talk to the parents about future illness of their unborn/newborn child in such joyous time of their lives.

There are limits to the interference of science in nature. To us, this boundary is to culture in vitro human body parts. After analyzing the evidence presented, I put a plea to stem cells. The use of stem cells is associated largely with ethical issues and it is not always effective in treatment. I suggest that culturing and medical

use of stem cells should be kept to a minimum, without showing any objections of a moral nature.

The lawyer's submissions: We learned that stem cells have unique properties compared to other cells in the body. They are able to both self-renew their own population and to differentiate into specialized cells. Because of these properties stem cells play a key role in embryonic processes, fetal development, growth of the organisms and are responsible for the regeneration of tissue in mature specimens. During the development of the organism the gradual specialization of cells takes place, that is why they can play certain functions within the body, eg neurons are responsible for transmitting nerve impulses, and the red blood cells transport the oxygen. The gradual specialization of cells is often accompanied by reduction or loss of ability to cell division, commonly known as the ability to proliferate. Stem cells, even those present in the adult organisms maintain undifferentiated nature and self-renewal ability. It means that as a result of stem cells division, the same undifferentiated cells can be developed. Confirmation of this fact is the evidence prepared by Dr. Karolina Archacka – diagram showing the properties of stem cells in the source: *Stem Cells, Part 1 – Introduction*.

The next argument given by lawyer is to draw attention to another property of stem cells – their ability to transform into specialized cells, known as differentiation potential of stem cells. Please see fig. 1 in the source text, which relates to the discussed issues. After getting familiar with the diagram, it can be concluded that the ability of stem cells to self-renew is essential to keep their amount in the body at the appropriate level. In the picture A there are visible colonies of embryonic stem cells emerged as a result of their rapid division. Due to the ability of stem cells to differentiate, different types of specialized cells are formed. Those specialized cells build tissues and organs of the body, such as heart (picture B) and spleen (picture C).

The question to be asked: What is the role of stem cells in adult organisms?

The answer can be found in the source material mentioned earlier: *Stem Cells, Part 1 – Introduction*.

We read the following:

> Stem cells present in adult organisms are usually in the state called 'sleeping state', which means they do not divide and are metabolically inactive. However, a tissue or an organ becomes damaged, stem cells become activated. Tissue or organ damage can be caused by mechanical, thermal, chemical factors, as well as the development of the disease. In this case, the stem cells begin cell division, creating new stem cells or transforming into specialized cells responsible for rebuilding damaged tissue or organ. As a result, damaged tissue or organ may be progressively reconstructed and recovered, at least some of their properties. The renewal of stem cell located in a given tissue or organ enables the occurrence of the next round of regeneration, in the situation of another damage or disease progress.

Stem cells are present in many tissues and organs of adult organisms. In humans, the presence of stem cells are found, between many, in: brain, cornea, bone marrow, skeletal muscle, intestine, liver, adipose tissue, and epidermis. One of the proposed methods for the treatment of degenerative disease is transplantation of stem cells derived from tissues and organs of adult organisms. Transplantation of stem cells has already been successfully used to treat for example hematological diseases such as leukemia or aplastic anemia, which can be cured by performing the procedure commonly known as a bone marrow transplant. It is worth to remember that the bone marrow was the first-known source of stem cells. Muscular dystrophies, like many other degenerative diseases remain incurable. Stem cell technology gives hope of effective treatment for a variety of diseases.

It is worth to ask the question: What is the use of adult organism's stem cells in medicine?

The disease that remain incurable, between many, include: Parkinson's disease, diabetes, and muscular dystrophy already mentioned above. One of the proposed methods for the treatment of degenerative disease is transplantation of stem cells derived from adult organism's tissues and organs.

Can we imagine a world without cancer, neurological diseases or people in wheelchairs? I realize that in the present state of medical knowledge it is still difficult, but not impossible. Science is moving forward and due to its recent development humans have even survived the attack of still mutating flu virus. Properties of antibiotics would not be able to be studied without testing them on animals and men. Without appropriate antibiotic treatment of most contagious disease would not be possible. Nowadays stem cells are an opportunity to deal with the majority of diseases which cause most deaths In population. We believe that an embryo becomes a human being at the moment of formation of the nervous system and the ability to feel. Also collecting stem cells in the early embryonic stage, it is not killing a man in favor of another, because simply a cluster of stem cells is not a human being. Human cloning is still a far-off possibility because we have not reach this level of knowledge and do not know yet if we ever succeed. If we talk about individual organs, stem cells offer a chance for cure most of the currently incurable diseases. Imagine that in the case of kidney failure, patients would not have to undergo long-term dialysis or wait for transplantation for years. It would be possible to 'produce' the kidney, which would be one hundred percent compatible with the recipient's tissues. The issue of stem cells banks from umbilical cord blood is also open. For now it is an expensive form of storage, but with the increase interest within society, the price will fall. It is possible that one

day the collection and storage of stem cells will be as natural as testing newborns after birth. We wish that to you and all the people in the near future.

The Judgde's submissions: He/she makes independent decision on ex vivo culturing and use in medicine stem cells on the basis of the arguments presented by the prosecutor and lawyer. He/she justifies his/her position and shows a possible way of appeal from the order / judgment.

III. The summary stage

The teacher summarizes the activities and returns to the definition of stem cells formulated together with students at the beginning of the class.

After gaining new knowledge, students modify the definition or leave it unchanged if they do not see the need of changing it.

Homework. The task is to find, using any source of reliable information, and describe in a notebook chosen method of isolation and culture of stem cells.

Materials

- Archacka K (2013). Stem Cells. Part 1 – Introduction: http://ebis.ibe.edu.pl/index.php?l=english&d=numery&rok=2013&nr=1
- Bauer D, Neska J, Archacka K (2013). Stem Cells. Part III – adult stem cells of organisms: http://ebis.ibe.edu.pl/index.php?l=english&d=numery&rok=2013&nr=4
- The movie, a piece of news program "Facts": http://www.youtube.com/watch?v=g5j-eBzQpns

Appendix 1. Student worksheet – stem cells

Task 1. How stem cells can be used in medicine?

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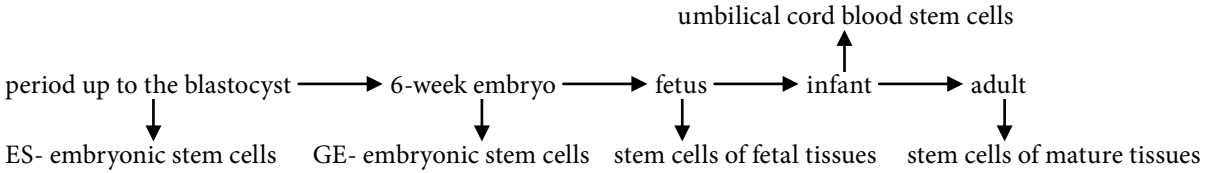
Diagram below shows the division of stem cells due to their origin.



Task 2. Assign definition to the appropriate type of stem cells.

1 – totipotent cells – .....
2 – pluripotent cells – .....
3 – multipotent cells – .....
4 – unipotent cells – .....

a) capable of forming all cell types and tissues of the body-building, however, do not form extra-embryonic structures.
b) they can generate all types of cells and tissues that build the body, as well as extraembryonic structures such as fetal membranes and placenta.
c) they have the most limited potential and can transform in only one type of specialized cells
d) capable of converting into different cell types; have a common origin, which is derived from a germ

Task 3. Explain what is the role of stem cells in adult organisms?

.....

.....

.....

Task 4. Analyzing fig. 3 and fig. 4 of source text 2 indicate the location of the occurrence of cells in adult organisms.

.....

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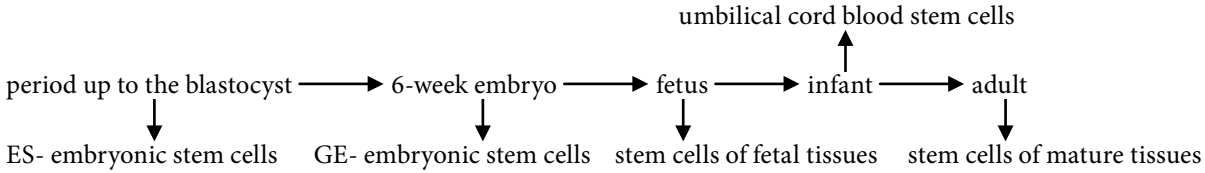
.....

Appendix 2. Examples of answer given in student worksheet

Task 1. How stem cells can be used in medicine?

In my opinion stem cells can be used in a variety of ways in medicine. First of all, they find their use in medicine, due to the ability of converting into various kinds of cells enabling the treatment of many hematologic diseases such as leukemia or aplastic anemia. They can even help in the reconstruction of whole organs, which plays enormous role in transplantation. Their properties are often used in cosmetology. Another example of the successful use of stem cell in medicine is the transplantation of limbal stem cells, which allows the recovery of vision. In addition, mesenchymal stem cells (MSC) are used in orthopedics and surgery.

Diagram below shows the division of stem cells due to their origin.



Task 2. Assign definition to the appropriate type of stem cells.

1 – totipotent cells – *b*
2 – pluripotent cells – *a*
3 – multipotent cells – *d*
4 – unipotent cells – *c*

a) capable of forming all cell types and tissues of the body-building, however, do not form extra-embryonic structures.
b) they can generate all types of cells and tissues that build the body, as well as extraembryonic structures such as fetal membranes and placenta.
c) they have the most limited potential and can transform in only one type of specialized cells
d) capable of converting into different cell types; have a common origin, which is derived from a germ

Task 3. Explain what is the role of stem cells in adult organisms?

Normally dormant stem cells are activated when an organ or tissue will be damaged. Then begin dividing intensive processes, which result in production of cells capable to transform into the tissues or organs, enabling full regeneration.

Task 4. Analyzing fig. 3 and fig. 4 of source text 2 indicate the location of the occurrence of cells in adult organisms.

These cells are found in many tissues and organs of adult organisms.

In humans, stem cells are found in the brain, cornea, bone marrow, skeletal muscle, intestine and liver, epidermis, adipose tissue.

Blooming – May classes

Scenario

Sebastian Pilichowski

Subject: May classes without a guide. Blooming in Zielona Góra Botanical Garden

Target group: students of elementary school and junior high school

Aims: familiarize students with the diversity of plants in regard to the structure of flowers and their pollination strategies

Time: 90–120 minutes

Character: A trip with a teacher

mgr Sebastian Pilichowski: Botanical Garden of the University of Zielona Góra, Faculty of Biological Sciences, University of Zielona Góra Zielona Góra 65-392, Botaniczna 50a street; s.pilichowski@wnb.uz.zgora.pl

Translation into English: **dr. Enzo Arévalo-García**

Reference to the core curriculum:

Learning outcomes/aims:

- Nature. 1st level of education, primary school early school education (I–III):
  Natural education. Education for understanding of and care of animate and inanimate nature.
- Nature. 2nd level of education, primary school (IV–VI):
  I. Rousing interests in world of nature.
  IV. Respect for nature.
  V. Observations, measurements and experiments.
- Biology. 3rd level of education, *gymnasium* (junior high school):
  I. Knowledge of biological diversity and basic biological processes.
  II. Knowledge of methodology of biological research.
  IV. Reasoning and argumentation.

Learning content:

- **Nature.** 1st level of education, primary school education, early school (I–III).
  6. Environmental education. Student finishing class III:
  1) observes and carries out simple experiments, analyzes them and associates cause and effect
  2) describes life in selected ecosystems: in the forest, garden, park, meadow and water reservoirs
- **Nature.** 2nd level of education, primary school (IV–VI):
  1. Me and my surroundings. Student:
  6) names human's senses and explains their roles in experiencing nature, uses safety rules during observation of nature;
  7) provides examples of devices facilitating the observation of nature (magnifying glass, microscope, binoculars), describes their usage, uses them during the observations;
  9) recognizes and names some plants (including pot plants) containing poisonous substances or substances harmful for a human, and provides principles of handling them.
  5. A human and the environment. Student:
  3) proposes activities favourable for the natural environment;
- **Biology.** 3rd level of education, junior high school:
  III. Taxonomy – principles of classification, methods of identification and review of variety of organisms. A student:
  8) observes specimens and compares morphological features of algae and land plants (mosses, lycopodiophyta, equisetopsida, ferns, magnoliophyta), lists features enabling to classify organisms to groups listed above and identifies an unknown organism as a representative of one of them on the basis of presence of these features;
  11) presents the importance of known fungi, plants and animals for the environment and for humans.
  IV. Ecology. Student:
  7) on a selected example, indicates that symbiosis (mutualism) is mutually beneficial for both partners;
  V. Construction and operation of the plant organism for example plant angiosperms. Student:
  2) identifies (e.g. in a diagram or drawing, or on a photo, on the basis of a description) and describes organs of magnoliophyta plant (root, sprout, stalk, leaf, flower, fruit) and presents their functions;
  4) distinguishes structural elements of a flower (perianth: sepals and corolla petals and gynoecium, androecium) and defines their role in sexual reproduction.

