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SCIENCE EDUCATION IN V4 COUNTRIES AND THE FORMATION OF SCIENTIFIC LITERACY

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ABSTRACT: *The article deals with the science education in V4 countries from the lowest levels of school to university preparation of students, including interest in science activities. The issue of the formation of scientific literacy is also discussed. In the final part of the article the most effective teaching methods appropriate for the science education are characterized.*

KEY WORDS: *scientific literacy, science education, teaching methods, V4 countries*

INTRODUCTION

Science education is an inseparable part of education in general. The goal of science education is the formation of scientific literacy. However, results of the international study OECD PISA (Programme for International Student Assessment) show that pupils at the end of the compulsory education in V4 countries achieve about average results in international testing of scientific literacy. Pupils have problems mainly with stating of hypotheses, application of various research methods, experimentation, acquisition and interpretation of data, assessment of research results, formulation and proving of conclusions.

The worst results among V4 countries achieved Slovak pupils. The problem is that the current Slovak school system is entrenched in traditional scientistic and a product-oriented manner characterized by memory learning (drill), acquisition of knowledge without understanding, and passivity of pupils in the educational process[321]. Mentioned problems are also peculiar for natural science education. It prefers collection and reproduction of theoretical knowledge to scientific investigation till now. It can be mentioned that the situation is similar in the neighbouring countries – Poland, Hungary and the Czech Republic.

[321] Cf. L. Held, B. Pupala, *Psychogenéza žiakovho poznania vo vyučovaní*, Bratislava 1995; E. Petlak, *Všeobecná didaktika*, Bratislava 2004; I. Turek, *Didaktika*, Bratislava 2008.

According to the National Science Educational Standards, scientific literacy is composed of "...knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity"[322]. Stemming from this definition, scientifically literate person is able to find the answers to the questions, which originated in his/her curiosity, explain and predict natural phenomena, read, understand, and be able to discuss natural topics presented in the media, identify natural topics, present fundamental information necessary for the creation of national and local decisions, make use of the data and pieces of evidence used for assessing the quality of natural information and arguments presented by the scientists or in the media. M. Their and B. Daviss[323] define scientific literacy as a set of knowledge about scientific facts and terms associated with the ability to communicate these ideas through language. The authors note that effective learning of natural sciences strongly depends on language competence. Science and language are interconnected in activity, determination and communication of sense in the context of material world.

In the OECD PISA study (Programme for International Student Assessment), the term scientific literacy is perceived as "...the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" [324]. Scientific literacy requires a certain degree of reading and mathematical literacy, and it is assessed by the PISA study as one of the key competencies. Acquisition of literacy is a life-long process, which not only takes place at school, during formal schooling, but also through the interaction of the pupil with parents, schoolmates and the broader community. Therefore, PISA concentrates on the broader understanding of the key terms, and not on the highly specified and specialised pieces of knowledge of particular subjects. The study does not test to what extent the pupils master the studied material prescribed by the curriculum and other pedagogical documents, for knowledge tends to lose its validity very fast in the contemporary knowledge-based society. Therefore, it should be constantly changed and supplemented.

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[322] National Research Council is one of four parts of National American Academy. Its role is to improve education, spread knowledge developing natural sciences, technologies and medicine; National Reasearch Council, *National Science Education Standards*, Washington 1996, p. 22.

[323] Cf. M. Their, B. Daviss, *The new science literacy: Using language skills to help students learn science,* Portsmouth 2002.

[324] National Institute for Certified International Measurements, PI*SA 2012*; http://www.nucem.sk/documents//27//PISA_2012_problem_solving.pdf, s. 29; (dostęp: 16.042016).

PISA defines 6 levels of scientific literacy:

At ***Level 1***, students, who obtained in test a score 335 – 409, have such a limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and follow explicitly from given evidence[325].

At ***Level 2***, students, who obtained a score 410 – 484, have adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving[326].

At ***Level 3***, students, who obtained a score 485 – 558, can identify clearly described scientific issues in a range of contexts. They can select facts and knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and make decisions based on scientific knowledge[327].

At ***Level 4***, students, who obtained a score 559 – 633, can work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of science or technology. They can select and integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and they can communicate decisions using scientific knowledge and evidence[328].

