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Finding out how the elementary school children manipulate with empirical material and how they process the obtained information

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Abstract
The article is aimed at a partial problem of science process skills development – the evaluation of educational outcomes. In comparison to evaluation of obtained knowledge, the skills development is not so easy to be objectively evaluated. The article provides a proposal of an evaluation tool and describes the first results of its research utilization. The described research tool is applicable especially when we would like to consider whether using of inquiry based science education at primary level has a required impact on pupils' science process skills or not.

Keywords: basic science process skills, causal thinking, empirical thinking, primary science education

Introduction

Until recently, most of researches in area of children's science preconceptions have been posed into descriptive methodological frame. The main idea was an understanding difference between preconception and the mature concept (Piaget, 1929). We have found out much information about how the preconceptions look like in different aged children and different topics of interest (e.g. young children preconceptions or alternative

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conceptions about prenatal development and human body in general, or animals: Bernstein & Cowan, 1965; Kreitler & Kreitler, 1966; Nagy, 1953; Prokop, Kubiatko & Fančovičová, 2007; Prokop, Prokop & Tunnicliffe, 2008; Žoldošová & Prokop, 2007). If we are able to move in the research activities from the mentioned descriptive to a procedural position, we could probably register a movement in understanding of the childreǹ s spontaneous learning and it will allow us to apply gathered findings and results into innovations of primary science education. For example, the gathered findings (from the descriptive researches about childreǹ s naive conceptions) allow us to consider whether the systematic education does or does not have a noticeable influence on desired science conceptions development. On the other hand the same findings are not giving us information about how the educational environment (within its methods, conceptions, used tools, etc.) needs to be changed to get more accurate results. On the contrary, if we are able to get information about the cognitive process the children use while they are operating the registered information, we should get relevant information which allows us to consider whether actually used educational methods are suitable or not. It means that we should try to move from description of preconceptions to investigation of how the children manipulate with information, especially in a form of empirical data processing. The same tendency of desisting from the educational content and approaching to educational process is noticeable not only in the research area (see researches aimed at science process skills: Beaumont-Walters & Soyibo, 2001; So, 2003; Bilgin, 2006; Etkina, 2007; Lawson, 2004; Mattheis & Nakayama, 1988; Monhard & Monhard, 2006 and others), but also in the primary science education process itself (Eshach, 2006). In to the bargain the mentioned tendency is tied with all-European interest for the science revival (Rocard et al, 2007). The main target of primary science education is aimed at development of cognitive skills which allow pupils to work with information of different kind and build up broadly effective knowledge system which is not only open for changes, but we can say that it almost awaits changes. Teachers´ effort to find suitable evaluative tools in area of cognitive skills development is a really natural consequential process. Teachers should be offered something effective and verified.

These are only very briefly designed main reasons why we have decided to concentrate not on the content of the preconceptions but on the process of its modification. This article tries to make the mentioned tendency visible and also to design prospective research methodology (including the research tools) that can make clear at least one way of approaching to this kind of the research purpose. And the last but not least, the article tries to show the teachers the principle of science education skills development.

Developing science process skills at primary level

Primary level children constantly create and modify their conceptions about surrounding reality. In these operations with empirical information it is quite inevitable to use science process skills. Science process skills are one of the most relevant tools of making and arranging information about world around us. Children use these skills to obtain new information and process them. If the skills are applied adequately we can acquire information effectively and create an information system open for changes. This shows that it is possible to influence children's preconceptions via effective and systematic development of science process skills. A child starts to perceive the ordinary reality more scientific way meaning that the child starts to be unsatisfied with descriptive information about reality and he/she very naturally starts to search for causalities and principles of the observed phenomena (and this is one of main goals of science education).

The theory of science process skills development is very complex. Practically we should speak about one complex skill which includes many partial skills. Some of them are more common and some of them are very specific; nevertheless they are always used together. That is why we can deal with particular skills only in a theoretic level. Practically they are closely connected with other parts of scientific literacy (science preconceptions, science attitudes, etc.) and it is impossible to separate them. If the teacher would like pupils to manipulate with their preconceptions he/she not only needs to know the pupils' preconception (Akerson, Flick & Lederman, 2000) but it leads to use pupils' science process skills. We cannot develop an individual skill separately. A child cannot solve the task while using just one particular skill. He or she needs to use the whole complex of skills to solve it successfully.

We (and also the children) possess numerous skills, but we use them only spontaneously and subconsciously. It means that the skills are developed in a very slow and ineffective way. Via directed development we can assign more targeted utilization of the skills and this can lead to getting more objective information and to more objective way of working with the information and get new, really disposable knowledge.