Description: The classes consist of visits to the Botanical Garden along the designed route. The teacher making use of this material highlights the differences in the structure of flowers and encourages students to express the impressions they collect, regarding flowers, using the sense of smell. It is recommended that students use a magnifying glass to observe the flowers. Students under teacher's instruction record the names of the plants. While testing the fragrances, students should record the plants that made an impression on them- positive (eg, the symbol +) and negative eg symbol -). At the end the teacher has a brief conversation with the students in order to find convergences and differences of opinion with regard to odors. Then the teacher explains the need to preserve the biodiversity of pollinators and plants for further mutual existence, thus, differences in the reception of fragrances by the students reflect, in some degree, differences among pollinators. Some plants emit, during flowering, an attractive odor for pollinators, such as flies that is, similar to the smell of decaying meat. Other pollinators are attracted to the sweet fragrance volatile substances. Because of the uneven flowering time, there is no chance to observe (during this trip) all the flowering plants at the same time. However, the main points of the trip are arranged sequentially, so the teacher will quickly learn which ones are currently blooming. Besides, he/she may personally choose which of the plants wants to show to the students first. To the instructions are also attached optional plants' info, worth watching, that may bloom at the time of the trip. The teacher should gather at the end of the course notes from the students and rate them. This guide focuses on the phenomenon of flowering, thus descriptions are usually limited to the characteristics of flowers, this in order to allow students to use their senses to perceive the distinctiveness of the plants and flowers. In the case of the selected plants, interesting facts worth telling are also included. In the case of older students, they can perform a so-called trip task, ie to equip small teams (~ 4 persons) with maps and have them ,separately, workaround the Garden. This option would evaluate student's orientation on the ground, while using a map.

Teacher's materials: The proposed scenario uses the resources of the Botanical Garden of the University of Zielona Góra. Please note that despite the small size and the short period since being established, it is a potential place to give interesting lessons based on: selected taxa (species and varieties), one period of flowering and happening only during one month (May). A similar scheme of classes, their presentation in written form, as well as the organization can be adapted to similar entities in the country and beyond.

I. The Garden – a short description

- Address: Botanical Garden of the University of Zielona Góra, 65-392 Zielona Gora, Botanical 50a
- Website: http://ogrod.uz.zgora.pl/pl
- Phone: 601 902 283
- E-mail: ogrodbotaniczny@wnb.uz.zgora.pl
- Buses to the Garden: Bus stop "Technikum Budowlane (214)", lines: 0, 27, 44, 80
- Bus fare: single ticket purchased at the vending machine on the bus or at selected stops, available also with the E-Card, issued at the Customer Service Center or Customer Service Points. Municipal Department of Communications in Zielona Gora: http://www.mzk.zgora.pl/AutoInternet/nowy_rj5/
- Opening hours: at the moment the Botanical garden is open IV–V and IX–X from 10 to 18 hours, while VI–VIII from 10 to 20 hours.

The Modern Botanical Garden of the University of Zielona Góra (UZ) was established in 2007. It is worth emphasizing, however, that it is a garden in some degree of restoration; built on the site of a previous garden of the last century. Unfortunately, only a small part of the former collection is part of the present one. UZ Botanical Garden occupies a small area (approximately 6 acres) and is divided into five sections:

1. Geographic Section (with a further breakdown on plants from Europe, Asia and North America as well as domestic plants),
2. Systematic Section,
3. Plant Mountain Section,
4. Water loving Plants Section,
5. Is also planned a Section of Useful Plants.

Due to the fact that this garden is a newly established institution, shrubs and trees are not fully develop yet, however they fulfill their educational and didactic role, as intended, for the Department of Biological Sciences UZ. Moreover the Garden is a haven of peace, lying in close proximity to the Park Piastowski and the Lasek Piastowski which have a positive effect on the biodiversity of the Garden's fauna. A more detailed history of the Botanical Garden UZ can be learned from free leaflets handed out at the entrance to the Garden, as well as on the website of the Botanical Garden UZ.

II. A tour (points marked on the attached map)

Classes at the Garden can be carried in two ways, based on the below scenario/script.

1) Teachers making use of the scenario as a guide. All of the important points are on the map attached to the scenario/script
2) The teacher forms groups of students (e.g., 4 persons), and supplies them with:
   a) Printed maps attached to the scenario/script
   b) Worksheets that at the same time present a chronological guide for important points in the Garden.
   c) Photographs of plants' flowers to be studied.

III. End of the tour

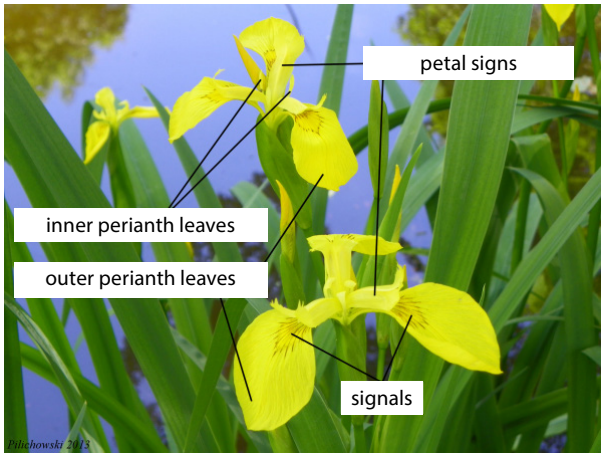
A wigwam, (wickiup or wetu) and lawn. Wigwam-shaped design allows to protect from the sun; it is also fitted with a place to sit. Students can also sit or lay down in the lawn. The teacher then talks with students who share their impressions, mostly regarding perception of scents. This leads to similarities and differences in the view of students, and further discussion on the role of different pollinators and pollination strategies in plants. The goal is to draw attention to the need to protect the biodiversity of plants and animals, as well as other organisms.

Reference Material: Detailed description of plants discussed during the tour.

Appendix nr 1. Description of plants encountered in the garden and the trip map

1. Yellow Iris (*Iris pseudacorus*)

Section: Moisture loving Plants

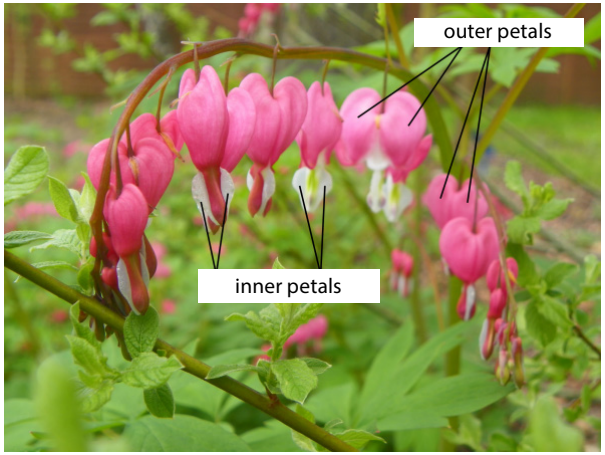


Iridaceae often known under the name of "iris". Iris yellow is a common species in Europe, including Poland. It is found on the banks of many ponds and lakes. It creates very dense and expanding bushes that in some parts of the world are considered an invasive species and fought extensively. Due to its high resistance to contamination, is sometimes used for purification, of heavy metal-containing water. Iris' underground parts are called rhizomes, They are altered stems that during growth increase the range of the plant. This is the second process, in addition to the transport of seeds with water, for dissemination of these plants. The rhizomes of this perennial hibernate, while the aerial parts (the parts above ground) fade in winter. Yellow Iris belongs to the varieties where their rhizomatous irises does not have the characteristic "beard" (a tuft of short upright extensions growing in its midline) present in many other varieties. Irises' flowers are composed of three outer leaves (three sepals, which are spreading or droop downwards), three internal (the three, sometimes reduced, petals stand upright, partly behind the sepal bases), under which there are stamens, stigma, and three chambered ovary. In addition, the outer sepals and leaves, are signaling spots used for attracting pollinators (mainly bees).

Student task: draw a flower, look at the flowers, sniff them (only when the irises are blooming at the edge of the pond!).

2. Bleeding heart (*Lamprocapnos spectabilis*) (until recently, *Dicentra spectabilis*)

Section: Moisture loving Plants



A wonderful perennial flowering, native to the Far East. From the main axis several flowers can develop. Their shape resembles a heart, this is due to the crown's two outer petals, usually of pink color. Two more petals – internal ones – are white. The plant is slightly poisonous, so it's not suitable for consumption. It easily hibernates in the soil in Poland. There is also a legend from Japan which tells a story of how the bleeding heart flower came to be, this legend claims that the individual parts of the flower are the gifts that a infatuated man wanted to give to a rich and beautiful lady. Every time She accepted his gifts, however, never accepted his love. Finally, heart-broken, the man perforated, with a knife/sword, his heart and at the spot where this happened, the first plant grown. The Pollinated (by insects) plant produces fruits with black seeds, fitted with elaiosomes. Elaiosome is a structure rich in fats and proteins. Its function is to lure ants that interested in collect seeds contribute to their dissemination.

Student task: draw inflorescence, sniff flowers.

4. Syringa vulgaris (*Syringa vulgaris*)

Section: Plants of Europe

A common shrub planted in gardens. Although it is commonly called elder or elderberry it is does not belong to that genus (Sambucus) It comes from the Balkans. In present times, the main varieties are of tubular flowers in different colors, sizes, and sometimes structure. It is an entomophilous species; it lures insects by the use of color, odor and nectar.

Student task: sniff different varieties of Syringa (Do they smell similar?), draw flowers.

3. Lily of the valley (*Convallaria maialis*)

Section: Mountain Plants

In our country it is found primarily in the lowlands, however this range also includes lower altitude mountain regions. Lily of the valley is a perennial that hibernates in the ground. It blooms from May to June, and her red spherical fruits are poisonous (as well as the whole plant). The plant has white, bell-shaped flowers, hanging together on the main axis. Flowers, pollinated largely by bees, are associated with chastity, hence it is used symbolically for example, during Holy Communion in the Roman Catholic Church.

Student task: draw and sniff flowers.

5.1. Spiraea (*Spiraea x vanhouttei*)

Section: Plants of Europe

A common shrub found in urban green areas. It produces numerous small, white flowers, gathered in inflorescences. The stamens are shorter than the petals. Spiraea of van Houtte is a crossbreed between *Spiraea cantoniensis* and *Spiraea trilobata*.

Student task: sniff flowers, identify stamens and compare the length of the petals, draw flowers.

5.2. Spiraea Norwegian (gray) (*Spiraea x cinerea* 'Grefsheim').

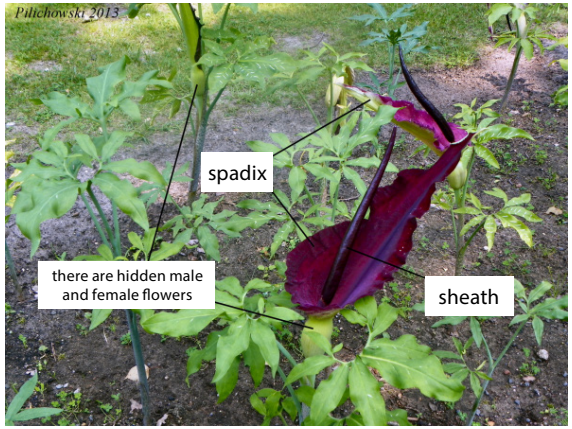
Section: Plants of Europe

A common shrub found in urban green areas. It produces numerous small, white flowers, gathered in inflorescences. The stamens are shorter than the petals. It's a hybrid bred in Norway in the nineteenth century.

Student task: sniff flowers, recognize stamens and compare the length of the petals, draw flowers.

6. *Dracunculus vulgaris* called: dragon tongue

Section: Plants of Europe



Perennial hibernating in the ground. It comes from the Balkans and Turkey. One of the two species found in Europe of Dracunculus. The second (*Dracunculus canariensis*) can be found in the Canary Islands. Dracunculus looks great during flowering as from inside the purple sheath it reveals an even more intense spadix. In the lower section there are male and female flowers (female above). Pollinators are primarily beetles and flies attracted by the smell of rotting meat, particularly intense in warm weather. Dragon tongues were once regarded as a magical plant capable of protection against poisonous snakes; It is however, itself, a poisonous plant.

Student task: draw a spadix and leaf sheath, indicate where the male and female flowers are located, smell their characteristic aroma.