At ***Level 5***, students, who obtained score a 634 – 707, can identify the scientific components of many complex life situations, apply both scientific concepts and knowledge about science to these situations, and can compare, select and evaluate appropriate scientific evidence for responding to life situations. Students at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments based on their critical analysis [329].

At ***Level 6***, students, who obtained a score 708 and more, can consistently identify, explain and apply scientific knowledge and knowledge about science in a variety of complex life situations. They can link different information sources and explanations and use evidence from those sources to justify decisions. They clearly and consistently demonstrate advanced

[325] Cf. Assessment Framework, Pisa 2009, p. 144; *Národná správa OECD PISA Sk 2009*, ed. P. Korsnakova, J. Kovacova, D. Heldova, Bratislava 2009, p. 46-47.
[326]Cf. ibidem.
[327] Cf. ibidem.
[328] Cf. ibidem, p. 46, 50.
[329]Cf. ibidem.

scientific thinking and reasoning, and they use their scientific understanding in support of solutions to unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support of recommendations and decisions that centre on personal, social or global situations. Students whose scientific literacy is on level 5 and level 6 belong to elite and they represents the potential of country for the development of science and technology[330].

In recent years the V4 countries participated in two significant international assessment of the level of scientific literacy – TIMSS in years 2007 and 2011 as well as OECD PISA in years 2009 and 2012.[331] In both assessments, we managed to get about average or even under than average results. The reasons for this unsatisfying level of scientific literacy can be found in the science education in the previous school years compared to other school years, when the pupils were tested.

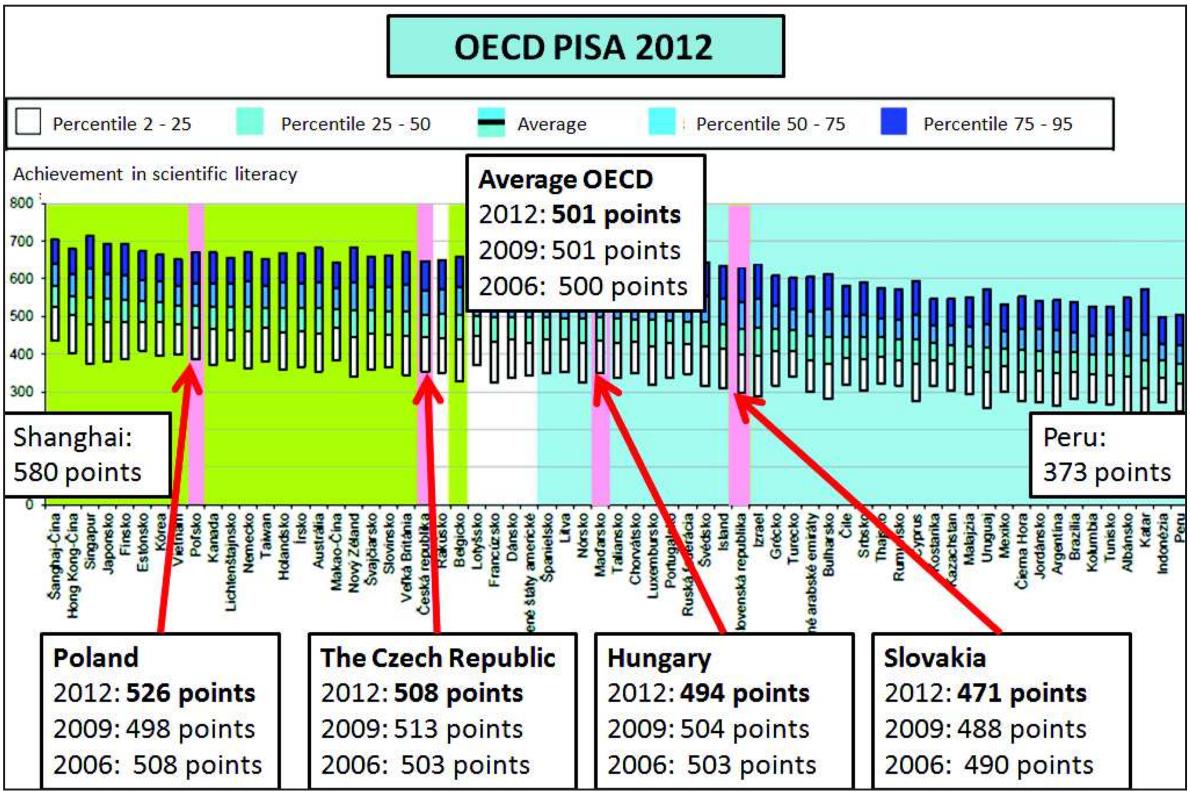

Figure 1 The results of OECD PISA study in 2012 (Source: NÚCEM, PISA 2012)