Science process skills are significant for meaningful learning as well; it involves linking new experiences to previous ones and extending ideas and concepts to include a progressively wider range of related phenomena. If these skills are not developed sufficiently, pupils cannot interpret knowledge, for example, relevant evidence is not collected, or conclusions are based selectively on those findings confirming initial preconceptions and ignore contrary evidence, then the emerging concepts will not help understanding the world around. Thus the development of scientific process skills has to be the major goal of science education (Harlen, 1999).

Science process skills can be defined as a utilization of methods and procedures of scientific investigative thinking (Bilgin, 2006). Padilla (1990) defines science process skills as a set of skills that reflect scientists' behavior. According to Hollins and Whitby (1998) science process skills are understood as a combination of skills and procedures practiced and used in scientific investigations. We can say that science process skills lead us to thinking in a specific way common for investigative thinking.

Science process skills are divided into two categories according to sophistication of its utilization: basic science process skills (BSPS) and the integrated science process skills (ISPS). There are five science process skills integrated into the category of basic science process skills; even though the exact separation is not possible and is done only in theoretical meaning: *observing, inferring, predicting, classifying, measuring and using space and time relationships***.** Similarly we can recognize nine integrated science process skills: *identifying and defining variables, collecting and transforming data, constructing tables of data and graphs, describing relationships between variables, interpreting data, manipulating materials, formulating hypotheses, designing investigations, drawing conclusions and generalizing* (Colvill & Pattie, 2002; Beaumont-Walters & Soyibo, 2001).

The basic science process skills are prerequisites for development of the integrated ones. The BSPS are used for arrangement and description of natural objects and events. They are attributed to empirical-inductive reasoning or Piagetian concrete operational reasoning. The ISPS are the terminal skills for problem solving, arranging and operating scientific experiments. These abilities are attributed to hypothetic-deductive reasoning or Piaget's formal operational reasoning.

While the skills are developed we should be respectful of children's cognitive level. We should support only the skills with real possibility to be developed. During pre-school and primary education we should pay attention to development of basic science process skills (it mainly means starting with empirical investigation based on observational activities with descriptive result and then proceeding to search for questions and deal with searching for empirical answers). After that we can consecutively start with development of integrated science process skills (it mainly means to set a hypothesis and to search for experimental way of testing it).

The ways of developing the skills are described in many publications (the most of them are dealing with Inquiry Based Science Education). Even though it is a very important topic, at this stage we would like to concentrate on a specific problem which flows out of an implementation of this educational attitude – evaluative process of progress in science process skills development. For this reason we have designed a research tool which tries to measure science process skills and uncover potential problems with usage of the skills. The evaluative tool is based on observation of how pupils manipulate with reality and how they deal with answers on different kind of questions (empirically based, causal and applicative ones).

Before we approach to the research tool clarification we will try to explain the way we should lead the pupils in their investigations to be better developed in science process skills. The below described activity is an active part of the research tool.

Example of an activity aimed at developing the science process skills (research methodology frame)

For example, we set these problems for solving: What is the shadow? How is the shadow made? The required investigation is aimed at changing the shadow depending on the light source and the way the light flows. All the pupils (divided into 4-5 member groups) will get the same instruction (level 0): Stand the nail on its head in the middle of the sheet of paper. Take a torch and light up the nail in some angle from distance of few centimeters. Mark the length of the shadow the nail has created on the paper. Try to observe more the way the length of the shadow changes depending on the changing way of a light exposed. Pupils should get as much time for the empirical investigation as they need. At the end the pupils are asked to formulate their findings. The pupils are verbalizing what they perceive as the most important information and what they perceive as a result. Verbalization of the results is very important. It is as important as the sharing of the results with other schoolmates.

In order to initiate pupils' further investigation, the teacher asks different questions (the formulation of the questions below has been inspired by researches of light and shadow preconceptions at preschool and primary age: Chen, 2008; Fleer, 1996; Driver, 2002). The main target is to clarify the conception and the additional target is to provide with children a thinking pattern. Theoretically we can divide the question into 3 groups, or better said levels, because by posing the questions we are forcing the pupils to use different cognitive skills. The first level is aimed at pupils' empirical investigation. It is possible to answer all questions only on the basis of empirical data the pupils have gotten. We can find out, whether the pupils are able to observe the phenomenon and whether they are able to notice the principles or the basic aspects of the observed situation.

1st Level

How would you make the shadow longer or shorter? How is it possible to make a shadow with direction to the right or left? Think about how you have to move the source of light in order to turn the shadow to the wished direction. Try to describe the findings. Does the shadow length depend on the angle the torch is shining on the nail? If you wish to make the shadow shorter, what do you need to do with the light? What do you have to do with the light (or with the nail) if you would like to make the shadow longer? Does the shadow length depend on the distance between the nail and the light source (the torch)? Are all shadows equally dark?