7. Purple magnolia (*Magnolia liliiflora*)

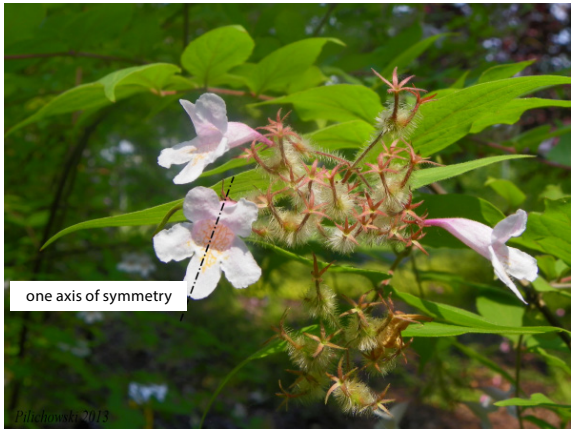
Systematic Section

It is believed that flowering of magnolias happens in early spring, before the leaves appear. Magnolia purple contrary to that belief, blooms during the development of leaves, i.e. the flowers appear on the leafy shoots. Fantastic bush with purple flowers. the perianth parts are undifferentiated and called tepals rather than distinct sepals and petals. Originally from eastern and central China. Due to the later flowering than other common species, It may freeze, effectively avoids the low temperatures that can cause wilting flowers. An entomophilous species.

Student task: sniff and draw flowers.

8. Kolkwitzia chinese (*Kolkwitzia amabilis*)

Section: Plants from Asia



Shrub naturally occurring in China, associated with mountain environment. It blooms in May producing pink tubular-shape flowers with yellow color in the calyx. Flowers are dorsiventral, with few stamens, gathered in bunches, in which flowers are grown together in pairs. An entomophilous species.

Student task: sniff the flowers, draw them from the side and front, then select the axis of symmetry.

9. *Abelia mosanensi*

Section: Plants from Asia

It comes from the Korean peninsula. It starts flowering at the end of May. The plant is then decorated with white flowers, gathered in inflorescences (up to a dozen pieces). A single flower has a five petals crown and pink colored sepals, often remain in the plant some time after the petals fall. This shrub looks nice even before flowering, due to its undeveloped pink buds. An entomophilous species; it is, pollinated, among others, by Sphingidae (group of butterflies).

Student task: sniff and draw flowers.

10. *Pyrus salicifolia*

Section: Plants from Asia

A non-confident observer can be confused by overhanging branches and long, lanceolate leaves-to the extent than may believe it is a willow more than a pear tree. However, May is the best time to overcome this illusion. Indeed, the whole tree becomes covered with white flowers, resembling those in other pear trees, as well as apple, cherry, cherry and plum, trees also blossoming in spring. From its pollinated flowers only small pears are produced, unfortunately they have no economic or food significance .

Student task: sniff flowers, identify stamens and stigma, draw.

11. Star Magnolia (*Magnolia stellata*)

Section: Plants from North America

This magnolia originated in Japan, it was introduced in North America, where it firmly established. It starts flowering in March or April until may. A thick, profusely blooming white bush; In this flower, the so-called petals (found in the corolla), are called tepals. This magnolia can have up to 30 in one flower. An entomophilous species.

Student task: sniff and draw flowers.

12. Canadian dogwood (*Cornus canadensis*)

Section: Plants of North America

This is a very interesting species of dogwood because it is one of the few non-shrub dogwoods. It structure is trailing-like (having a long stem which spreads over the ground or hangs loosely) due to that, during flowering many passersby call it wild strawberry. Dogwood Canadian, outside Canada, occurs also in Alaska and Greenland, where it forms a cross-breed with Swedish dogwood (Cornus suecica). Canadian dogwood blooms in a hardly noticeable way, its small flowers fuse together and visible four white "like-petals" are actually an overgrown bud. They are called bracts. Looking from some distance you may say that the dogwoods are "impostors" luring pollinators to large "flowers with large petals". This dogwood posses an interesting mechanism for the ejection of pollen. When a single flower opens, the rods straight up while the anthers twist; this takes place in less than one millisecond. Then the ejected pollen can hit the stigmas, carried by the wind or insects. In relation to pollinators is critical that the Canadian dogwood pollen is not sticky like in most entomophilous species. Thus, as a result of ejection forces it hooks into insect hairs leaving the pollen on the next flowers. An entomophilous species.

Student task: draw inflorescence and bract, sniff flowers.

13. Rhododendrons (*Rhododendron spp.*)

Systematic Section

Rhododendrons and azaleas-plants are commonly grown in many varieties, they usually blossom in May. Then they bloom profusely, in different colors and shapes, as a wonderful accent for gardens. The genus Rhododendron is associated with lasting of foliage. While some of them discard them in the winter, some others at low-temperatures carry water away from the leaves and as a result, they twist into rolls. This protects the leaf against freezing of cellular water. It is worth to properly fertilize Rhododendrons two times a year during early spring and summer, when the plants tie up their flower buds for next year. These flowers are pollinated by insects such as, among others, bumblebees.

Student task: Walk single file between the plants. See and sniff the flowers of different varieties and species. Draw the selected flower.

For larger groups organize the walk in the following way: one teacher is among the rhododendrons, students in groups of 5-10 people come down the path deeper into the collection to the teacher and turning, walking in subsequent specimens. The teacher then sends another group.

14. Hawthorn (*Crataegus monogyna*)

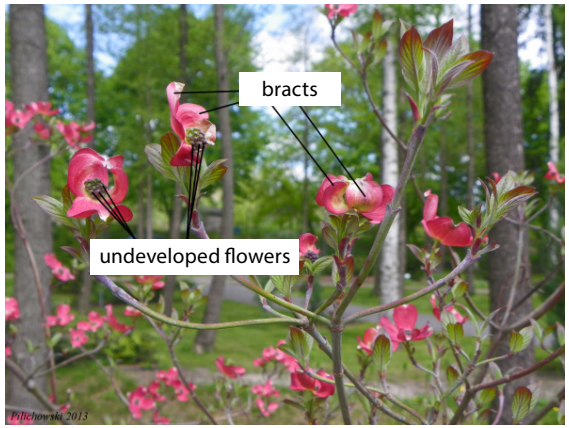
Section: Plants of Poland

Native polish species, may produce offsprings along with two other native species, such as *C. laevigata* and *C. rhipodophylla*. The resulting hybrids are, respectively, *C. x media* and *C. x subsphaericea*. Hawthorn blooms profusely in May, the flowers have white petals, numerous stamens and pistil with a neck. Just like *C. laevigata*, its leaves, flowers and fruits are used in the treatment of cardiac disorders (improve blood flow, stimulate heart muscle). An entomophilous species.

Student task: name the individual elements of a flower, sniff and draw flowers.

15. Florida dogwood (*Cornus florida*)

Section: Plants of North America



Small shrub/tree originating in central and eastern North America. It tends to frost, however, if protected (for the winter), they bloom richly. Like the Canadian dogwood, the Florida dogwood behaves like an "impostor plant"; its attractive "petals" are buds that grow around small and inconspicuous flowers. These buds are of red and white color and are called bracts. These bracts as well as some fragrances present in this tree, lure insects needed for pollination.

Student task: Draw and sniff inflorescence.

16. Crataegus – 'Paul's Scarlet' commonly called hawthorn, thornapple, whitehorn, or hawberry (*Crataegus x media*)

Section: Plants of Europe

Crossbreed between *C. Monogyna* and *C. laevigata*. Displays intermediate characteristics; also is characterized by a full, intense red flowers, with bicolor petals (white/pink and red) with a predominance of red. An entomophilous species. However its dense flowers can hinder the penetration of insects to flowers.

Student task: name the individual elements of a flower, sniff and draw flowers.

17. *Vinca minor* (common names lesser periwinkle or dwarf periwinkle)

Section: Plants of Europe

An entomophilous species; It blooms from April to May. Flowers of five blue or violet petals, five stamens and one pistil are used in medicine (including leaves), among other things, to lower blood pressure. Unfortunately it is also a poisonous plant. Naturally occurring in Poland; it is a partially protected species.

Student task: draw and sniff the flowers.

18. Oriental poppy (*Papaver orientale*)

Section: Plants of Asia

Asiatic species of poppy. It's found mainly in gardens as an ornamental plant. Oriental poppy 'Brilliant' is completely resistant to frost in Poland. Prized perennial, quite high (about 90 cm in height), with large flowers, which as a result of pollination produces (characteristic for poppies) a seed capsule. This, after ripening cracks up and spills the seeds capable of germination. Oriental poppy is characterized by intensively red flowers.

Student task: draw and sniff flowers.

Optional points of the trip

A. European or common Beech (*Fagus sylvatica*), different varieties

Section: Plants of Europe and Poland

European Beech is a native species of Europe, its north-eastern limit of occurrence is in Poland. It is worth to travel across the country to visit the Pomeranian beech-wood found in Wolin National Park or Carpathian beech forest in the south. In the Lubusz Voivodeship is recommended to visit, among others, Łagowski Nature Park and Beech Mountain reserve. Mature beech trees have smooth, gray-silver bark and sometimes rugged trunk. The leaves are characterized by a certain irregularity, reflecting the many varieties of beech. Some researchers distinguish in Europe two subspecies: *Fagus sylvatica* and Fagus sylvatica orientalis, and some others distinguish separately beech and Eastern beech (*Fagus orientalis*). Beeches are monoecious, i.e., single individuals produce both reproductive organs female and male. In the case of beech flowers, they are separately fitted with stamens (male- found long and hanging axis) and pistil (female-found in short and rigid axis). These pairs are fitted in addition with a perianth that over time lignifies, closing two developing seeds. When they mature, the cover opens and releases the seeds. Beeches are anemophilous. Additional info: Along the common beech, grow in the garden as well as eleven individuals from ten other varieties, besides that, one individual from the Eastern beech 'Iskander'. Among these, some have flourished and seemed fruit. These beeches are marked on the map with the letter "A".

Student task: look at the flowers, distinguish male from female flowers, draw and sniff the flowers.

B. *Fothergilla major*

Section: Plants of North America

A shrub with flowers without petals and gathered in large numbers in the inflorescences. The flowers are bi-sexual with a decorative stamens with thick, white filaments, pistils fused with the bottom of the flower.

Student task: take a look at stamens, draw and sniff the flowers.

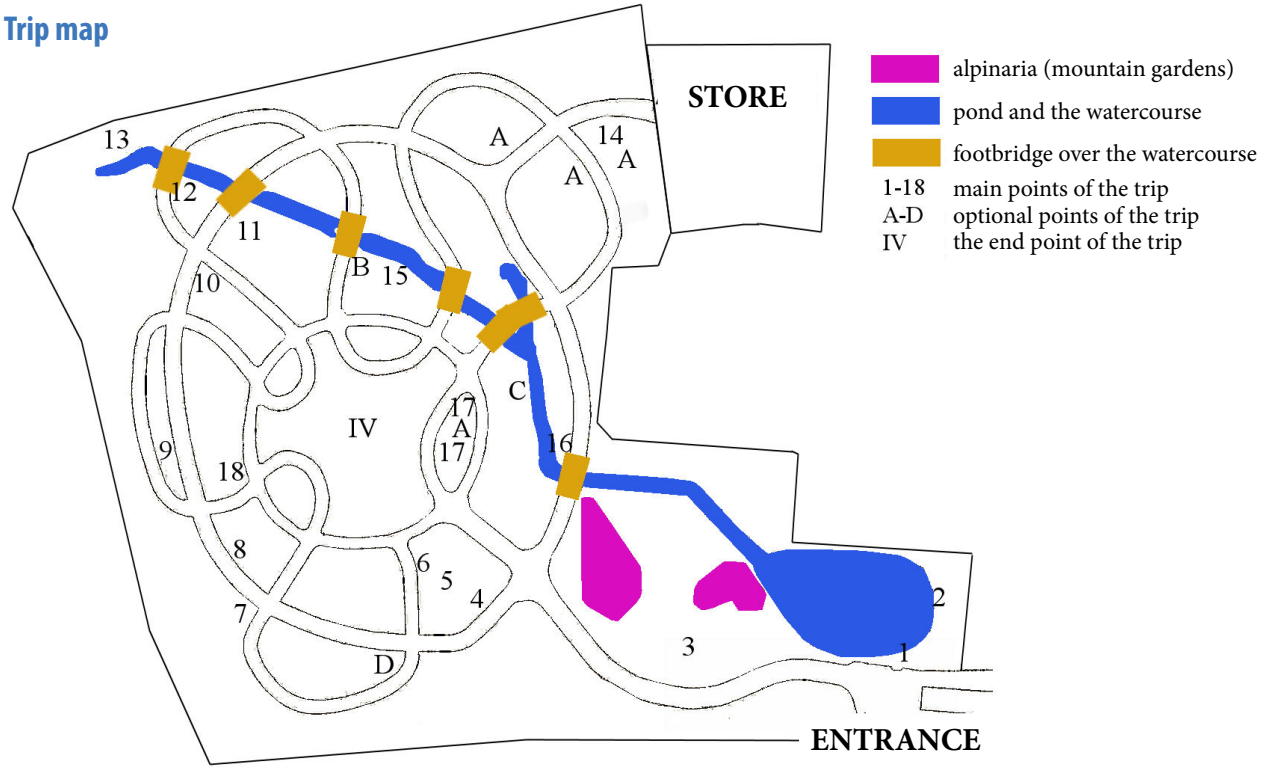
C. Manna Ash (*Fraxinus ornus*)

Section: Plants of Europe

South European species of ash, flowers are bisexual, white, fragrant and pollinated by insects. Flowers have four (rarely 2) petals, two stamens and one pistil. Studies have shown this ash contains numerous compounds with a very wide range of applications, which confirms the use of the bark in folk medicine. Ash is used as: anti-inflammatory, antibacterial, antiviral as well as contributes to wound healing.