[330] Cf. ibidem.
[331] When preparing the study they were the last results published.

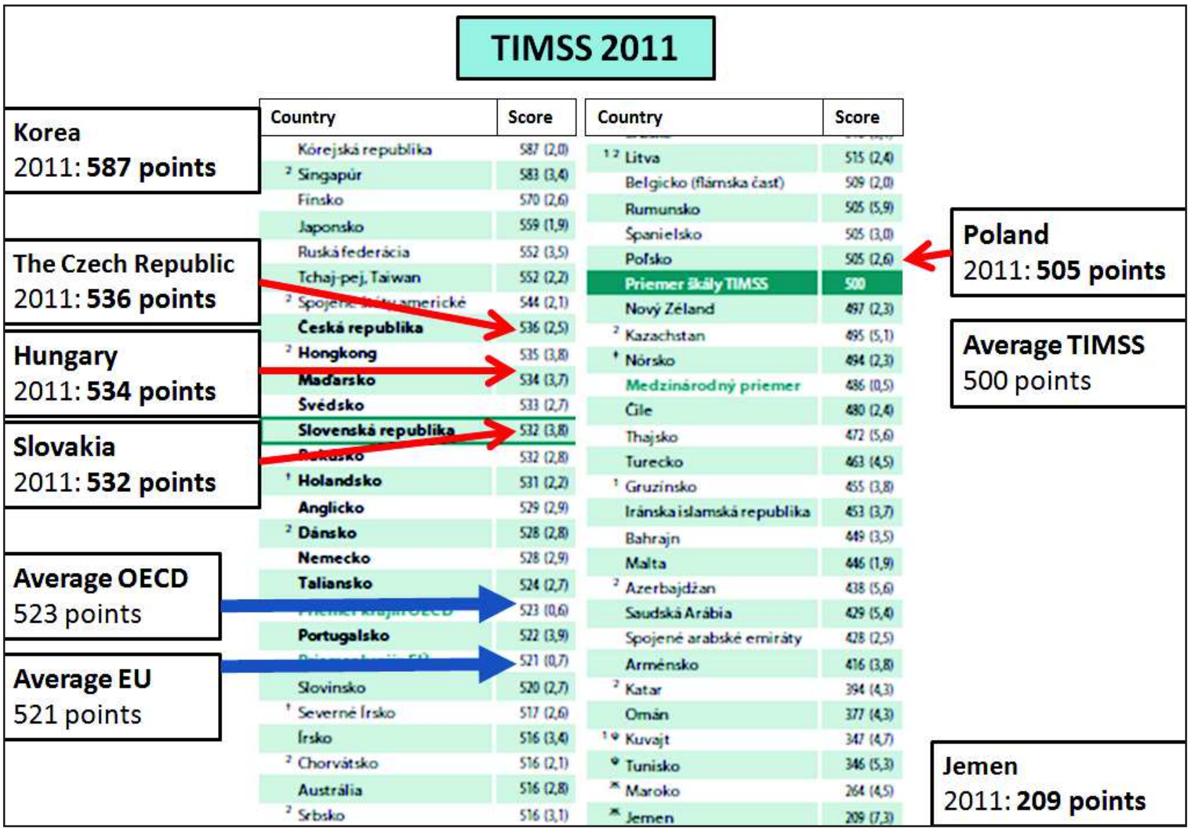

Figure 2 The results of TIMSS study in 2011 (Source: National Centre for Educational Statistics, 2011)

Science education in V4 countries

In the text below we briefly characterize the organization of the science education within the education system in V4 countries which shows similarities with Central European and ex-socialist countries.

