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THE EFFECTIVENESS OF INQUIRY BASED SCIENCE EDUCATION IN RELATION TO THE LEARNERS´ MOTIVATION TYPES

Jiří Škoda,
Pavel Doulík,
Martin Bílek,
Ivana Šimonová

Abstract. *The study presents the results of the quantitative research focusing on the effectiveness of the inquiry based science education (IBSE) in correlation to motivation types of learners. Reflecting the fact that the learning results are impacted by the inner motivation, the main aim of the research was to find out whether there are differences in IBSE effectiveness in four motivation types - explorers, directors, coordinators, and accurators.*

The IBSE a*pproach was applied for the period of five months to 395 fifteen-year-old learners of Czech lower secondary schools. The IBSE effectiveness was tested before the instruction (pre-test), immediately after it (post-test1) and four months later (post-test2). The results of four motivation types were compared. Directors reached the best results in post-test1; explorers in post-test2; accurators´ results were the worst of all. These findings show that the IBSE cannot be applied as a universal method; teachers should adjust its exploitation to learners' individual particularities.*

Key words: *educational practice, inquiry-based science education, learners' motivation types, quantitative research, testing.*

Jiří Škoda, Pavel Doulík
Jan Evangelista Purkyně University in Ústí nad Labem, Czech Republic
Martin Bílek, Ivana Šimonová
University of Hradec Králové, Czech Republic

Introduction

Numerous theoretical and research studies in the field of subject didactics in the last 5 – 10 years strongly focus on strategies driving pupils´ learning activities towards developing the cognitive process based on learners´ inquiry activities. These activities are most frequently applied in Science subjects; that is why they are called the Inquiry Based Science Education (IBSE). As a result of scientistic paradigm within the science education, the IBSE application into the real education process is often unrestrained, non-systematic, more leaning on teacher´s enthusiasm than on a deep insight in the core of inquiry-based strategies driving pupils´ learning activities. Satisfactory answers to the IBSE-relating questions can solely result from the long-time, coherent and systematic application of these strategies which do not focus on specific and (in essence) isolated learning contents but on the development of learners´ general competence to apply inquiry-based strategies of problem solving and development of self-regulated and auto-didactic abilities of learning individuals (comp. Lamanauskas, 2012). However, the development of these abilities is not possible without adequate stimulation of learning individuals and appropriate support to their inner motivation. But within research activities strong attention has not been paid to these questions. Strategies of efficient stimulation and motivation differ in relation to various motivation types of learners. Similarly to testing individual learning styles, teachers should reflect learners´ motivation types and decide for appropriate (i.e. effective) ways of individual motivation to learning. That is why this research was conducted focusing on long-time experimental instruction applying the IBSE principles in Science teaching and learning (Physics, Chemistry, Biology) of 15-year-old Czech learners reflecting their motivation types.

Theoretical Basis of IBSE

A large number of IBSE definitions exist in today´s scientific literature. A general definition understands the inquiry as a process focused on framing problems, critical experimentation, assessment of alternatives, planning, exploration and verification, drawing conclusions, gathering information, designing models of the studied processes, discussing with others and forming coherent arguments (Linn, Davis, Bell, 1999). The authors of this paper define the IBSE as a driving strategy for learning activities, which lead to the pupil´s own active construction of the studied piece of knowledge. The IBSE can be understood as a specific variation of heuristic approaches in education. Such approaches are to be deduced from Socrates Maieutic method, dialogue-based and concerning features significant on a personal level. Pupils are exposed to known units in a new context; that is confronted with the pupil´s ideas and transposed to a contradiction (aporia). This cognitive conflict can be approached as a problem. Excluding individual hypothesis, the pupil gradually reaches their knowing and axioms on which the knowledge has been based (Kanakis, Chatzidimou, 1980). Heuristic teaching methods are not to be limited to teaching through dialogue. In a broader context, they cover larger complexes of learning activities, including problem identification, setting hypothesis, asking questions, observation, experimenting, collecting data and their evaluation, comparison, discussion, generalization, result verification and so on (Boud, Felletti, 1997).