The second level is aimed at guiding the pupils to recognize causal relations. The questions are aimed at recognition of different relations in the stimulating situation. It is interesting to notice, whether the pupils are answering the questions without further investigation or they have tendency to search for the answers in the empirical manipulation. The second valuable thing we should notice is whether the pupils just guess the answers without arguments or they try to pose more valuable prediction or the most valuable hypotheses.

2nd Level

Give the torch to your schoolmate. The schoolmate will take the switched-off torch and point with it on the nail in some random angle and distance. Try to draw on the paper under the nail the direction of the shadow the light will make after the torch is switched on. Try to explain your prediction. Switch the light on and verify your prediction. Would it be possible for you to make successful predictions also about the length of the shadow? Why is the shadow of the same nail sometimes longer than other times? How does the length of the shadow depend on the angle between the nail and the light source (the torch)? Try to explain why you think this way (try to draw a scheme in which you demonstrate how the light travels from the torch to the nail and the paper under the nail). Describe how you should light on the nail with the torch in order not to make any shadow and explain why the shadow does not create.

The third level is aimed at pupil's ability to apply knowledge – it means that the questions are forcing the pupils to recognize principal matter and to create a transfer to a different situation with the same principal matter. Eventually the questions are asking the pupils to explain the observed phenomenon through different situation mediation.

3rd Level

Cover one of your eyes with a palm of your hand and observe the nail with the second eye. Try to observe it from overview. Try to draw as you can see it. Then try to look at the nail the same way but sidelong and draw the nail again – how you see (perceive) it now. Be sure you keep also the disproportions of the nail. The third drawing will be made from slantwise view. Compare the drawings and try to find differences and represent them. How does the shape of the nail change when you try to look at the nail from different points of view? Try to generalize your findings. What is the shadow? What is the similarity of the shadow and the darkness? Where are the shadows made? Where you cannot find any shadows? How are the shadows made in a room with few light sources? Is it possible to make more than one shadow of one object? Try to explain where, how and what you need to make them.

A shadow is a reality we have so much experience with. But because this and also because of the conception difficulty we usually think how much we understand it, but when somebody asks us to define or explain it we find out it too difficult and whole idea about shadows immediately seems so vague. It is quite easy to explain what the shadow is, but only in case we have already understood the rules, laws and principles of light travelling. Finally the understanding depends on how we understand the conception of light (mainly the differences between properties of light and properties of matter).

The conception is continuously modified while we are unconsciously using similarities of the analyzed reality with the previous experience. For example, very typical is a spontaneous application of a conception about flowing matters consisting of small particles – like sand or water. It is very important to realize that usage of these ideas is very spontaneous, that is why we usually do not realize that we are comparing reality with something we already know. Only in case when we are led to use examples or we are led to explain how we perceive the phenomena we can start to recognize what kind of generalized idea we are using. In this case we can also enrich or modify both ideas – the already existing and the newly created one.

If we are trying to verbalize our idea about the phenomena explanation, or much better, if we are trying to schematically draw the situation, the concrete reality and the manipulation with it will help us less than abstract manipulation. If the new knowledge (idea) has been created via abstract manipulation, we need to verify it and usually we are approaching back to empirical investigation. We need the reality to prove the functionality of its explanation concerning the reality. For example, we can create an idea that light behaves like flowing particles of sand. Some particles hit the obstacle (nail) and are driven back or driven in different angles; some of them change their flow direction minimally. None of the particles can get closely behind the nail. If we use this analogy, we can explain shadow existence as an absence of light. If the conception was build up this way, also usage of concept *shadow* can be enriched. For example, we can use the *shadow* as a concept that tries to explain function of safety shield. In cases of different angles of arrival the safety shield can provide a *shadow* of different sizes.

Abstract manipulation with conceptions provides possibility for clarification of those concepts we have used for the explanation. Very important aspect of this process is hidden in enriching the possibilities of applying the idea on different kind of realities – the concepts become more general. For instance, we can take an idea about matter particles movement. The idea can be created via observation of some matter hitting different kind of obstacles (sand or water on an umbrella or on a roof). This idea can be transferred from this phenomenon to different ones with similar basic attributes – the presence of some matter before an obstacle and absence of the matter behind the obstacle.

Even though the whole activity is aimed at clarifying the idea of a shadow (whereby also the idea of light is enriched); we do not need to perceive this goal like a decisive one. With a good guidance the pupils can develop their observational abilities, abilities of generalization, or ability to construct a test of a prediction or hypothesis.