Science education is included in the curricula of ***pre-primary education*** in each of the ***V4 countries***. Science learning in pre-primary level of school is focused on the regularities of the surrounding natural reality, on acquiring an elementary knowledge about nature and on achieving qualitative changes in the understanding of the sense and meaning of environmental attitudes. Based on educational standards, the curriculum can, within science learning, be drafted to reflect the seasons, to learn that nature is composed of living and non-living nature, to get to know fauna and flora, to stimulate an awareness regarding the need to protect them, as well as the protection of the planet Earth and its components. It is desirable to deepen the feeling of a need and fellowship towards nature.

In ***primary education*** in the ***Czech Republic***, science education takes place primarily in the curriculum programme *Human and His World*, in the subject with the same title. One of the five themes is entitled *Diversity of Nature*, the others themes are titled: *Place Where We Live*; *People around Us*; *Human and Time*; *Human and His Health*. The last theme also relates to science education.

In Grades 1 – 3 the subject matter from the five mentioned individual thematic areas is integrated into one subject. In Grades 4 and 5 the subject matter is divided into two separate subject areas: the first one drawing on the thematic areas: *Place Where We Live; People around Us; Human and Time* (as foundation for Geography and History), and the second one drawing on the thematic areas: *Diversity of Nature*; and *Human and His Health* (as foundation for Natural sciences).

In the subject area *Diversity of Nature* the following subject areas are implemented: *Substances and Their Properties; Water and Air; Minerals, Rocks and Soil; Earth and the Universe; Plants, Fungi and Animals; Living Conditions; Natural Balance; Conservation and Protection*. The subject area *Human and His Health* consists of the topics such as *Human Body; Health*.

In ***Hungary***, the subject with the title *Natural Sciences* is included into curriculum of primary education and it integrates natural sciences topics as follows: *Methods of Cognition; Basics of Inanimate Nature; Maps and Mapping; Human Body and Its Functions*.

In the first one pupils investigate, understand and describe ideas about commonly experienced natural phenomena. Within the topic *Basics of Inanimate Nature* pupils observe and measure properties of different materials, identify and observe the most common changes of materials and the environment. Within the third topic pupils deal with representation of the most important surface features and water forms on Earth and their identification on the map. The topic *Basics of Animate Nature* relates to the observation of plants and animals in the local environment. The last topic is focused on the identification of the important functions of the human body, learning about common illnesses, personal hygiene and healthy lifestyle.

In ***Poland***, primary school consists of two periods: integrated teaching (Grades 1 – 3) where one teacher covers most of the content across, and teaching subjects (Grades 4 – 6). In both periods, science education is realized within the subject *Natural sciences*.

In Grades 1 – 3 science education relates to the following content: nature in the immediate surroundings, observing and reporting natural phenomena and processes, preserving nature in the immediate surroundings, knowledge about one`s body, health, care and personal hygiene, nutrition, safe use of common technical appliances.

In Grades 4 – 6 the subject is divided into the subjects areas: *Me and My Surroundings; Orientation in Landscape; Observations, Experience Nature and Modelling, The nearest* *locations, Human and Environment; Properties of Substances; Polish and European Landscapes; Human body; Health and Health Care; Electric and Magnetic Phenomena in Nature; Earth in the Universe; Lands and Oceans; Landscapes of the World; Substances Changes; Motion and Forces in Nature*.

In primary education in ***Slovakia,*** science education takes place primarily in the curriculum programme *Nature and Society,* mainly in the subject *Introduction to Natural Sciences*. According to the previous curriculum valid to 2008, the subject *Basics of Science* was taught in first two classes (Grades 1 and 2) in primary school, and it formed the platform for continuous natural science education within the subject *Introduction to Natural Sciences* and social science education within the subject *Homeland* taught at the last two classes (Grades 3 and 4) in primary school.

Currently, the revision of the State educational programme is realized, according to which the curriculum program *Nature and Society* will be cancelled, and, instead of it, the curriculum program *Human and nature* will include the subjects *Basics of Science* and *Introduction to Natural Science*s, and the curriculum program *Human and Society* will include the subject *Homeland.*

The subject Basics of Science includes the topics*: Plants; Animals; Human; Inanimate Nature and Investigation of Natural Phenomena*. The subject Introduction to Natural Sciences implements the topics: *Plants and Fungi; Animals; Human; Inanimate nature and Investigation of Natural phenomena; Natural Communities*.