Student task: if possible, take a look at the flowers.

Trip map



D. *Syringa reflexa*

Section: Plants of Asia

Shrub from China. For some distinguished as a separate species, for others as a subspecies of *Syringa komarowii*. It blooms a little later than the common Syringa and much more rarely cultivated. Its name comes from the overhanging pink-purple inflorescences. Similar to *S. vulgaris*, it is an entomophilous species; it lures insects by the use of color, odor and nectar.

Student task: sniff and draw flowers, then compare their impressions of the scents of common Syringa.

Appendix nr 2. Source text to summarize activities in the garden

Among the many strategies used by the plants to lure pollinators we may mention: aroma, color and shape of flowers or inflorescences. Keep in mind the fact that pollinators are bound to specific plants by co-evolution, i.e. common evolution. Sometimes we meet very drastic examples of interdependence, where one particular species of plant is pollinated by a particular species of pollinator. It is then very easy to imagine the consequences of the extinction such animal. However, for the above relationship to exist, insects visiting the flowers have to get some benefit from this. In fact it happens, because the plant produces an amount of pollen (or nectar), that besides reproductive functions is very nourishing. This one, in fact, does not have any other function than luring. Hence different plant species have either nutritious pollen or nectar, as having both would be extremely costly. An after effect of these strategies can be seen perfectly in insects, including highly evolved butterflies exhibiting sucking mouthparts, designed, among other, to drink nectar, as well as in the case of long beaks and tongues of hummingbirds. Regardless of the attractant factor, when animals visit bisexual or male flowers, they cover their bodies with pollen or in any other way transfer the pollen, which in the case of visits flowers with pistils it sticks to their stigma. We call this process; pollination. Then, if nothing stands in the way, fertilization happens and seeds are produced, while those in angiosperms develop in fruits. An older method of pollination is, Anemophily or wind pollination, it is a typical method for gymnosperms and angiosperms. Subtle flowers from gymnosperms plants have a simple structure, they are often decorated with long stamens that produce a lot of pollen. Additionally at certain parts of these plants they are structures that facilitate pollen flight – they are called air chambers. For many plants, it is important flowering, even before leaves appear, which can help keep pollen on their surface. Due to the fact that gymnosperm do not have their pollinators, flowers are odorless. Let's keep in mind, however, that a person does not have a sensitive sense of smell, and even if it cannot smell a flower fragrance, it can emit a scented attractant-stimuli for selected insects. Finally, not only insects are known pollinators also birds and mammals. The above associations between pollinators and plants are examples of symbiosis. Symbiosis, in its broad sense, is considered for selected systems both antagonistic (where at least one of the elements harm the others, benefiting from that) and non-antagonistic (the elements remain neutral towards each other, or at least one of them receives certain benefits, but not at the expense of the other). Symbiotic associations include, protocooperation, (i.e. commensalism), and parasitism. In a very simplified definition, symbiosis means mutualism. Mutualism is a symbiosis, where the partners derive mutual benefit from coexistence, which is necessary for their existence. Protocooperation reminds mutualism, however this correlation is not a strict one, i.e. the organisms contained in this system are free to live without each other. In turn, parasitism is an interaction antagonistic, wherein one organism benefits at the expense of the other. An example of mutualism is the extremely close link between entomophilous species and their pollinators. Due to pollution and destructive human activity, these associations are weakening. This happens because in selected areas some plant species may disappear, whose pollen or nectar are food sources for their pollinators. On the other hand, the uncontrolled use of products for plant protection affects the Apidae family, insects that play a key role le in the pollination of numerous plant species. Sometimes, the pollinators are not able to keep up with changes in the composition of plants, thus, the efficiency of pollination drops (i.e. due to livestock overgrazing, drying, burning or mowing of wet meadows, this specially during the flowering of nectariferous plants), and since this happens, it leads to less seed formation. Then less seeds will be sown and fewer progeny plants will grow. In extreme cases, this leads to far-reaching changes in the ecosystem.

Hence it is very important to be aware of nature, wildlife and actions leading to their conservation. It should be remembered that garbage, especially batteries, chemical containers, and many others, are harmful elements in the biological and aesthetically sense, (does it look attractive a wild garbage dump in the woods?). It is not worth cutting/plucking flowering plants, especially if we do not know whether we pick plants protected or rare and significant ones for the place in which they grow. As Ewa Mochtak wrote: "You cannot mindlessly destroy plants, especially for ephemerous bouquets thrown away right before returning home". Similarly, insect collecting should proceed not only in accordance with the law, but also with common sense. Predatory practices also have a negative impact on the above associations.

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1. Yellow Iris (*Iris pseudacorus*) **Student task:** draw a flower, look at the flowers, sniff them (only when the irises are blooming at the edge of the pond!).	2. Bleeding heart (*Lamprocapnos spectabilis*) (until recently, *Dicentra spectabilis*) **Student task:** draw inflorescence, sniff flowers.
3. Lily of the valley (*Convallaria maialis*) **Student task:** draw and sniff flowers.	4. Syringa vulgaris (*Syringa vulgaris*) **Student task:** sniff different varieties of Syringa (Do they smell similar?), draw flowers.

5.1. Spiraea (*Spiraea x vanhouttei*) **Student task:** sniff flowers, identify stamens and compare the length of the petals, draw flowers.	5.2. Spiraea Norwegian (gray) (*Spiraea x cinerea* 'Grefsheim') **Student task:** sniff flowers, recognize stamens and compare the length of the petals, draw flowers.
6. *Dracunculus vulgaris*. called: dragon tongue **Student task:** draw a spadix and leaf sheath, indicate where the male and female flowers are located, smell their characteristic aroma.	7. Purple magnolia (*Magnolia liliiflora*) **Student task:** sniff and draw flowers.

8. Kolkwitzia chinese (*Kolkwitzia amabilis*)	9. *Abelia mosanensi*
Student task: sniff the flowers, draw them from the side and front, then select the axis of symmetry.	**Student task:** sniff and draw flowers.
10. *Pyrus salicifolia*	11. Star Magnolia (*Magnolia stellata*)
Student task: sniff flowers, identify stamens and stigma, draw.	**Student task:** sniff and draw flowers.

12. Canadian dogwood (*Cornus canadensis*) **Student task:** draw inflorescence and bract, sniff flowers.	13. Rhododendrons (*Rhododendron spp.*) **Student task:** Walk single file between the plants. See and sniff the flowers of different varieties and species. Draw the selected flower.
14. Hawthorn (*Crataegus monogyna*) **Student task:** name the individual elements of a flower, sniff and draw flowers.	15. Florida dogwood (*Cornus florida*) **Student task:** Draw and sniff inflorescence.

16. Crataegus – 'Paul's Scarlet' commonly called hawthorn, thornapple, whitehorn, or hawberry (*Crataegus x media*)

Student task: name the individual elements of a flower, sniff and draw flowers.

17. *Vinca minor* (common names lesser periwinkle or dwarf periwinkle)

Student task: draw and sniff the flowers.

18. Oriental poppy (*Papaver orientale*)

Student task: draw and sniff flowers.

A. European or common Beech (*Fagus sylvatica*), different varieties	B. *Fothergilla major*
Student task: look at the flowers, distinguish male from female flowers, draw and sniff the flowers.	**Student task:** take a look at stamens, draw and sniff the flowers.
C. Manna Ash (*Fraxinus ornus*)	D. *Syringa reflexa*
Student task: if possible, take a look at the flowers.	**Student task:** sniff and draw flowers, then compare their impressions of the scents of common Syringa.

The new tasks

of the Science Section of the Educational Research Institute

Presented tasks are prepared by the Science Section of Educational Research Institute for the third and fourth stage of education. Some of them were constructed for the study Laboratory of thinking and declassified after the second stage. Presented tasks have not been previously published. They are valuable mostly because of the significant practical context: touching real problems that students may encounter in everyday life.

More about the Laboratory of thinking you can find on the web: http://eduentuzjasci.pl/en/en-badania-naukowe/120-english-categories/research/512-laboratory-of-thinking-diagnosis-of-science-education-in-poland.html

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Biology – An experiment at your fingertips

Task

If we watch an object with both eyes, we see it three-dimensionally, which makes it easier for us to determine the distance between us and the object and to see how fast it is moving. Derek wanted to verify if three-dimensional vision is helpful in catching objects. To check it, he covered his left eye with his left hand, and tossed and caught a ball with his right hand. He repeated the tossing 20 times, but he managed to catch the ball no more than six times.

What sort of control sample should he have used in his experiment?

- ☐ A. Cover his right eye with his right hand and catch the ball with his left hand.
- ☐ B. Cover his right eye with his left hand and catch the ball with his right hand.
- ☒ C. Not cover any of his eyes and catch the ball with his right hand.
- ☐ D. Not cover any of his eyes and catch the ball with both hands.

Commentary

Skills relating to scientific methodology and results analysis are important not only during science lessons at school but also in real-life. During the process of scientific research analytical thinking is developed. While conducting a research, students have a possibility to learn how to: ask scientific questions, formulate hypothesis, design experiments, predict results, organize work (including group work), collect and analyze data as well as conduct critical analysis and reasoning. The procedure described in the item is not a real scientific experiment because of too simplified form, for instance the sample contains only one person. To formulate general conclusions about the influence of three-dimensional vision on the ability to catch objects, at least several dozen people should be tested and variables such as handedness and vision defects in one or both eyes should be taken into consideration. The main advantage of the described procedure is the fact that it can be very easily performed at school. It is possible do conduct this experiment within two minutes using a ball or a rubber; one has only to remember to toss the object high enough, over the head. However, even in such an easy experiment it is necessary to include a control sample and knowledge of this particular aspect of scientific method is diagnosed in the presented item.

In order to choose the correct answer, a student has to:

- understand what a control sample is;
- select from the text the information about the scientific question Derek wanted to answer in his experiment; it is described in the second sentence of the text: Derek wanted to verify if three-dimensional vision is helpful in catching objects;
- understand that to answer the question, Derek should compare two situations: the one when he sees the ball with both eyes with the another situation when one of his eyes is covered;
- remember that the difference between these two situations must be limited to just one variable (the number of eyes watching the ball) and the other variables must stay unchanged. So in the control sample the ball must be caught with the same, right hand.

The presented item was given to 1839 students from the first classes of secondary schools in Poland (16 years old) during the study "Laboratory of Thinking – Diagnosis of Science Education in Poland". The table shows the frequency of given answers (the percentage does not sum to 100% because of omissions).

Answer	Percentage of answers [%]
A	21,7%
B	26,2%
C*	37,5%
D	12,5%

The proper answer C was the one chosen most frequently, however over 60% of students weren't able to give the correct answer. The probability of answering correctly correlates strongly with the general student's performance in the test, as it is shown on the graph below (fig. 1).

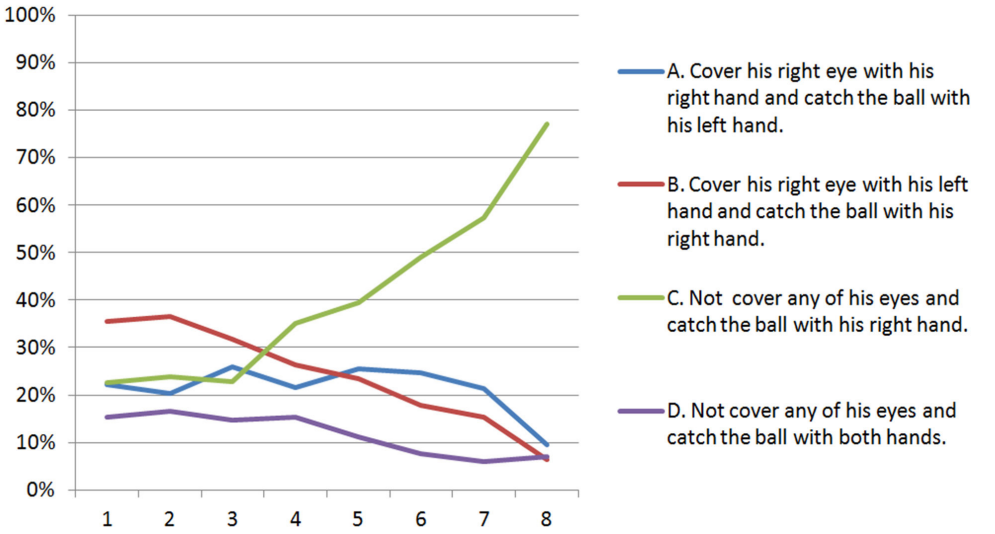


Fig. 1. Distribution of students' answers frequency plotted against students' performance in the test

The X axis shows 8 equal numbered groups of students of rising performance (1- the group of students with the lowest performance in the test, 8 – the group of the highest performance). The Y axis shows the percentage of the students' answers in each group.