At the aforesaid first level of the conceptions clarification we can aim the activity at development of observational ability. Children are observing well known phenomenon and it is very interesting to verify a validity of the ideas the children already have. For example, they can realize and express the empirical generalization that the shadow has the same shape as the object before the shadow. The tendency to generalize the empirical data is naive and spontaneous. If we would like to develop new abilities we should ask more questions. For instance we can ask the pupils to explain, why the shadow has the same shape as the object does. Pupils on the first level with emphasis to empirical searching usually have a problem with answering this kind of question. Either they do not understand why the shapes are the same, or they understand but the verbalization of the idea is too difficult for them (nobody has ever asked them to express something they learn via experience). If we are forcing the pupils to verbalize their ideas, we are also forcing them to analyze the observed attributes and to clarify the observed details. Simply said, the child is driven to create causal knowledge via factual knowledge through the use of cognitive manipulation which is developed just with this process.

If we would like to develop mainly the observational abilities (1st level; preschool age), we should focus pupils attention at the connection between some observed changes on the phenomenon and the intervention they did. Realizing the logical connection between the result of the changes and the way how and what they have intervened is a meaningful first step to development of causal thinking. For example, if the child moves the light source to the right, the shadow will move to the left. Even though the child can predict this also without doing that only on a basis of previous experience, if we tend to force the child to express the prediction before the realization and express the result after the realization as a verification of the prediction, the spontaneous assuming can become more intentional and conscious. These are suitable circumstances for cognitive development – to change spontaneous cognitive operation to intentional ones.

Realizing the connection between the phenomena changes and the interventions is transformed into different situations. In this case the child can much better understand everyday's situations and in context of this the child can get much more material (information) needed for further creation and modification of more developed ideas.

The first level of the concept clarification is very important, because the children can develop their ability of generalization. The ability of generalization means that the children can create summary principle of phenomena (or attributes of one phenomenon) which are in some kind of connection. For example, the child can make a generalization about relation between angle size and shadow length (larger the angle, smaller the shadow). Even though the generalization is very spontaneous, verbalized version can contribute to cognitive development.

There is a very narrow connection between this ability and ability to select exceptions and on the other side to include relevant, even though not very expressive attributes or details. For example, in this activity the children very often make a generalization that the length of the shadow depends also on distance between a light source and an object (nail). The incorrect generalization is made mainly because the shadow starts to be not so expressive (very faded) when we prolong the distance between the light source and the object. Simply, the children incorrectly mark the end of the shadow. Furthermore, it is quite difficult to hold the torch in the same direction (angle) and change only the distance without any helping tools (stand and so on). These measurement errors, exceptions and empirical details are more difficult to be objectively evaluated. The incorrect generalization can be tested, but for pupils in the first level it is very difficult to create suitable tests.

It is evident that we should offer the preschool children mainly that kind of situations where they cannot be lost in data and do not move out of the preconceptions. On the other side, if the children cannot experience also situation with polemical generalization, very soon they can start to perceive the experimental results as absolutely valid. This is neither a good educational nor the scientific target.

In the second level of concept clarification we are aimed at development of causal thinking and causal knowledge (primary level of school education). This level stands at the beginning of abstract thinking. At the first phase we are aimed at experience systematization and comparison of their essential attributes.

After asking few questions children start to search in previous experience for similar phenomena. They are trying to search for such experience which is reminded by the actually experienced situation (for example – few shadows of the same object on the football stadium or under streetlights). It is useful if we are trying to analyze all these experience concerning the inquired situation, because the experience is an excellent material for verifying the validity of actually constructed predictions or newly constructed conceptions about how the situation works. For example, if we create a prediction that more shadows of one object can be present in a room where more than one light source is placed; the proposition can be supported by experience with evening walk under streetlights. While one shadow disappears the second becomes darker. It is very important to have enough experience with different phenomena (that is why the first level in preschool age is so important) if we want the children not only to construct the prediction, but also to accept it. The acceptation of the result happens only when the new construction is compatible with previous experience. The experience is empirical in its principles and that means that experience is as much objective as the empiricism is. For comparison, abstractly constructed hypotheses (explanations, ideas ...) loose the objectivity.

The third level (represented by secondary education) is aimed at application of the modified knowledge. In the second level the pupils are led to argue about their ideas and constructions and this way the constructions (knowledge, ideas) get their stability. The third level is aimed at application of these constructions on different situations. More important meaning of this level lies on a solutions design. Practically it means that if the child makes a hypothesis about how the light flows around objects, he or she will be able to use this idea when he/she is trying to design a definition of "shadow". This level is principally about awareness and utilization of the basic principles of the main concept (how the light travels). For example, if the child realizes that the shadow making relates to directness of light flow, he or she will be able to draw an explanatory scheme about how the light hits the nail from different directions (different light sources). Than we can read out of the scheme (drawn or only cognitively constructed in mind) that theoretically the length of the shadow cannot depend on the distance between the object and the light source. This finding is a good starting point for re-evaluation previous generalization and the child can consider whether the first prediction was caused by measurement error or it was correctly measured and evaluated result. This way the child's ability for sensitive reaction to some findings can be improved.