In ***lower secondary education***, in the ***Czech Republic***, science education is undertaken through the curriculum programme *Humans and Nature*, which consists of the subjects *Physics*, *Chemistry*, *Natural Sciences*, and *Geography*. While the first three of them are strictly natural science-related, the last one consists of both social science-related topics and natural science-related topics (*Natural Image of the Earth*, *Environment*).

In ***Hungary***, the lower secondary education curriculum includes the subject as follows: *Natural Sciences*, *Physics*, *Chemistry*, *Biology and Hygiene, Earth and Environment*.

In ***Poland***, the lower secondary education curriculum includes the subject as follows: *Physics*, *Chemistry*, *Biology*, *Geography*.

In lower secondary education in ***Slovakia***, science education is undertaken, similarly to the Czech Republic, mainly through the curriculum programme *Human and Nature*. This curriculum programme is created by separate subjects *Biology*, *Physics* and *Chemistry*.

In ***higher secondary education***, the situation is very similar in all of the mentioned V4 countries. Science-related subjects are taught mainly at grammar schools, and at the technical schools with natural-science specification, for example, in the fields of forestry, electrical fields, chemical and food and other fields.

Science education can be developed not only at schools, but also in various extra-curricular organisations, and through a number of projects. The project ***Schola Ludus*** can be mentioned. It is a Centre for supporting education towards science and development of life-long learning. Within this project, several programs for pupils, students and public were realized, such as exhibitions, projects for primary school pupils (e.g. *Think, create, show* – see also Teplanová, Biznárová); interest activities for primary school pupils, summer physical camps, conferences and workshops etc.[332]. ***Association for youth, science and technology*** (***AMAVET***) is non-governmental, non-profit, leisure and educational organization for children and youth which deals with developing non-formal scientific and technical education. Other organization titled ***Association of young debrouillards in the Czech Republic*** focused on leisure time activities for children and youth related to developing their abilities and knowledge of science, technique and ecology. In chosen schools in Slovakia, the project ***FAST*** (Project of integrated education of natural sciences) for natural science development of 12-15 years old pupils was realized. The authors emphasized the tendency from reading of text to inquire-based education[333]. At the Faculty of Education, J. E. Purkyně University in Ústí nad Labem, the practical realization of so-called ***Method of active construction of knowledge*** was developed. The method was verified in Chemistry in 8th and 9th classes[334]. The authors proved the need for visualization as an integral part of teaching Chemistry by constructivist methods.

The Faculty of Education, Trnava University, is successful investigator of two projects – Pollen and Fibonacci. The main idea of the ***Fibonacci*** project is the transfer of the traditional school into a modern one by accepting European trends in natural science education. The Fibonacci project is focused on the support of natural science education on the level of teaching and learning in pre-primary education, at the 1st and 2nd grade of a primary school. It is a reaction to a successful project with a similar focus, which was solved as a sixth Framework Programme

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[332] Cf. K. Teplanova, V. Biznarova, Žiacke *koncepcie, ich testovanie a využitie v každodennej školskej praxi*, in: *Inovácia obsahu fyzikálneho vzdelávania*, Nitra 2003.

[333] Cf. B. D. Young, *Nové prístupy vo vyučovaní prírodných vied. Didaktika bádania proti didaktike prijímania*, "Pedagogická revue" 1996, nr 48, č. 5/6; F. M. Pottenger, *Vývoj projektu FAST*, in: *Zborník z konferencie FAST-DISCO,* Bratislava 1997; L. Held, *Skúsenosti s konštruktivistickou výučbou v integrovanom prírodovednom projekte FAST v Slovenskej republike,* in: *Aktivní konstrukce poznání,* Ústí nad Labem 2002; L. Held, B. Pupala, *op. cit.*

[334] Cf. P. Doulik, J. Škoda, *Otázky diagnostiky při výuce chemie metodou aktivní konstrukce poznatků žáka*, "Moderní vyučování" 2001, nr 7, č. 6; J. Škoda, M. Pecivova, P. Doulik, *Studie efektivity účinnosti konstruktivistické výuky chemie na ZŠ*, in: *Aktivní konstrukce poznání,* Ústí nad Labem 2002.

of the European Commission – the Pollen project. Moreover, based on this project, children learn to experiment and develop their abilities to think and argue scientifically.