The IBSE also uses analogical learning activities and driving strategies. Pragmatism in education, the principles of which were formulated by John Dewey, is seen as one of the very important sources of the IBSE concept. According to Dewey, the basic method of gaining knowledge is through the pupils´ practical work and experimentation. Pupils learn through solving tasks and problem situations at school. They should experiment and test a variety of views, information and solutions and then remember the optimal one/s. The basic method towards finding the correct solution in terms of pragmatism in education is the personal conduct, subjective practical work, experimentation, and experience (Fishman, McCarthy, 1998). Dewey's concept of the practical school and his principle of "learning by doing" are both based on the philosopher´s understanding of experience. The experience is however defined quite broadly in Dewey's philosophy. It includes the object of perception, the person conducting the perception and also the process of perception. In terms of IBSE it is then essential that, according to Dewey, the experience becomes a process in which people acquire knowledge about themselves and the world around them. Experience is therefore extremely important for Science education.

The most influential theoretical paradigm determining the IBSE concept is undoubtedly the constructivist pedagogy. The foundations of constructivist pedagogy, particularly the individual constructivist forms, were mainly laid by L. S. Vygotsky and J. Piaget. Many psychologists associate the theory with non-behavioural learning theories and discuss cognitive theories in terms of Bruner´s concepts and in terms of shape (Gestalt) psychology as samples of individual constructivism (McInerney, McInerney, 1998). This approach favours individual confrontation with the world and gives meaning to individual experience (similarly to the philosophy of pragmatism). The observer´s personality becomes a crucial element of understanding the reality. The observer´s cognitive activity therefore shapes the reality. The constructivist approach is based on the conviction that the learner does not passively absorb new understanding. During the natural spontaneous learning stages young children are interested in a wide range of different objects and events in the world around them, they try to understand why things work the way they do and why they behave a certain way (Norman, Chmidt, 1992). This approach is clearly identified as inquiry. The IBSE concept is trying to utilize elements of spontaneous learning, especially the learners´ ego engagement and other processes which shape the knowledge. The newly acquired information is actively integrated into the child´s already existing cognitive structure. The information is understood through these cognitive schemas already formed but it also transforms the schemas. Everything we learn is therefore set in the context of what we have already known and what was developed on previous personal experience. Although the constructivist pedagogy is currently undergoing some critique of both its application and theory (Kirschner, Sweller, Clark, 2006), the impact on the IBSE concept is absolutely clear. We do not hesitate to identify the IBSE as a concept directly connected to constructivist pedagogy.

The Basic Theory of Motivation

Approaches to motivation are based on several motivation theories. The general objective of these approaches is to describe and explain what the motivation really is and discover what the causes of human behaviour are. Various theoretical concepts differ mainly in their focus. To provide the basic insight, three of the (primarily manage-

rial) motivation theories are introduced which can be applied in driving pupils' learning activities: A. H. Maslow´s Hierarchy of Needs, F. Herzberg´s Motivation-Hygiene Theory and Vroom´s Expectancy Theory.

Maslow´s hierarchy of needs states that the individual is willing to produce efforts to at least partially saturate a certain, currently lacking, need. Maslow defined five groups of needs and ordered them into a hierarchic system. Mutual inter-relations within the hierarchy are described by e.g. Wahba, Bridwell (1976).

Herzberg´s Motivation-Hygiene Theory works with two groups of factors – motivators and hygiene factors. It arises from the precondition that people are able to precisely determine and communicate conditions which make them satisfied, or not (Miner, 2005). Those giving them satisfaction are mostly connected with success, recognition, higher responsibility, important tasks etc. On the contrary, feelings not providing satisfaction in the school environment are connected with teacher´s unfair approach, negative relations to the schoolmates, negative school/class climate, lack of management and control.

Vroom´s Expectancy Theory arises from the conviction that people are motivated to doing something towards reaching a certain objective if they believe it is valuable and they can make sure that the activity helps them reach the objective. Thus, it can be summarized that human motivation to doing any activity is determined by the importance the man sets to the result of efforts which is multiplied by the trust it really leads to reaching the objective (Gagné, Deci, 2005).

These theoretical concepts resulted in the following findings applied in the school instruction:

- The school motivation aims at learners´ inner engagement into fulfilling the task or learning activity in such a way which enriches and supports their further development. This inner interest forms the basis for development of auto-didactic strategies, which learners apply in IBSE.
- Within the school instruction such situations should be avoided which might induce learners' feelings of frustration and dissatisfaction and thus decrease their motivation.
- Within the school instruction various individual needs of learners should be emphasized, as well as their time and situation variability.