Methodology

The target of the research is the construction of suitable research tool (tool ought to be as simple as possible and at the same time ought to offer objective evaluation) that is able to identify a level of science process skills development. The research tool is going to diagnose those cognitive skills which are used in a process of practical modification of the pupils' preconceptions. It is quite evident that the way the pupils manipulate with the empirically obtained information can be investigated only indirectly, using qualitative research methodology. The core of the research tool is based on structured observation of pupil's empirical activity and supported by semi-structured interview (in Paget's conception). We have used the situation, which leads the pupil to investigate chosen phenomena described in the previous paragraph of this article. We have chosen phenomena the pupils have a lot of experience with and in spite of that they have never intentionally investigated it (shadow, mirror reflection). While the pupil investigates the phenomenon, the researcher asks the pupil questions which lead the child to search for more information and to think about what she/he is actually investigating. The questions are divided into 4 levels depending on its difficulty within the context of cognitive skills the pupils have to use in order to construct an answer.

Research investigation starts with stimulating situation (0) constructed for the pupil to reinitiate his/her process of thinking about the phenomena. The pupil manipulates with the light source and the object to observe the shadow. The researcher asks the pupil questions. There are 3 levels of question difficulty. The questions of the first level (1) are aimed at description of the observed phenomena. The questions of the second level (2) are aimed at searching for causality and explaining the functioning and the third level (3) is aimed at constructing principles and applying the principles on different situations based on the same principles.

Tasks are divided into four different levels. Each group of questions is aimed at identification of specific skills. The items of level 0 and 1 are specially oriented to trace the basic science process skills (BSPS) which gradually approach to the integrated science process skills (ISPS) in the 2nd and 3rd level. Of course, we cannot say that pupil uses just one skill to solve one task. Therefore we concentrated on that skill (sometimes two skills) which is used in a concrete task the most.

If the pupils are able to answer all questions of the first level we can predict that the pupils are able to specifically and intentionally observe the phenomena and that their observation has been detailed. In addition we can consider, whether the pupil is or is not able to select the principle aspect of the phenomena and on its basis to verbalize suitable results of detailed observation.

If the pupils are able to answer all questions of the first and second level we can predict that the pupils are able (and also have a tendency) to explain observed reality, to link causal information and to create objective and generalized information.

If the pupils are able to answer all questions of the first, the second and the third level we can predict that the pupils are able to match new information with previously generalized information, they are able to create meaningful statements which can provide suitable explanation in a theoretical (abstract) form. Finally they are able to recognize actually generalized theoretical principle in different situations (for example in previously experienced situations).

All the research meetings with the pupils had been recorded and further analyzed on the basis of defined categories (see Appendix). The categories have been constructed following the pupils partial observable abilities (skills). After ranging the observed skills the chart of the categories provides results which represent a measure of the pupil's science process skills. The partial categories have been ranked following quality of the pupil's answers together with quality of pupil's manipulation with reality while she/he was searching for the suitable answer. That is why the researcher needs to pay attention not only to the simple answer to posed question, but in parallel also to how the pupil handles the reality, while he/she creates the answer.

It is important to be aware that the research is not aimed at finding out whether the pupils get a correct knowledge or not. It is aimed at how the pupils manipulate with empirical information. If any of the skills (included in twelve categories C1 – C12) is not identified, we should assign 0 points for the relevant category. If the skill is identified, we should express a level of the skill quality in the range (for example in the category C1 we can identify measure of generality or strictness of the pupil's observational activity).

The items of level 0 (C1-C2) are ranked on the basis of stimulating situation realization and forming conclusions out of the realization. The first category (C1) speaks about pupil's ability to observe the phenomena and manipulate the reality to get as much information as possible. For example, for ranking the category we need to consider amount of noticed details and its essentiality. First task is focused on a utilization of an observing skill (BSPS). The second category (C2) identifies ability to verbalize suitable conclusion based on the phenomena principle. To solve this problem a child needs to use an inferring.

Further the researcher starts to ask 1st level questions. While and after getting the answers the researcher can range the pupil's skills into the corresponding categories (C3 – C5). The main target of these categories is aimed at evaluation of the pupil's empirical investigation skills. The category C3 (it involves predicting and inferring to handle the item correctly) evaluates the pupil's ability to answer questions without using further investigation or with further investigation used for arguing for her/his answers (it means that pupil explains the answer and at the same time supports the answer by demonstrative manipulation with the reality). The category C4 evaluates the pupil's ability to be aimed at principal aspects of the investigated situation. And to a certain extent the C4 category measures how exactly the pupil has answered (comparing the content of the answer with the requested content of answer – what the question asked for). This task is oriented on using a classifying skill in the way of separation significant and insignificant aspects. To solve a problem in the category C5 a measuring needs to be used. It completes the previous category by measuring how the pupil is able to analyze the investigated situation into its details using goal-directed investigation while the pupil constructs own proceedings to get as much information as possible. The last category (C6) of empirical investigation measurement evaluates the pupil's tendency to move from simple description of what has been seen to interpretation (or explanation). We should emphasize that we are evaluating only tendency to move mentioned way, it means that the interpretations have to be recognized as a pupil's spontaneous activity, not as an answer to question which requires the explanation. In this category a child needs to interpret data (part of ISPS), and it involves predicting from the BSPS as well. The

C6 is a transitional category because it combines a utilization of BSPS and ISPS as well.