The idea of the ***Pollen*** project rose up from the solution of the French project ***La main à la pâte*** (Roll up our sleeves). This project is focused on the support of science education, preferring knowledge acquirement by the way of observation, research, investigation, experimentation, mutual discussion, team work and the presentation of the results based on one own experience[335]. The Reference Centre of the Fibonacci Project, in Trnava (with a seat at Trnava University) has an accredited system of trainings set up for teachers in practice, within the research accommodated conception of science education.

The overview of chosen extracurricular projects and organizations is not comprehensive. We mentioned only such examples of projects and organizations which are mainly presented in media.

METHODS USED FOR THE DEVELOPING SCIENTIFIC LITERACY

In science education it is suitable to use all of the didactic methods related to the issue. If we take into account the division of methods into verbal, visual and practical, all of them are effective in the case when we use them in appropriate proportion. The teacher`s task is to encourage the students to apply presented knowledge in practice. Therefore, a student should verify his/her knowledge then he/she could implement it into practice. It means that, a teacher should prefer and use the methods that motivate students to activity.

On the contrary, a university/college student would be able to argue theoretically. Therefore, the methods such as lecture or Socratic dialogue are the essential part in teaching of natural science-related subjects within the university preparation of students.

The effectiveness of a didactic method can be assessed according to the achieved objectives. Therefore; sometimes it is more suitable to have a practical exercise, another time a lecture.

From the concrete didactic methods which are considered most effective by science teachers we can list, for example, activating methods (mainly discovery learning, problem

[335]Cf. M. Nogova, L'.Bagalova, E. Marusincova, *Experimentálne overovanie vyučovania prírodovedných predmetov na 1. stupni základnej školy na základe francúzskej metódy La main á la pâte – Vyhrňme si rukávy*, Bratislava 2006; http://www2.statpedu.sk/buxus/docs/ vyskum/projekt_vyhrnme_si_rukavy/Priebezne_hodnotenie_za_rok_2005_2006.pdf; (dostęp: 24.04.2016) K. Žoldosova, L'.Held , P. Mardelle, *Projekt Vyhrňme si rukávy ako priestor na preskupenie vzdelávacích kompetencií v primárnom prírodovednom vzdelávaní*, in: *Kontexty edukačných vied v dimenziách informačnej spoločnosti*, Žilina 2006.

method, searching problems, planning researches, experiment, seeking information, constructing models, observation, methods developing creativity, panel discussion), verbal methods (mainly discussion, brainstorming, argumentation), visual methods (mainly static and dynamic projection), self-study, work with actual textbooks including foreign textbooks.

Investigative methods are extremely effective in science education, even in the lowest levels of school. Investigative methods include: manipulation, observation, demonstration, investigation, discovering and experimentation.

When *manipulating*, learner gets to purposefully know environment and objects, where he touches, moves and analyses them. Manipulation is connected with activities, such as modelling, constructing, etc.

Observation should be effective; therefore, the teachers' task is to teach learners to observe. When observing, Ľ. Held[336] emphasises the importance of previous knowledge and experiences, as well as the level of understanding of the observed phenomena and on the suitability of the learner's abilities. "The more I understand and know, the more my observation can be successful. Observation should be part of a controlled activity. To acquire purposeful, controlled and concentrated observation is a difficult and long-lasting matter. Therefore, practice is important, where the principle of minimum situation is applied: it is recommended to observe a simple situation in a limited space" [337].

K. Žoldošová[338] explains that for observation we use all the senses and we process the acquired information further. When observing, we consider important aspects to be, the focus of a learner's perception on details, developing the ability to receive and put variables into relationships, monitoring changes in situations after various interventions and comparing them with previously acquired information. She highlights the importance of a teacher asking a learner stimulating questions. The author also explains the difference between the method of observation and a trial or an experiment. "Observation is a method that does not enable actively entering into the observed situation and changing the variables. If we change the variables, it is considered to be a trial or an experiment (according to how we manipulate the variables). Thus, observation is a method that enables us to check our preconditions (hypothesis) based on the observation of a natural situation"[339].