Research Activities in the Field of Motivation and IBSE

The IBSE has been a subject of research activities for approximately 30 years. Large amounts of research studies deal with the IBSE impact on the results of instruction with pupils of various age groups. An excellent study of this type was written by e.g. Minner, Levy, Century (2010). In numerous studies the question of learners´ motivation is also solved, but usually in relation to changes in learners´ attitudes to Science education and Science as such, e.g. by Taskinen, Schütte, Prenzel, 2013; Cavas, 2012; Önen, Ulusoy, 2014. In other words, the impact of IBSE on learners´ motivation has been detected, not the impact of motivation strategies and individual motivation characteristics on the relation to inquiry based teaching and specifics driving pupils´ learning activities which are included in this approach (i.e. group and co-operative instruction, collecting, classifying, analysing and assessing information, the requirement to plan activities, check opinions etc.). Healey (2005) emphasizes the differences in motivation to IBSE among students of various study programmes but does not run further analyses. Another inspiring study was published by Thomas (2000); he detected the impact of various types of awards on learners´ work in projects within the project instruction. Neither in this study the search for direct link to motivation and effectiveness of the given teaching strategy was mentioned. Moreover, the experience collected after the project instruction may not be applicable on IBSE. Salovaara (2005) published the results of the research study dealing with using learners´ cognitive strategies in the inquiry-based computer-supported collaborative learning. A process-oriented interview framework on cognitive activity, self-regulation and motivation, and a coding category for analysing cognitive learning strategies and cognitive self-regulation were developed. The results of the study were not unambiguous and the author discussed the reason that students should be motivated in various ways but these ways could not be applied universally, on all types of students. Thus, she indicates the requirement for various motivation approaches in relation to individual specifics of each learner. In conclusion of this short survey, the study by Hsiao-Lin Tuan, Chi-Chin Chin, Chi-Chung Tsai, Su-Fey Cheng (2005) should be mentioned. The authors monitored differences in motivation to Science education using the SMTSL tool (Students´ motivation toward science learning questionnaire) in the IBSE-taught group compared to the traditionally-taught students (i.e. without the IBSE) in relation to their individual learning style. Even in this study its authors discovered contradictory results. Higher motivation was discovered with four learning styles in the IBSE group; but differences were not significant compared to other four learning styles.

The results of the above mentioned studies show there exist certain correlations between IBSE and learners´ motivation to Science instruction. This correlation was described but not closely analysed; the reasons of some contradictory results in learners´ motivation to Science subjects learning have been neither identified, nor researched in detail. Considering the bibliographic search and the results presented in these studies, learners' approach to the Science education (either exploiting traditional teaching methods, or IBSE), might be impacted by learners´ individual characteristics determined by their motivation type. And, as they closely relate to individual´s temperament, they can be supposed to be inborn and unchangeable to a certain extent. Thus, the main research aim is to answer the question how/whether the results of IBSE can be impacted by learners´ motivation type.

Research Methodology

General Background of Research

The conducted research was based on the systemic five-month application of IBSE in Science lessons of Czech 15-year-old learners. Within this research the following main question was set: Is there any correlation between learner´s motivation type and the effectiveness of IBSE? Consequently, the main research aim is to discover whether there exist any correlations between learner´s motivation type and the IBSE effectiveness.

Partial research questions were defined as follows:

1. What are the learners´ motivation types in the research sample? The results will be classified according to the strongest one.
2. What is the learners´ starting level of Science knowledge (expressed in pre-test score) before the IBSE is applied? Learners´ knowledge could have been obtained from previous formal, non-formal and/or informal education, media, peers etc.; it was understood as learners´ pre-concepts.
3. What is the learners' knowledge (expressed in post-test1 score) after the application of IBSE approach for five months?
4. What is the learners´ knowledge (expressed in post-test2 score) after another four-month period after the application of IBSE approach?
5. Are there any differences in learner´s knowledge (expressed in post-test1 and post-test2 scores) in single groups of motivation types?