The second level of the questioning evaluates how the pupil is able to recognize causality in the obtained information. Category C7 identifies if the pupils are able to create hypothetic answers without further investigation. It is important to mention that in the empirical investigation elaboration of causal tasks requires construction of experiment (constructing hypotheses (ISPS) or predicting (BSPS) needs to be used to get lower score). The C8 category measures whether the pupil tries to explain what has been seen in a causal way or not (whether description of relationships between variables is used or not). If the researcher cannot recognize this kind of pupil's effort, the pupil still can get some points in this category, but only for ability to identify principal aspects of the situation. The last category (C9) of the second (causal) level of questioning is aimed at measurement of ability to argue for the pupil's declared hypotheses or empirical generalizations (interpreting data and drawing conclusions are used). The category determines a level of pupils ability to explain observed reality in logical way following the empirically obtained information or/and previously obtained knowledge.

The level of application tries to measure how the pupils are able to use all information they have at their disposal to create explanations, characteristics of principles and how they are able to apply these principles and explanation on different situations based on the same principles. The 10^{th} category (in C10 making hypotheses is required) is aimed at pupil's ability to search for relations between what is currently observed and what he/she already knows, because some of the pupils might have nothing but tendency to define the main principle of the observed situation.

The next category (C11) specifies how the pupil is able to search for examples which can validate and confirm the created hypotheses. It is important to consider whether the pupils are really offering to confirm experience or they just search for visually similar situations. We can assign the points only if the pupil mentions different previously experienced situations and has a tendency to use them for clarification of the recognized principle. If the pupil is not able to interpret logical relation between observed situation (its principle) and some of the mentioned previously obtained experience or knowledge, we cannot assign any points, because this is not application or synthesis, it is only (very often subconscious) word association and it has nothing in common with abstract thinking as we would like to identify and measure it (we are identifying ability to generalize results).

The last category (C12) identifies how the pupil is able to elaborate general conclusions as a part of the ISPS. At the very best the elaborated general conclusions should describe the basic principle of the observed situation in a way which allows us to use it for explanation of many other different situations. If the pupil is able to identify the principle of the observed phenomena but for the explanation he/she uses only actually observed situation, we will assign less points. For example this can happen if the pupil is able to draw a scheme of the observed phenomena with essential characteristics included, but he/she is not able to eliminate those characteristics which are typical for the observed situation, but are not principal.

Generalization of results: If the pupil obtains 0-6 points we can say that his/her observational skills are not developed enough to provide him/her as much empirical information as required for making explanation of the observed situation. It means that pupil's skills to realize scientific observation should be developed first. If the pupil gets from 6 to 22 points, we can say that he/she is able to make detailed observation, but without tendency to start the causal analysis of the obtained information. These pupils are able to generalize even though they still do not dispose with causal thinking. If the pupil obtains from 22 to 48 points, we still cannot say that the pupil disposes with abstract thinking, but his/her tendency to explain what he/she observes is apparent even he/she is still aimed at observed evidence. If the pupil gets 48 – 78 points, he/she disposes with abstract thinking and is able to make descriptive hypotheses, even though he/she is still not able to make application (to make connections between observed situation and previously experienced situations following the recognized principle). If the pupil gets more than 78 points, we can say that he/she is able to make application of the recognized and generalized principle.

Sample

The tool is going to be used in a sample of 10 primary pupils aged 8-10 in Slovakia. The simple size is in coherency with our main intention which is oriented to proposal of a suitable research tool. We wanted to appoint that in a case the pupils are not systemically led to develop the science process skills we cannot recognize any differences between pupils of lower classes and pupils of higher classes. 6 pupils are from 3rd grade and 4 pupils are from 4th grade of the same school oriented to classical education. The compulsory education starts in Slovakia in the age of six.

Results

The results show us that the children who have participated in our research have SPS differently developed. Even though the arithmetic average has got value of 60.5 point for pupils from 3rd class and 61.3 for pupils from 4th grade (no significant difference has been found), the standard deviations indicate a presence of qualitative differences in the SPS evaluation (the best score has been 94 and the worst has got value 29). After considering the data from the correlation matrix we can form a conclusion that the respondents have differently developed science process skills and the differences are not related to the class grade. We found significant correlations between pupils of 3rd class and 4th class as well as within the assigned groups; for lover or opposite correlation the same (see Table 1 – correlation matrix).