The discrimination value of the item is high, so it may be therefore a useful diagnostic tool, however its difficulty is also high.

The fundamental principle of scientific method is applies also to everyday life. It says that to detect the influence of one factor on a phenomenon, it is necessary to compare the situation with another situation that differs only with this one factor. Meanwhile the other factors must be controlled. People sometimes forget about it. Someone may say "I used to catch flu very frequently but since I take this medicine, I am healthy." But the medicine doesn't have to be the only factor that caused the improvement of that person's health. Other factors like season and weather could have changed as well and could have decreased the person's flu incidence independently. Another example: can we determine which of the two football forwards is better by comparing just the number of goals scored by each one? It is necessary to realize that the number of goals scored in the season depends not only on the forward's skills but also on the performance of his team and his opponents, as well as the number of matches he played.

It is important to underline that teaching principles of scientific method is necessary in education not only for future scientists but also for future citizens. Those skills allow a conscious citizen to critically analyze all kinds of information and to better understand surrounding world.

The item is compliant with the following requirements of the core curriculum for biology at ISCED 2 level:

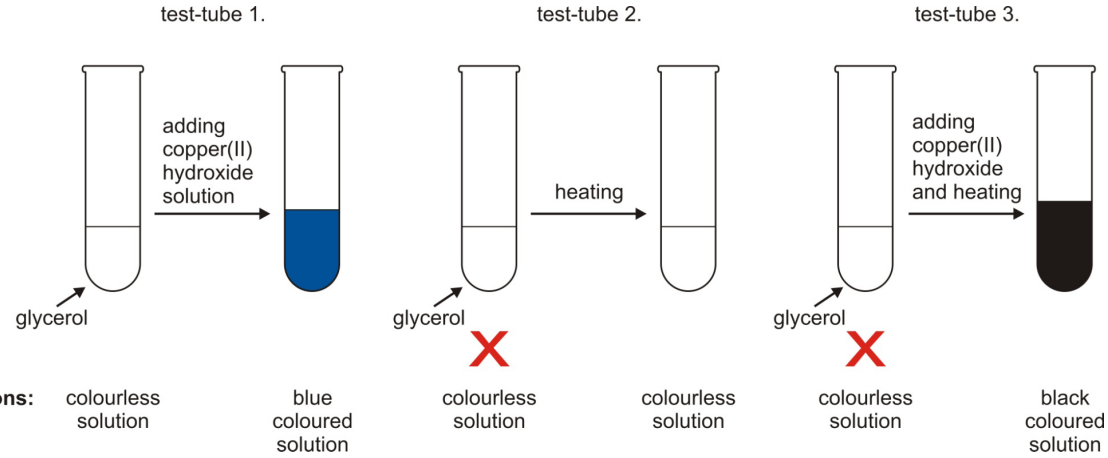
General aims of education – learning outcomes:

II. Scientific methodology. The student designs, conducts and records observations and biological experiments, describes the experiment's variables and control sample.

Chemistry – Glycerol's properties

Task

A student performed the following experiment during the chemistry lesson:



For each of the statements in table decide whether it is correct conclusion from the experiment.

	Statements	Is it the correct conclusion?
1.	Glycerol always reacts with hydroxides.	☐ Yes / ☒ No
2.	Copper(II) hydroxide undergoes reaction with glycerol.	☒ Yes / ☐ No
3.	Black colour in the test-tube 3. is the effect of glycerol heating.	☐ Yes / ☒ No

Commentary

The presented item has been developed in order to investigate the ability of reasoning based on the observations of the conducted experiment. It is one of the key skills related to the scientific method that student should acquire in the course of learning chemistry in lower secondary school. In the introduction to the task a diagram of the experiment referring to the learning content listed in the section 9.3 of the core curriculum was presented: *Student (...) explores and describes the properties of glycerol (...).* The diagram shows test-tubes with substrates used in the experiments and the observations of solutions' appearance recorded before and after the reaction (if it occurs). Students should not have any problems with reading this type of simple diagrams of experiments, especially that they refer to section 3.2 of the general aims in the curriculum: *The student designs and carries out a simple chemical experiments.*

The student should analyze the description of the experiments shown in the drawing, and then answer the question whether the conclusions listed in the table can be drawn on the basis of recorded observations. The first statement refers to a generalization – the student must decide whether it can be concluded that *Glycerol always reacts with hydroxides* only on the basis of the reaction of glycerol with copper(II) hydroxide. Obviously the answer is *no* – we cannot draw such a conclusion on the basis of reaction of glycerol with only one hydroxide.

Another statement concerns the reaction of $Cu(OH)_2$ with glycerol – on the basis of recorded observations and changes in the test-tubes, the student must determine whether such reaction actually occurs. The diagram shows three test-tubes: to the colourless glycerol in a test-tube No. 2 no solution of $Cu(OH)_2$ has been added, and after heating glycerol remained clear; a solution of $Cu(OH)_2$ was added to glycerol in a test-tube No. 1, and

colour change to the blue was observed, thus a chemical reaction occurs; in the case of test-tube No. 3 a black colour solution was obtained – student should conclude that after mixing of glycerol with $Cu(OH)_2$ a blue solution will be created, followed by the reaction which resulted in the formation of black precipitate under heat treatment. Reactions that occurred in test-tubes No. 1 and 3 are the confirmation of 2nd statement – *Copper(II) hydroxide undergoes reaction with glycerol* (the experiment in test-tube No. 2 acts as a control sample).

In the case of 3rd statement student should note that the experiment in the test-tube No. 2 is the control sample for the experiment in the test-tube No. 3 - if the heating of pure glycerol solution does not lead to the formation of a black-colour solution, also the heating of glycerol cannot be the cause of a black precipitate formation in the test-tube No. 3. Moreover, a black solid also could not arise from mixing a glycerol with a solution of $Cu(OH)_2$, because the observation of test-tube No. 1 indicates that the solution should be blue then.

This item was tested on a group of 203 students from the 3rd grade at lower secondary school. The results obtained by the students who were solving this task are reported below.

	Statements	Is it the correct conclusion?
1.	Glycerol always reacts with hydroxides.	Yes 71,4% / No **28,1%**
2.	Copper(II) hydroxide undergoes reaction with glycerol.	Yes **84,2%** / No 15,8%
3.	Black colour in the test-tube 3. is the effect of glycerol heating.	Yes 54,2% / No **45,3%**

Table 1. The percentage distribution of students' responses to the questions posed in the item (the correct answers are marked with a blue print)

In general the entire item was properly solved only by 8.4% of the students participating in the study, thus this task turned out to be extremely difficult for students. The obtained results were even lower than the probability of giving the correct answer at random, equal to 12.5%.

The worst results were obtained by the students in the case of 1st statement – only 28% said that this is not a valid conclusion. Almost three-quarters of students solving this task found that the general reactivity of glycerol with all hydroxides can be concluded on the basis of the results of an experiment with a single hydroxide. Even in the group of students who achieved the best results in the entire test, the correct answer was pointed out by less than 53% of respondents. The reason for such a mistake can be the way the experiments are carried out in the classroom – experiments conducted during the classes are mostly illustration of certain general laws and phenomena, and therefore students may have a tendency to generalize on the basis of individual experiments. Students should be taught from the beginning that formulating a rule related to the reactivity of some compound often requires a broad spectrum of reactions.

A much better results were achieved by the students in the case of 2nd statement – over 84% of them felt that such a conclusion can be drawn from the experiments described in the item. Students, who chose the wrong answer, probably did not recognize the symptoms of reactions in test-tubes No. 1 and 3, although they were very clear, which may indicate serious deficiencies at the level of basic knowledge and skills concerning the identification of chemical reactions.

In the case of 3rd question 45.3% of the students participating in the study chose the correct answer, and only in the group of students who obtained the highest scores in the entire test, the correct answer was given by 79% of respondents. Others erroneously interpreted the results of the experiment in test-tube No. 3, as they most likely did not notice that this results need to be compared with the experiment No. 2, wherein the effect of temperature on pure glycerol was investigated. It also cannot be excluded that the majority of students could not identify the substance from which black precipitate had originated, because they did not understand what exactly happened in the third tube.

A very low percentage of students who correctly answered all three questions suggests that during chemistry classes an insufficient time is spent on the development of basic skills concerning scientific method – the correct reasoning from observed phenomena, distinguishing between control sample and test sample, as well as analyzing the impact of various factors on the course of experiment. The survey results also showed that even the best students tend to generalize on the basis of individual experiment and do not know when such conclusions are justified, and when not, so solving with students more items that develop this type of skills is worth consideration.

The item is compliant with the following requirements of the core curriculum for chemistry at ISCED 2 level:

General aims of education – learning outcomes:

II. Reasoning and application of acquired knowledge to solve problems.

2.1. The student describes the properties of substances and explains the course of simple chemical processes.

III. Mastering the practical activities.

3.2. The student designs and carries out a simple chemical experiments.

Learning content – specific requirements:

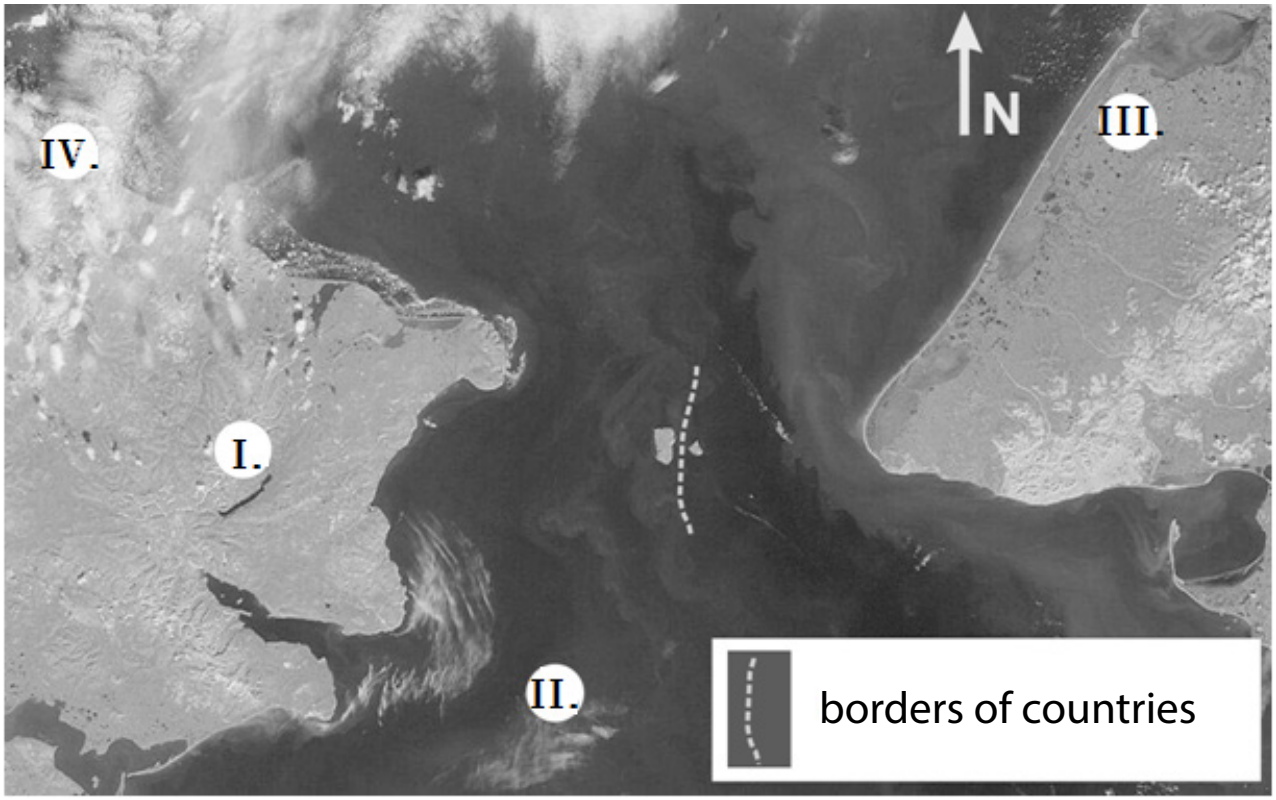
9.3. Derivatives of hydrocarbons. Substances of biological importance. The student (...) explores and describes the properties of glycerol (...).

Geography – Diomede Islands

Interesting geographic location of two islands, which are located on the both side of the International Date Line, became an inspiration to examine important geographical skills: orientation on the map and observe consequences of Earth movements. Three presented tasks can be used in teaching geography in secondary school.

Information to the tasks

The Diomede Islands consist of two rocky islands – Little Diomede and Big Diomede. The Diomede Islands are separated by an international border between United States of America and Russia, which is also a part of the International Date Line. While standing on one of the islands you can look not only to another country, but also to another day ("yesterday" or "tomorrow").