Research Hypotheses and the Verification Process

The research hypotheses verified within the research reflect the above mentioned main research aim. Considering the fact, that the multiple comparison of various selected factors is expected in the process of hypotheses verification, the null hypotheses were set as follows:

H_{01}: Pre-test scores of four motivation types of learners do not differ.
H_{02}: Post-test1 scores of four motivation types of learners do not differ.
H_{03}: Post-test2 scores of four motivation types of learners do not differ.
H_{04}: Differences in pre-test and post-test scores of four motivation types of learners do not differ.
H_{05}: Differences in post-test1 and post-test2 scores of four motivation types of learners do not differ.

First, the research hypotheses were tested by ANOVA (variance analysis). If the analysis rejects the global null hypothesis on the impact of the variable (if the observed value of significance level p-value < 0.05, ANOVA will be supported by other statistical methods focusing on detecting differences by multi-comparative tests. These provide information about the statistical significance of single differences in mean values of all possible pairs of compared groups. For the purpose of data analysis the conservative Tukey-HSD test is applied. It makes appropriate decisions on lower significance level, thus eliminating dangerous increase of type I error α, which is characteristic for more liberal tests, e.g. Fisher´s LSD test. All statistical analyses are conducted by the statistic software Statgraphics Centurion XVI on the significance level $\alpha = 0.05$.

Research Sample

The quantitative research design on the basis of quasi-experiment was applied for reaching the main research aim. Fifteen classes were intentionally selected where the IBSE approach was used in teaching Science subjects for five months. The research, i.e. pre-test, instruction, post-test1, was conducted with the 8th grade learners, the post-test2 was applied with 9th grade learners of lower secondary schools (in cities and towns, not in rural areas) in the Czech Republic, one class per one school. Totally, 395 learners from 15 schools participated in the research. Only those learners were included in the sample who participated in all phases of the research, i.e. in the motivation type detection, pre-test, instruction, post-test1 and post-test2. The lessons were led by teachers – graduates of the course focused on the IBSE application (12 women, 3 men, mean length of pedagogical practice was 12.9 years). The quasi-experiment was conducted from December 2013 to October 2014, the IBSE approach was applied from January to May 2014. Participating classes were to meet the following conditions:

- appropriate material equipment enabling to apply the IBSE approach in Science subjects,
- Science teacher having a five-year practice as minimum, trained in the IBSE course,
- school curriculum enabling the IBSE application,
- support and approval of the school management for running the quasi-experiment,
- no specialized classes and schools (i.e. in mathematics, foreign languages etc.) were intentionally included in the study, as this factor might have impact on the results and decrease the validity of the research.

The total validity of the research is given by the facts that intentional research sample was exploited, determined by the person of the teacher trained in IBSE, so the results can be generalized to a limited extent. Exploiting the identical learning content the research could be easily reproduced.

Tools and Procedures

Two research tools were exploited within the research: motivation inventory and didactic test.

For detecting the motivation type of the respondents, the original inventory by Plaminek (2010) was modified for the group of 15-year-old learners. The inventory is structured into two parts. Part 1 deals with the purpose and means of motivation and differentiates learners on the effectiveness – usefulness scale. It consists of 14 items. In each of them the respondents (1) express their preferences on the five-point scale providing their evaluation of pairs of motivators, e.g. the applied procedure – results of the solution; good relations – good results; interesting approaches – reached objectives etc., and (2) evaluate what the intensity of preference in the pair is (possible combinations of points are 5:0, 4:1, 3:2, 2:3, 1:4, 0:5). In Part 2 the inventory focuses on challenges and safety, and differentiates learners on the stability – dynamics scale using another set of 14 items constructed and evaluated on the identical principle as in Part 1, providing e.g. following pairs to be evaluated: new tasks and procedures – time-tested tasks and procedure; restlessness – patience; appropriate risk – appropriate assurance etc. Then, total score is calculated and the motivation type of each respondent is defined by the combination of scores in both parts of the inventory, i.e. by the effectiveness – usefulness and stability – dynamics scales. These scales arise from the vitality theory, which belongs to the self-determination theory (more in Deci, Ryan, 2008). As this is the core of this study, below the characteristics of single motivation types are provided:

- Explorers (dynamics, usefulness). The behaviour expresses a considerable portion of independence and self-reliance. The explorers are strongly attracted by conquering constraints and rising to challenges, they are often impatient, eager for information, they appreciate freedom and autonomy but cannot stand to be driven. Disagreement is not a means to taking control over others but protecting their own freedom. Their argumentation primarily focuses on the matter, and man is referred only to support the argumentation. This motivation type is in the frame to succeed in disciplines in which social skills are not strongly required. They have maximum rational intelligence and the highest preconditions for scientific and creative work.
- Directors (dynamics, effectiveness). The dynamic component of their motivation structure does not prevent them from running risky activities, the effectiveness factor pre-determines them for expressing dynamics mainly in social processes and human relations. Therefore, they are attracted by the possibility to have impact on other people. At the same time they strive to achieve maximum freedom

for themselves – not within the voluntarily accepted restrictions but the real freedom and unlimited possibilities. Directors appreciate to be in the centre of attention, their motivation type predetermines them for social success. They are susceptible to impulses what is/is not appropriate to the situation. Directors are able to persuade people about their ideas, they succeed in "selling" the ideas, often are leaders of social groups (e.g. classmates).

- Coordinators (stability, effectiveness). The existence and importance of coordinators is the evidence of how social relations are important for the stability and effectiveness of the system. Coordinators fully focus on people, their relations, feelings and satisfaction. They like talking to others, asking questions, listen to answers, they are open to discussions. Compared to other motivation types, discussions with coordinators are always helpful and pleasant, they have the ability to understand the others, particularly in the field of feelings and emotions. Moreover, their empathy is highly developed, they are pillars of social structures so that the environment they work and live in to be warm, human and understanding.
- Accurators (stability, usefulness). They are reliable, accurate, and hard to themselves and the environment. They appreciate good organization of work, of the order in their matters and the workplace, they require clear tasks and reach them precisely. Regulations and rules are important for them, they neither like risks, nor negotiating with people. Their communication aims at making the problem clear, collecting and verifying the data etc., thus they seem look calm in social relations. They perform in a rational and emotionally flat way. They are open only to those who they closely know and trust them. Accurators are loyal to school and teachers they have respect for.

The didactic test included 15 tasks built according to the PISA style towards testing Science literacy. Ten of them were convergent and five divergent ones. Pre-defined and strictly correct answer was required to the convergent tasks, totally providing 30 points. In divergent tasks learners designed a process of solution (e.g. how to separate components from a compound, verify the impact of various factors on growth of plants etc.), whereas several solutions were correct. The maximum score was 25; total score of the didactic test was 55 points. The didactic test was piloted and optimized on the sample of 26 fifteen-year-old learners. The didactic test was first applied as pre-test in December 2013 before the quasi-experiment started. Second, it was used as post-test1 in June 2014; third, as post-test2 in October 2014. Then, the results were statistically processed from the point of success in task solving (i.e. test scores) in relation on learners' motivation type. The reliability of the research tool was calculated from the post-test scores, separately for convergent and divergent tasks. In convergent tasks the Cronbach's alpha = 0.847, in divergent tasks Cronbach's alpha = 0.729. Lower value with divergent tasks resulted from their higher heterogenity, higher test score and fewer amount of them was included in the didactic test. But, both values of Cronbach's alpha are acceptable. The validity of test tasks is determined by the fact they were designed according to the PISA tasks which are exploited worldwide for the given age group of 15-year-old learners.

Research Results

Following the above presented research aims and hypotheses, first, according to the results of the motivation type inventory, the respondents were divided into four groups (Explorers, Directors, Coordinators, and Accurators). Frequency and relative frequency of different motivation types of the respondents in the research sample are displayed in table 1.

Table 1. Respondents' structure reflecting the motivation type.

Motivation type	Frequency (n)	Relative frequency (%)
Explorers	55	16.2
Directors	107	31.6
Coordinators	93	27.4
Accurators	84	24.8
Total	339	100.0

The highest occurrence of directors was detected in the research sample, explorers were of the lowest occurrence. Both these groups are of dynamic type. The difference is given by the specifics of the respondents´ age

group (15 years) – learners still do not strongly target at performance, i.e. on the usefulness. In their age, peer relations and building social contacts are strongly emphasized, that is why they focus on effectiveness which accents human relations in the process of work and learning. This is clearly visible with motivation types targeting at the stability where (again) the motivation type focused on effectiveness (coordinators) prevails.