Table 1. *Correlation matrix expresses correlations between 10 respondents in the evaluated categories (C1-C12). Highlighted numbers are correlations significant at p < 0.01.*

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9
R_1									
R_2	0.051								
R_3	0.364	**0.890****							
R_4	**0.620***	0.287	0.475						
R_5	**0.634***	**0.672***	**0.812****	0.494					
R_6	0.227	0.079	0.171	-0.240	0.418				
R_7	0.306	**0.927****	**0.914****	0.361	**0.827****	0.256			
R_8	-0.069	0.204	0.248	-0.581	0.270	0.478	0.235		
R_9	0.264	-0.247	-0.188	-0.338	0.207	**0.585***	-0.084	0.459	
R_10	0.406	0.142	0.314	0.006	**0.521***	**0.620***	0.315	0.434	0.264

R_1 – R_6 are respondents from 3rd grades; R_7 – R_10 are respondents from the 4th grade

Considering the target of this research, the qualitative analysis of the differences is more interesting and important. We would like to pay an attention to a distribution of obtained scores between the assigned levels of the evaluated skills. As you can see in the Table 2 and 3, some of the respondents have got very high score in the empirical level (level 0 and 1) and further not so high score in causal and application level, but we cannot find respondents which have got higher score in causal and application level and lower score in the empirical levels. Another interesting result is that some of the respondents do not get enough high score in a causal level, but they have got quite a high score in application level. It means that it is easier for the pupils to identify coherences and similarities between observed phenomena and their previous knowledge than to identify causal relations and create causal knowledge (for example, it is easier for them to create answer for an application question: *What is the similarity of the shadow and the darkness?* as for a causal question: *How does the length of the shadow depend on the angle between the nail and the light source - the torch*?).

Table2. Percentual formulation of the SPS evaluation in the assigned 4 levels – 6 respondents of 3rd class

	R_1		R_2		R_3		R_4		R_5		R_6	
level 0	9/10	90	10/10	100	10/10	100	8/10	80	6/10	60	7/10	70
level 1	12/20	60	11/20	55	12/20	60	12/20	60	4/20	20	9/20	45
level 2	16/30	53	18/30	60	13/30	43	11/30	37	11/30	37	9/30	30
level 3	20/40	50	29/40	73	31/40	78	25/40	63	15/40	38	12/40	30

Table 3. Percentual formulation of the SPS evaluation in the assigned 4 levels – 4 respondents of 4th class

	R_7		R_8		R_9		R_10	
level 0	10/10	100	10/10	100	8/10	80	6/10	60
level 1	13/20	65	14/20	70	11/20	55	4/20	20
level 2	21/30	70	21/30	70	15/30	50	7/30	23
level 3	35/40	88	12/40	30	12/40	30	6/40	15

Three children have got their score in a range 22 - 48 (R_5, R_6 and R_10). According to process of qualitative evaluation (designed in methodology) we point out that these pupils still do not have their abstract thinking well developed. A child who reaches this level is not able to think in a causal way. It is important to mention that all of these children have achieved only 2 or 3 points in a category 1 (where the pupils needed to get empirical information for further processing). We can say that the pupils have not observed the reality well enough and this fact created a barrier for using the other skills which directly depend on information acquired in observational process. Therefore they could not get better evaluation in the next tasks (upper levels).

Four children have got their score in a range 49-78 (R_1, R_4, R_8 and R_9). These pupils are able to use ISPS fractionally, because they still quite significantly incline to empirical information (in the causal and the application level they have achieved lower ratings). The main problems are connected with a hypotheses creation and with a result generalization. It has been really difficult for these pupils to think about the investigated reality in a general and critical way; even though they have demonstrated presence of abstract operations.

The last three children (R_2, R_3 and R_7) are assigned to the highest evaluative category (78 -100). We should mention that all of them have reached maximum points in the 0 level, which means that these pupils have well developed observational skills. For this reason they have been able to get as much information as they can about investigated reality and connect their new data with previous ones. The result validates the proposition that well developed BSPS are necessary for progress of ISPS development. The pupils of this evaluative category did not have a problem with identifying, understanding and manipulating with variables.

Anyway, the most important result is related to higher score obtained in an application level of questioning in comparison to a causal level of questioning. It is quite clear, that the pupils have much greater problems with dealing with “*why”* questions in comparison to “*how”* questions. For example, the pupils are more able to successfully deal with a question *how would you cause a slower downfall of a ping-pong ball* in comparison to a question *why a ping-pong ball falls down slower than a wooden ball of the same size*. Similarly they are more able to deal with the problem posed in a question: *how would you make more than one shadow of the only one object?*

In comparison to a question: *why does the shadow become longer when you change the direction of the light flow?* It means that pupils of this age are more oriented to an application of their previous experience and knowledge in comparison to a creation of new knowledge based on a formation of causal relations between information.