Map. 1. Location of Diomede Islands

Task 1

In the following sentence, select the right words so that created a true statement.

In the satellite image number I. indicates:

- ☒ A. Russia
- ☐ B. United States of America

and number II. indicates:

- ☐ A. Atlantic Ocean
- ☒ B. Pacific Ocean

Commentary

This task refers to the first point in the general requirements of the core curriculum, which checks if students are able to use different sources of geographic information (...), maps, plans and photographs (...) in order to collect, process and present information. Particular requirements checked in this task are: reading ability, interpretation skills and using maps, especially identifying the geographic location of objects in the photographs, satellite imagery and topographic maps (section 1.4).

During the lessons the most frequently used world's maps are these in which Europe is in the middle of the world – meridian 0 degree is located in the central part of the map. However, students should also understand, how the "other side" of the globe looks like, especially, that International Date Line has been determined here, near meridian 180.

Due to the location of the meridian 0 degree in the center of world's map, students are accustomed to the location Asia on the right and America on the left side of a map. Instead of giving directions, determine the location by using wordings "on the right / left side".

The picture has been done on the other side of the Earth so the International Date Line is located in the

middle part of image. This kind of task can verified an ability to determining the directions on the globe.

Analyzing the results of the study it can be said that the tested skill is difficult for students. The correct position of Russia (on the eastern hemisphere) was pointed out approximately 60% of the respondents, slightly more than 39% of the students confused hemispheres and state. This is not a satisfactory result because it was only 10% over a random distribution. So there is no certainty that 60% of the students mastered this skill.

Analysis of the results gives one more information – this part of the task rather well divided students into better and worse. This is shown on the graph by rather large slope of the line. The results of this part of the task is presented on fig. 1. The vertical axis indicates the response rate, the horizontal axis indicates the students divided into groups according to the results of the whole test. The correct answer has been marked 1, the wrong answer has been marked 2, number 9 indicates which students no answer in this task.

Signing the oceans on the satellite photo seems to be an easy task, therefore somewhat surprising is that only over 58% of respondents indicated correctly Pacific Ocean, and over 40% chose incorrectly Atlantic Ocean (fig. 2). That choice is surprising due to the fact that in the photo is only one of these oceans. Furthermore distribution of continents and oceans student should remember from primary school.

Solutions of the second part of the task (2) shows the second graph. As the chart on the first row, on the vertical axis marked the percentage of responses, and the horizontal – a group of students according to skill levels.

The whole task correctly solved 40% of the students. Distribution of answers in groups is presented in fig. 3. Number 1 indicates the students who have responded correctly to both rows tasks, 0 indicates students who

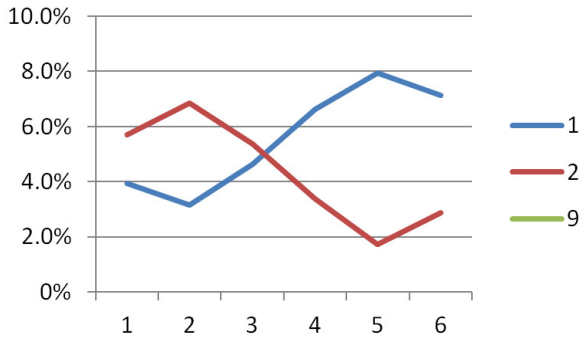


Fig. 1. Results of the first part of the task

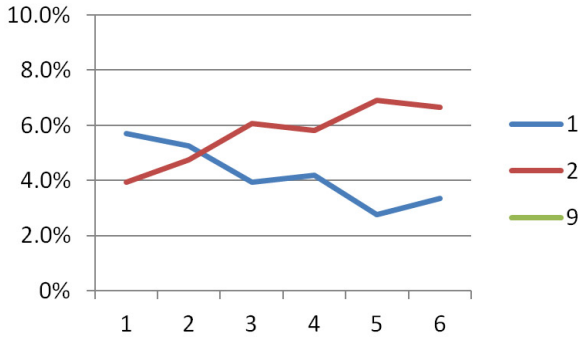


Fig. 2. Results of the second part of the task

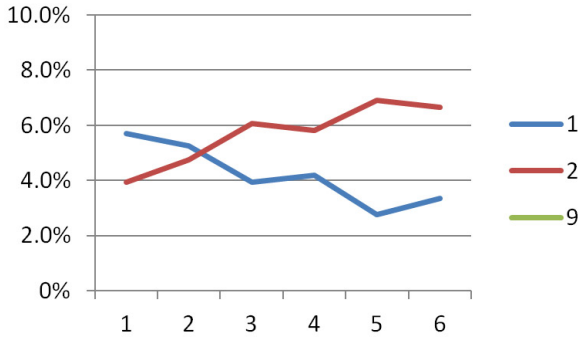


Fig. 3. Results of whole task

have made a mistake in at least one row. No indications of any response was marked 9.

The cause of errors committed by the students can be infrequent use of satellite images during geography lessons. The second reason may be the use of the map of the world, where Europe is in the center. More issues discussed during geography lessons relates to the northern hemisphere, especially Poland, less attention is focused on areas south of the equator. Discussed task could be used during the repetitive lesson. It will be good opportunity to check the students before class test.

Task 2

Two points, III. and IV., located north of northern Arctic Circle**,** was marked in the satellite image.

In the following sentence, select the right words so that created a true statement.

(1) During Christmas:

☐ A. in both points Sun is shining 24 hours

☒ B. in both points is dark 24 hours

(2) this is a consequence of:

☐ A. Earth's rotation

☒ B. Earth's orbit

Commentary

The second of bunch of tasks verifies that the student understands the consequences of the movement of the Earth. To solve the task is also necessary knowledge how the length of day and night during the year influences latitude. Additionally the student will not knowingly give the right answer, if you will be able to use freely the geographic directions. If solving a task knows when and in what area are polar days and nights, should apply their knowledge and choose the right answers for the specified time (Christmas).

The whole task correctly solved 32% of the surveyed students, fewer difficulties made it more able students, which can be traced on the chart below (fig. 4).

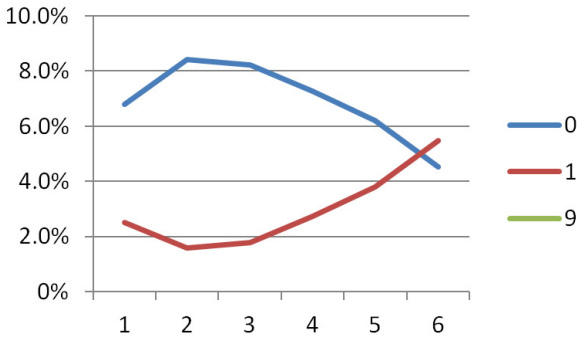


Fig. 4. Results of the whole task

In the first part, students often chose the correct answer, namely the polar night (B) – almost 58% of the responses. In the graph we can see that the number of correct answers increased among the best students. The first part of the task good differentiates the test group.

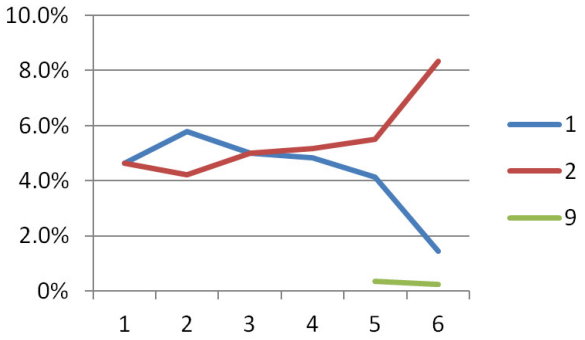


Fig. 5. Results of the first part of the task

The second part of the task (2) also caused a lot of problems, because only less than 53% of the students have confirmed relationship of occurrence of day and night polar and Earth's motion around the Sun (B). 46% of students connects effect polar days and nights to the Earth's rotation (A). Perhaps those students remembered that the effect of rotation is the existence of day and night, but no longer remembered, the days and nights polar appear because of the inclination of Earth's axis to the plane of the orbit, so the reason for their occurrence is epicycles motion.

Considering results of the task, also be this task requires solving a lesson, for example, the repetition of issues the movements of the Earth.

Task 3

In the following sentence, select the right words so that created a true statement.

Taking this picture an author was:

- ☒ A. north of the islands
- ☐ B. south of the islands
- ☐ C. east of the islands
- ☐ D. west of the islands

so he had the north pole:

- ☒ A. behind his back
- ☐ B. in front of him
- ☐ C. on the right side
- ☐ D. on the left side

The Diomede Islands: Little Diomede (left) and Big Diomede (right)

Fot. Dave Cohoe; source: http://upload.wikimedia.org/wikipedia/commons/c/c6/Diomede_Islands_Bering_Sea_Jul_2006.jpg

Commentary

This task, similarly like the first task, checks whether the students are able to use different sources of geographic information. The students interprets the additional material – a photography taken from the sea level. Based on this photo, students should identify the location where the photographer was at the time of his work. The task checks the skills and the ability to efficiently navigate the issues related to the geographic directions.

The whole task correctly solved slightly more than 37% of the respondents, the results illustrated the fig. 6.

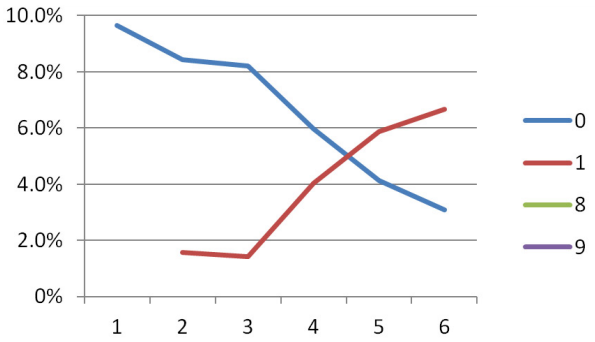


Fig. 6. Results of the whole task

In the first part of the task, a lot of students chose the correct answer (A) – about 52%. The choices other answers may have an interesting interpretation. 35% of the students chose the not valid but opposite answer (B), these students, possibly, could imagine where there was a photographer, but could not properly express in words this position. Marking answers C (5%) or D (6%) indicates the random selecting.

Analyzing the results of the second part of the task, we can check how consciously students responded to the first part. A group of students who correctly located the north pole and chose answer A (46%) was only slightly less than the group of students who correctly solved the first part of the task. Answer B was chosen by the 21% of the respondents, these people probably noticed that the picture shows the strait between the islands but they failed to take advantage of the hints of placing on the map arrow indicating the north direction. Answers C and D also in this part of the task has chosen by the 12% of the students. Perhaps among the respondents there were some students who have problems not only with geographic directions, but also the determination of the directions "right" and "left".

If you want to arouse students' interest in the unknown islands, we can search the Internet resources in the search for interesting relationships with travel and interesting additional information, such as political geography. One such message may be the fact that the distance between the Diomede Islands in water at a temperature of about 6° C. tried to swim across the American – Lynne Cox in August 1987. This feat took her two hours and 12 minutes, but the swimmer had no right to go ashore on the Great Diomedzie, therefore, returned in the accompanying boats, grateful that she was allowed to reach so far. This adventure Lynne Cox in the book "Queen of cold water".

Physics – Artificial satellite

Task

There are 5 geosynchronous satellites used by some known company. The supervisory committee recognized, they need also a scientific research satellite moving around the Earth in circular orbit with an orbital period of 12 hours, instead of 24.

Which one of the following statements about additional satellite, stated during the meeting of the committee, is correct?

- ☐ A. 'An additional satellite should orbit at the same distance on the Earth like geosynchronous satellites, but it should have twice the speed of geosynchronous satellites.'
- ☐ B. 'An additional satellite should orbit at the same distance on the Earth like geosynchronous satellites, but it should have half the speed of geosynchronous satellites.'
- ☐ C. 'An additional satellite should orbit at the same distance on the Earth like geosynchronous satellites, but it should have four times larger speed then geosynchronous satellites.'
- ☒ D. 'An additional satellite must not orbit at the same distance on the Earth like geosynchronous satellites.'

Commentary

So called geosynchronous satellites are very important type of satellites. They orbit around the Earth, all the time staying in the same position above chosen point on the surface of our planet. This is possible only for geostationary orbit, that is a circular orbit above the Earth's equator. Additionally the orbital period of the

satellite has to be the same as the Earth rotation period, that means approximately 24 hours. The last requierement forces specific speed, we have to give to the satellite to place it in the orbit. If the speed is smaller then required, the satellite begin to fall down. If the speed is to large, the satellite moves away from the Earth. In both cases the value of orbital period will change.

The purpose of presented item was to reveal the high school students understanding of the term of a geosynchronous satellite, their understanding of the relation between the speed value and the orbit radius and also to reveal how well they were able to use this knowledge in practical applications. Described story is related to the debate on the additional satellite, required by a company for scientific research. In this case a student had to choose the statement consistent with laws of physics.