[336] Cf. L'. Held, *Príroda – deti – vedecké vzdelávanie*, in: *Predškolská a elementárna pedagogika*, ed. Z. Kollarikova, B. Pupala, Praha 2001.
[337] Ibidem, p. 357
[338] Cf. K. Žoldosova, *Implementácia konštruktivistických princípov prírodovedného vzdelávania do školských vzdelávacích programov MŠ a 1. stupňa ZŠ*, Prešov 2010.
[339] Ibidem, p. 81- 82.

Also, the method of *demonstration* is connected with observation, where demonstro means "I show". I. Turek[340] explains that teacher enables learners to observe objects, phenomena and processes according to the content of teaching. The observation can be direct (a real object or model, and either a static or dynamic one) or indirect (pictures, photographs, films…). The aim is for the learners to understand the principle of the observed object or phenomena. Therefore, it is necessary to connect demonstration with the teacher's interpretation. It is suitable to show learners first the complex object or phenomenon and gradually to simplify it in the course of demonstration, until the principle discussed in the curriculum is reached.

The investigative method of observation is followed by an *experimental method*; however, in the case of experimenting, a conscious interference of the experimenter into reality is necessary. It is necessary to secure the following:

- a precise description of the object of the experiment before interference,
- a precise description of the interference into the object of the experiment,
- a precise description of the object of the experiment after interference[341].

Ľ. Held [342] points out that during investigative methods and activities learners express a precondition that does not have any support in its theoretical reasoning, with experimental methods some hypotheses are connected that have meaningful theoretical reasoning. Part of the experimentation is the identification of variables that can influence the results of the experiment.

Specific signs of an experimental activity in education are defined by Ľ. Zelenický [343]:

- educational adjustment of an experiment (definition of monitored connections and regularities),
- learner's activity when acquiring information,
- sufficient scope for feedback,
- support of logical working processes for memorising,
- an interest in the tasks and developing creativity when solving them.

K. Žoldošová[344] puts forward the following requirements of a natural science experiment:

- to formulate a question so that it would not require only a bipolar answer,

[340]Cf. I. Turek, *op. cit*.
[341]Cf. J. Manak, *Nárys didaktiky*, Brno 1995.
[342]Cf. L'. Held, *Príroda – deti ...*,op. cit.
[343]Cf. L'. Zelenicky, *Moderná experimentálna činnosť žiakov*, in: *Vybrané problémy z didaktiky prírodovedných predmetov*, Banská Bystrica 1999.
[344]K. Žoldosova, *Implementácia konštruktivistických princípov...*, op. cit.

- the possibility to find at least two answers to a question,
- the problem's topic should regard real world,
- a clear studied problem,
- to focus only on one studied thing,
- to secure the explicitness of the problem solving.

CONCLUSION

Modern society is characterised by extremely fast growth of new technologies, information and information sources. Therefore, people who want to be successful on the job market should be competent and literate in such information environment, i.e. they should have the knowledge, skills and abilities adequate for the 21st century. Preparation should begin with pre-primary and primary education, which would help children and pupils from an early age to obtain and develop competences enabling full inclusion in life and society. This, however, requires teachers literate for the 21st century who would have such competences and would be able to give children and pupils fundaments of such competences as platforms for their further development.

The aim of education for the 21st century is the developing key competences of children, pupils and students. Such competences stem from Delors[345] and his generally accepted formulation of education aims – learn to learn, learn to act, learn to live together and learn to be. European programmes for the support of education are united in the aims of education which include acquiring of key competences including basic competences in science and technology. On the other hand, it can be stated that science education in V4 countries has been emphasized collection and reproduction of theoretical pieces of knowledge more than the essence of scientific research and thinking. According to opinions of professionals on natural science education of young school-age pupils (e.g. Melicherčíková, Kopáčová, Durell, Lorbeer, Nelson, Glover, Held, Pupala, Wiegerová, Žoldošová, Podroužek, Senćanski, Stawiński and others) is the process which should include such activities enabling the pupils to use the acquired knowledge in new situations which would develop their competences in problem solving.

[345] Cf. Deloros J., *Učení je skryté bohatství vzdělávaní pro 21. století*, Praha 1997.

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