Discussion

Actually many authors (Beaumont-Walters & Soyibo, 2001; So, 2003; Bilgin, 2006; Etkina, 2007; Lawson, 2004; Mattheis & Nakayama 1988 and others) are interested in research on the science process skills (SPS). A majority of the researchers use science process skills tests as the main research method (for example: Mattheis & Nakayma 1988; Bilgin, 2006; Beaumont-Walters, Soyibo, 2001). The test as a research method cannot be used in specific situations, for example, when we would like to investigate science process skills of very young children. We are offering different way of SPS investigation with usage of structured interactive observation (as Harlen advices in her study: Harlen, 2000). Similar methods (observation and analyses of children's writings) can be found in a So's study (2003). The research explores children's cognitive processes during their own scientific investigation. On the contrary of our research all of those children attended a primary science project and were 1–2 years older than children in our research. Nevertheless we have acquired many related results. The children in both researches were neither able to ask testable questions nor make hypotheses. All of the children had problems to discover the relationship between empirical data and scientific theory, too. On the other hand the children from the So's research were able to give appropriate explanation and make reasonable conclusion which was not found in our study. The difference can be brought on either by a fact that the children in So's research were previously experienced in scientific investigation or (more likely) their skills were really better developed (concerning PISA results).

SPS tests were also applied in Beaumont-Walters & Soyibo's research (2001). They investigated 9th and 10th grade students and were focused on integrated science process skills. If we take our results only from the level 2 and 3 (related to investigation of integrated science process skills), the children from our research have had nearly no problem with identification of variables and they achieved the worst score in the category of formulating hypotheses. The same problem with appropriate formulation of hypotheses has been found also in the Beaumont-Walters & Soyibo's study. This result is confirmed also by Etkina's et al. (2007) study, even though the study has been aimed at much older respondents. Etkina investigated skills of making predictions and hypotheses of Ph.D. students. All of the students in a control group (without special science project) had problems with predicting and creating hypotheses. On the contrary, Mattheis & Nakayama (1988) marked formulating hypotheses as the second well developed skill; even though he has aimed at 6th, 7th and 8th grade students. Identifying variables has been marked as the best developed skill, which has been shown in our research as well.

Conclusion

The described research tool is applicable especially when we would like to consider whether using of inquiry based science education at primary level has a required impact on pupils science process skills or not. The results can help to modify educational content of primary science education so that it will help the pupils to develop abstract manipulation more quickly. For example we should become aware of kind of questions we are going to use for initiating the pupils' inquiry activities. The inquiry based science education is not only about hands-on activities, it is mainly about minds-on activities. The IBSE should lead the pupils to improve their way of thinking. The result is that pupils can be better prepared for that kind of subject which requires the abstract manipulation as the physics, mathematics or chemistry. Using the research tool can also make the teachers' understanding of the inquiry based science education more clear. The teachers in practice can perceive their methodological interventions better way. They can find out what is the real educational efficiency of the IBSE.

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Appendix

Categories of observed skills

			scale						points
Stimulating situation level 0	C1	investigation of the reality is very general	1	2	3	4	5	investigation is very detailed and intentional	
	C2	constructed conclusion (results) is very general	1	2	3	4	5	constructed conclusion (results) is about basic principle	
sum of points obtained in level 0									
Empirical investigation level 1	C3	correct answers formed by additive investigation	1	2	3	4	5	correct answers formed by already gathered information	
	C4	attention paid on unessential aspects of the situation	1	2	3	4	5	attention paid on essential aspect of the situation	
	C5	spontaneous investigation is superficial, trivial	1	2	3	4	5	spontaneous investigation is detailed, intentional and exact	
	C6	movement from description to explanation is guided by questions	1	2	3	4	5	movement from description to explanation is spontaneous	
sum of points obtained in level 1									
Causal thinking level 2	C7	correct answers formed by additive investigation	6	7	8	9	10	correct answers – hypothetic, based on previous information	
	C8	persisting on empirical investigation, searching for empirical evidences	6	7	8	9	10	targeting the causality	
	C9	correct conclusions and statements without argumentation	6	7	8	9	10	correct conclusions with correct argumentation	
sum of points obtained in level 2									
Application and synthetic thinking level 3	C10	focusing on the evidence provided by the empirical situation	6	7	8	9	10	identification of relations to previous knowledge	
	C11	giving examples which have only visual similarity with observed situation	11	12	13	14	15	giving examples with equal basic principle	
	C12	conclusions are correct and result from an empirical evidence	11	12	13	14	15	conclusions are generalizing the main principle	
sum of points obtained in level 3									
sum of points obtained in all levels (max. 100 points)									

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