The additional satellite has to surround the Earth with an orbital period of 12 hours, so it cannot be placed on the orbit having radius equal to the radius of geostationary orbit. The reason is very simple: artificial satellites movement is result of gravitational force and the specific speed is 'attributed' to any orbit. The orbital speed is given by equation $v = \sqrt{\frac{GM}{R}}$, where G is the gravitational constant, M is the mass of the Earth and R is the radius of orbit for the satellite (in the case of geostationary orbit R = 35,786 km). Thus there is no possibility to increase or decrease speed of objects moving on given orbit without any drive. For some reasones mentioned above a satellite do not use any drive, with the exeption of the situation, where the radius of the orbit has to be changed.

Most probably, some of the students did not take into account the last fact. As many as 53% of examined students chose 'A' as the correct answer. The answer 'A' was preferred mainly by the students achieving the weakest results in the whole test. Without any doubt they interpretation was like that: 'to obtain two times smaller orbital period, we must give to the satellite two times larger speed'. But that statement would be correct only if the satellite had any drive.

Students achieving the best results in the whole test indicated mainly 'D' as correct answer. This answer chose almost 26% examined persons. It is interesting that students obtaining average scores chose mainly between answer 'A' or 'D', very rarely indicating 'C' or 'B'. Furthermore, the last two answers was chosen with relatively slow probability (about 8% in both cases).

The results of our investigation show that students have some difficulties in understanding of the term of a geosynchronous satellite and in understanding the principles of artificial satellites movement. More then half of them just have mistaken, thinking that it is possible to make a satellite moving with any speed, independently on the radius of the satellite orbit.

The item is compliant with the following requirements of the core curriculum for physics at ISCED 2 level:

General aims of education – learning outcomes:

I. Making use of physical quantities to description of known phenomena.

Learning content – specific requirements:

1. Gravitation and astronomy.

6) The student understand the term of geosynchronous satellite; describes the movement of artificial satellites around the Earth.

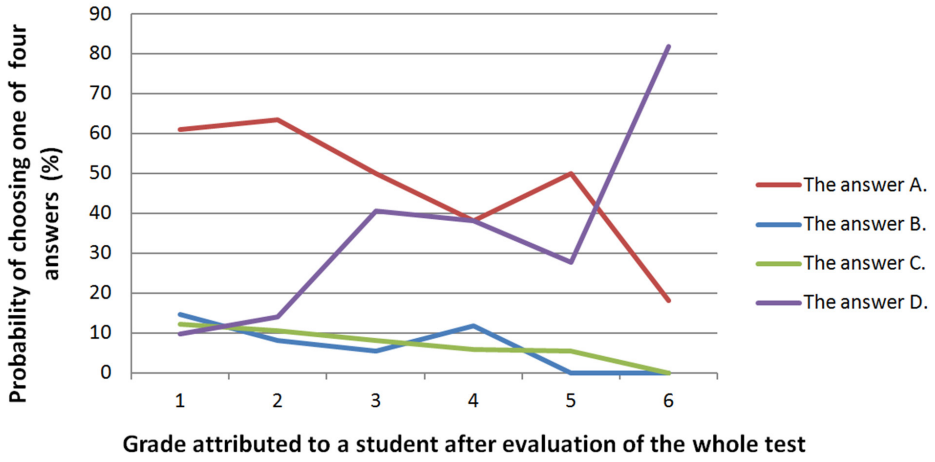


Fig. 1. Distribution for the probability of choosing one of four proposed answers

The lowest level of achievement is represented by 1, the highest one – by 6.

Review of the book

Education for sustainable development: theory – practice – research

Ilona Żeber-Dzikowska

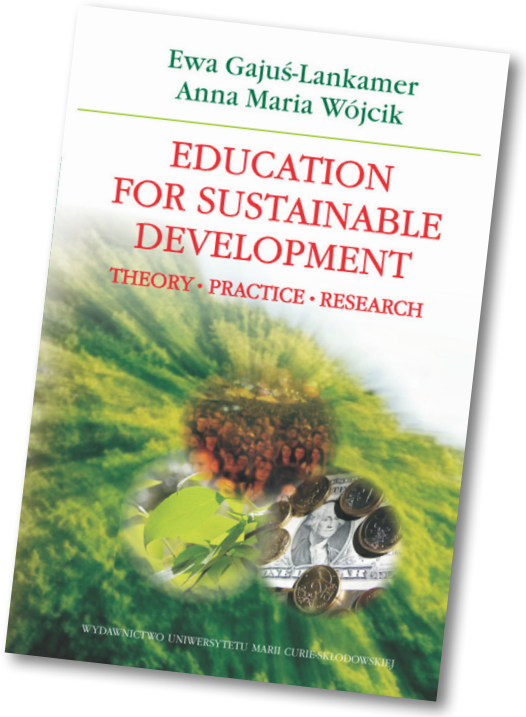
The book written by Ewa Gajuś-Lankamer and Anna Maria Wójcik is very valuable work which touches theory, practice, and research on various aspects of sustainable development. This recently published book might serve as the source of information needed in scientific research or teaching in schools.

It is on the key importance that the book is the answer of authors to the Educational Strategy for Sustainable Development issued by United Nations. Along with the most important statements of the strategy, the book contributes to propagation of research results and education on sustainable development. Importantly, the book reviewed here is an opportunity to share Polish experiences in the field of sustainable development with people from all over the world. It must be stressed that the book can be read by people involved in either formal or informal educational activities.

Additionally, authors discuss in detail such topics as (i) results of their own research work, (ii) engagement of scientific community in execution of declaration entitled Educational Decade for Sustainable Development 2005–2014, and (iii) future perspectives of above-mentioned problems.

The work reviewed here presents efforts for promoting sustainable development of society, economy, and ecology – supporting, at the same time, formation of society.

Societies, in era of globalization, should have following characteristics; high social activity, ecological self-governance and ability of cooperation for common goodness. In Poland, building up such society needs stimulation; there is need for initiatives and commonwealth responsibilities which lead to common decisions about real education and the human-environmental relation.



Ewa Gajuś-Lankamer, Anna Maria Wójcik
Education for sustainable development: theory – practice – research
Uniwersytety of Maria Curie-Skłodowska Publishing House, Lublin 2013, pp. 138

Long-term efforts regarding ecological awareness of the society has positive effects. However, the level of awareness is far from satisfactory. Schools and other educational institutions are used to the environmental education in very formal way. For this reason, an informal education would complement existing, insufficient way of environmental education. Only by these methods, it is possible to change incorrect attitudes and values, and achieve ecological society.

The book consists of introduction, ending remarks, and chapters containing sub-chapters:

- Theory of education for sustainable development;
  - International recommendations for education for sustainable development;
  - Formal education for sustainable development;
  - Informal education for sustainable development;
  - Education for sustainable development in practice;
- Education for sustainable development in own research;
  - Methods, organization and the course of research;
  - Results;
  - Discussion and conclusions;
- Education for sustainable development in case studies;
  - Actions for sustainable development in Polish and international documents;
  - Education for sustainable development in biological studies;
  - Sustainable development in advertisements of corporations;
  - Ecological awareness in Poland in 2000–2010.

In a first chapter entitled "Education for sustainable development in theory and practice" one can find a history of sustainable development with current, integrated definition which includes also environmental, economical, and social aspects. Authors mention also about Polish and international recommendations which

have influence on the direction and aim of formal and informal education in Poland. In many cases, authors refer to their own research results regarding the presence of sustainable development in national requirements for school students and competence of Polish school teachers in teaching in accordance with sustainable development. These issues are presented along with other research results the newest documents published by Ministry of Environment. An extensive part of the chapter is the presentation of didactic solutions recommended to education for sustainable development, which is mainly the result of many years of research and academic work at university. According to the assumptions of the Decade the book presented also good practice in the most effective methods of teaching and learning for sustainable development.

The second chapter "Education for sustainable development in own research" presents research conducted to determine the knowledge of biology students (future teachers) on sustainable development. It also contains a description of the experimental research on the effectiveness of course which prepares students of biology at the University of Maria Curie-Skłodowska University in Lublin to a function of educator sustainable development.

In the third chapter entitled "Education for sustainable development in the case studies" a selection of activities in Poland and in the world in the implementation of sustainable development in environmental, economic and social aspect is presented. Their descriptions expand and illustrate the issues discussed in the book, such as:

- national and international efforts to promote sustainable development in the documents adopted in Poland and in the world,
- education for sustainable development on the academical level,
- non-formal education for environmental protection and sustainable development in the promotional activities of companies,
- changes in the environmental awareness of Poles over ten years.

The questions posed in the case study provide an opportunity to deepen knowledge, assessment of described phenomena and reflection on self involvement in the process of transforming the idea of sustainable development in the reality.

It is worth noting that the subject of the next chapters and subchapters is logically ordered and includes issues necessary for education for sustainable development in academical education and teacher training, and for the promotion of the international activities of the Decade of Education for Sustainable Development, from the content associated with international programs, through EU and national legislation, to reflecting the main areas of promoting sustainable behavior and stimulation of critical and creative thinking that will enable finding solutions to problems hindering the development of a sustainable world by human activity in relation to the environment. The content of the publication can not only broaden the theoretical knowledge, but can also indicate the methods of transfer theory into everyday practice.

The book should be noticed by the wider audience, as it is an opportunity to significantly contribute to improve the competence of various bodies responsible for the development and implementation of local environmental programs, including environmental education with regard to sustainable development. What is more, it is worth noting that the publication deserves a high rating because of emphasizing both the practical and theoretical aspects necessary in the preparation peaople for responsible, informed and reflective functioning in a changing world. The authors underline that the role of education and the school is not to promote modern unethical producer and consumer unsaturated, which is subjected to sophisticated marketing pressures. An important condition of education is currently saturation it by reflective, critical and interpretive knowledge, leading to the wisdom – environmental education in conjunction with sustainable development.

The publication has an international range because it was published in English.

The authors are academics in the Laboratory Teaching of Biology and Environmental Education University in Lublin. On their account thay have many years of training and an extensive knowledge of the presented range.

Science-world news

The news are prepared by the specialists
from the Science Section
of the Educational Research Institute
(Instytut Badań Edukacyjnych)

Fairy chemistry of fungi

In January a group of 22 scientists from Japan published in Angewandte Chemie a paper dedicated to *fairy chemicals* isolated from plant tissues [1]. Short after that a little rewiew: *Fairy Chemicals* has been published in Nature [2].

Both substances have already been known to scientist since 2010 as the factors causing formation of the *fairy rings* by the fungi (fig. 1).

The first scientific communication about *fairy rings* phenomenon by fungi was published in 1675 [5]. Since then people believed rings were an effect of fairies or other supernatural forces action. In 2010 scientists from the Japanese Shizuoka University claimed that one of these *fairies* is in fact 2-azahypoxanthine (AHX) [6]. Figure 2 shows chemical formula as well as model of the substance mentioned above. 2-azahypoxanthine was isolated from *Lepista sordida* fungus which is widespread in northern temperate zones throughout the world. What is interesting scientists revealed that this substance isolated from fungus influenced the growth of germinating seeds, for instance rice, wheat and other plants (fig. 3).

What is more the group of scientists isolated AHX and its metabolite from tissues of different plants: rice, *Arabidopsis*, potato, tomato, eucalyptus and *Chlorella*

Fig. 1. Exemplary photographs of the *fairy rings* [3], [4]

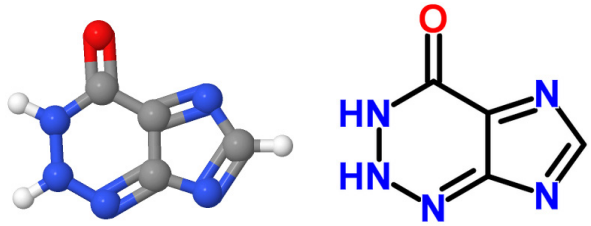


Fig. 2. Model (left) and stucture of 2-azahypoxanthine (AHX). Click in the link [7] to see 3D structure of AHX

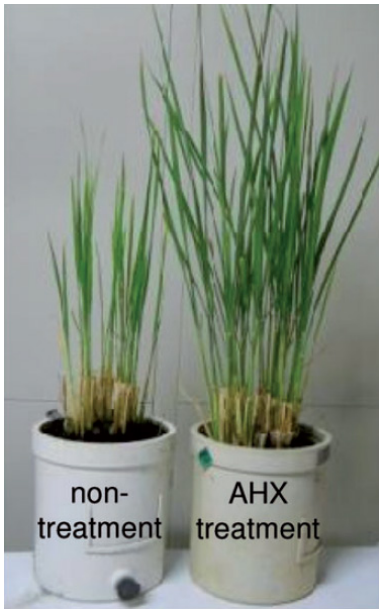


Fig. 3. Rice grown in soil non supplemented (left) and suplemented with AHX – 5µmol/dm3 (right) [1]

although plants and algae don't form *fairy rings*. Detected concentrations of ASX were similar to concentartions of known plant hormones, for example strigolactones responsible for plant growth or plant steroids -brassinosteroids. In the next stages of research researchers had set up a hypothesis that *plants themselves produce 2-azahypoxanthine through a biochemical pathway similar to the laboratory chemical synthesis*. Detailed laboratory analysis led them to the confirmation of the settled hypothesis.

As authors of the paper [1] stated, the increase of the seed yields of rice and wheat in pot experiments after treating them with AHX suggest the possibility of its practical use in agriculture.

Marcin Chrzanowski, Science Section

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[3] http://upload.wikimedia.org/wikipedia/commons/d/d7/Fairy_ring%5E_-_geograph.org.uk_-_573051.jpg

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[5] Hutton Ch, Shaw G, Pearson R (1975), *The Philosophical Transactions Of The Royal Society Of London, From Their Commencement, In 1665, To The Year 1800; With Notes And Biographic Illustrations, from 1672 to 1683*, Vol. II., 225.

[6] Choi JH, Fushimi K, Abe N, Tanaka H, Maeda S, Morita A, Hara M, Motohashi R, Matsunaga J, Eguchi Y, Ishigaki N, Hashizume D, Koshino H, Kawagishi H (2010). Disclosure of the "Fairy" of Fairy-Ring-Forming Fungus Lepista sordida, *ChemBioChem A European Journal of Chemical Biology*, 11:1373-1377.

[7] http://www.chemspider.com/ImageView.aspx?mode=3d&id=70758

A new cure for defects in the heart

A new superglue, officially known as *hydrophobic light-activated adhesive* (HLAA), was developed in a collaboration between researchers at Boston Children's Hospital, Massachusetts Institute of Technology (MIT), and Harvard-affiliated Brigham and Women's Hospital. This novel surgical adhesive is strong enough, and elastic enough, to seal a beating heart (Lang et al., 2014).

Many infants born with heart defects such as *atrial septal defect* (ASD, commonly known as *a hole in the heart*), which must be treated surgically. Unfortunately, this kind of medical interventions is difficult to perform since both sutures and staples can damage the delicate heart tissue, and applying sutures is time consuming. Replacing the surgical sutures with fast-acting, biodegradable glues could make these cardiac procedures faster, safer, less invasive and help reduce postoperative complications, as well as recovery times. However, existing, clinically approved surgical adhesives have several drawbacks i.a. they do not bind strongly enough to tissues in wet and highly dynamic environments within the body, and some of them can be toxic, thus they are applied mainly to the skin. Furthermore, infants often need subsequent operations to "replug" heart defect again. This is going to change soon since scientists at Bo-

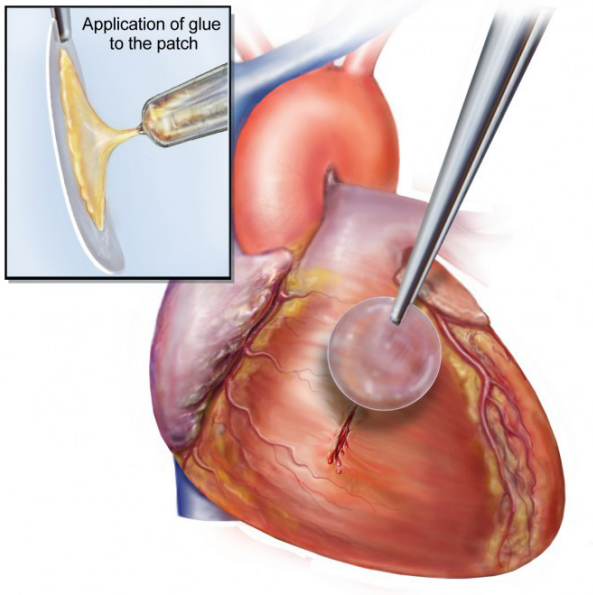

Fig. 1. Application of HLAA-coated patch to a heart defect

Source: http://www.gizmag.com/heart-hole-glue-hlaa/30414/pictures#2

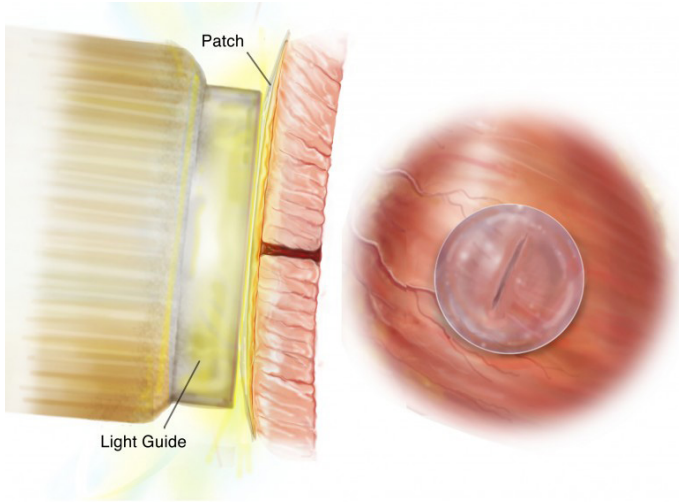

Fig. 2. HLAA sets in just five seconds, once it's exposed to an ultraviolet light source

Source: http://www.gizmag.com/heart-hole-glue-hlaa/30414/pictures#2

ston Children's Hospital, MIT, and Harvard-affiliated Brigham and Women's Hospital have developed a sort of superglue, that quickly and securely bonds patches to the holes in the heart tissues. A biomaterials researcher Jeffrey Karp and his co-workers have described in the January issue of the journal *Science Translational Medicine* the engineering of elastic and biocompatible *hydrophobic light-activated adhesive* (HLAA) that achieves a strong level of adhesion to wet tissue and is not compromised by pre-exposure to blood. The study revealed that HLAA can provide an on-demand hemostatic seal, within seconds of light application, when applied to high-pressure large blood vessels and cardiac wall defects in pigs. HLAA-coated patches were attached to the interventricular septum in a beating porcine heart and despite high pressure they remained attach for 24 hours, which is relevant to intracardiac interventions in humans. Due to HLAA's unique properties patches will remain adhered to the heart tissue even in liquid blood, it won't be rejected, loosen up or torn by the contractions of the heart muscle, and it will biodegrade, when the hole has healed over.

Unlike adhesives that work through a chemical reaction, HLAA works by a physical mechanism. HLAA remains liquid in normal conditions but sets in just five seconds when it's exposed to an ultraviolet light source (fig. 2). Microscopy studies indicate that the glue becomes physically entangled with collagen and other proteins on the heart tissue surface (fig. 3).

According to the researchers, the HLAA glue can be used in cardiac surgery, and other kinds of surgical interventions requiring immediate repair of defects and surgical hemostasis. Until now the surgical adhesive has been tested on pigs and mice and is being developed by French company *Gecko Biomedical*, which plans to release HLAA as a commercial product to the European market in one to two years.

Małgorzata Musialik, Science Section

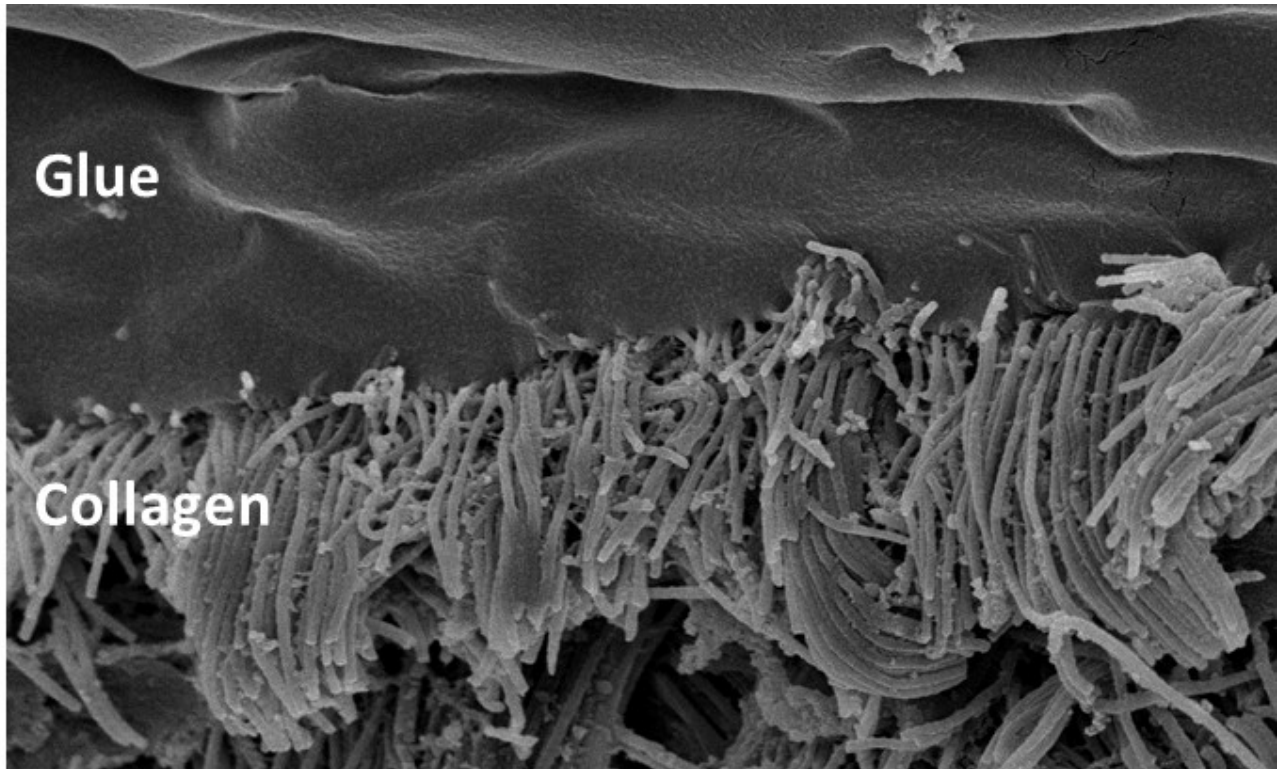

Fig. 3. A closer look at how the collagen in the tissue bonds with HLAA patch

Image: Pedro del Nido, Boston Children's Hospital, source: http://www.gizmag.com/heart-hole-glue-hlaa/30414/pictures#3

Photo of the issue

Bumble bee on *Echinacea purpurea*

Author of the photographies:
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Text authors:
Piotr Bębas, PhD, D.Sc., Faculty of Biology, University of Warsaw;
Marcin M. Chrzanowski, PhD, Science Section, Educational Research Institute

Photographies were captured in the garden near house in Poland, Świętokrzyskie Voivodeship, in the city of Starachowice (coordinates: 51°03'N 21°04'E).
date of caption: 31st of July 2013
The photographies were captured with the iPhone4S mobile phone.

Scientific classification
Domain: Eukaryote
Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hymenoptera
Family: Apidae
Subfamily: Apinae
Tribe: Bombini
Genus: *Bombus*
Species: *Bombus terrestris*

There are about 300 known species of bumble bees living on Earth. In Poland occurrence of 30 to 40 species of bumble bees has been stated dependently on the source of information. Almost all species of bumble bees in Poland are under the protection of law (status of endangered and protected species) except *Bombus terrestris* as well as *Bombus lapidarius*. This group of animas has a very strong significance in the process of the flower-plants pollination, especially those whose flowers have long tube structure, or composed of long tubular disc florets. There are some plant species exclusively or almost exclusively pollinated by bumble bees, for example: *Aconitum firmum*, *Digitalis purpurea* (the common foxglove), or *Antirrhinum majus* (the common snapdragon).

Similarly to honey bees (*Apis mellifera*) bumble bees are social insects and form colonies. Those colonies are much less numerous comparing to those formed by bees. They consist of a single queen and up to 500 worker females. Fertilized females (queens) of the *Bombus terrestris* pass the winter hibernating in so called imaginal diapause state. In the spring the diapause state terminates and females using grass, dried up leaves or moss start to build the nests, usually in hollows, under stones or in rodents' burrows. Inside the nest queen prepare two kind of cells made of wax. In one of them they collect nectar, and the second one is filled up with pollen. They lay eggs to the second type of cells – those with pollen. This act is repeated many times. All the cells are

than successively connected by queen in the form of one "kindergarten". At night, when temperature drops down, queen warms eggs and hatching larvae. During the time when larvae grow up queen supplies them with new rations of pollen. Fully developed larvae undergo metamorphosis and just after eclosion (moult to the imaginal stage) adult bumble bees chew their way out of the silk cocoon and after 2 or 3 days of eating the nectar collected by their queen, they go out of the nest and became grown-up foraging workers. Empty cocoons are being recycled and used as pollen capsules for the next larvae generation. Adult bumble bees take the responsibilities from queen and take care of the nest and queen starts to laying legs only

From part of eggs laid by queen males and new queens also develop. After copulation they will diapause and the new life cycle will start again. Interestingly, males of bumble bees just after going out of the nest never go back to it and live on their own. Just like females, males are also pollinators of a large variety of plants what differentiates bumble bees from honey bees.