Further data processing followed the hypotheses. Before the IBSE approach was applied to the instruction of 339 learners, they administered the didactic test (pre-test) detecting the starting level of their knowledge in the field of Science learning contents which were the object of the experimental instruction. In this way the impact is excluded of learner´s pre-concepts originating from previous formal and/or non-formal education on the total result of the experimental inquiry based instruction. The pre-test scores of single motivation types were subjected to the ANOVA test providing the following results: F-value (F-Ratio) = 1.55; the observed value of significance level p (p-value) = 0.2014. The detected difference was not significant which means that the impact of the observed parameter (learner´s motivation type) on the test score was not proved. The research hypothesis H_{01} was accepted. In other words, the level of learners´ pre-concepts before the experimental inquiry-based instruction was not impacted by the motivation type of the learner. Figure 1 shows means (see the ´cross´) and 95 per cent Tukey HSD Intervals (see the ´line´) for the pre-test results in relation to the learners´ motivation type.

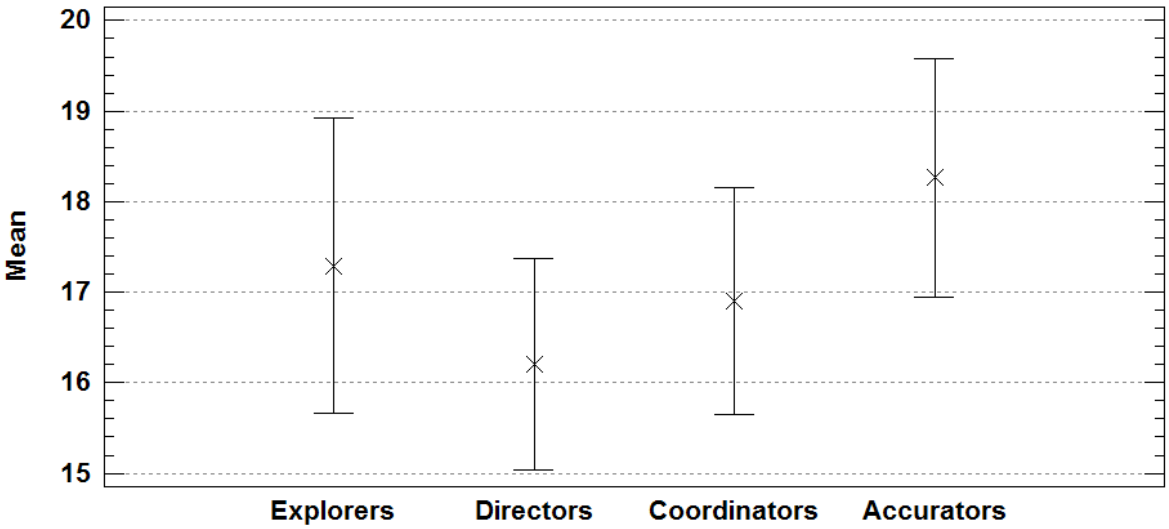

Figure 1: Means and 95 percent Tukey HSD intervals (Pre-test).

As seen in figure 1, the largest difference in pre-test scores was detected between groups of directors and accurators, nevertheless it is not significant, even if a more liberal Fisher LSD test is applied. Reflecting the fact the total score in the didactic test was 55 points, the starting level of knowledge is rather high.

After processing and interpreting the pre-test data in December 2013, the experimental inquiry base instruction in all Science subjects (Physics, Chemistry, Biology) was conducted from January to May 2014. After that in June 2014 the didactic test (post-test1) was administered. The test scores of single motivation types were also subjected to the ANOVA test with the following results: F (F-Ratio) = 7.12; p (p-value) = 0.0001; i.e. the statistically significant difference was detected in single groups. Therefore, another analysis followed – the Tukey HSD test was applied for identification of statistically significant differences in means of four independent groups. Statistically significant differences in post-test1 means were detected in groups of explorers and accurators (3.821), directors and coordinators (3.229) and directors and accurators (5.192). The results are displayed in figure 2.

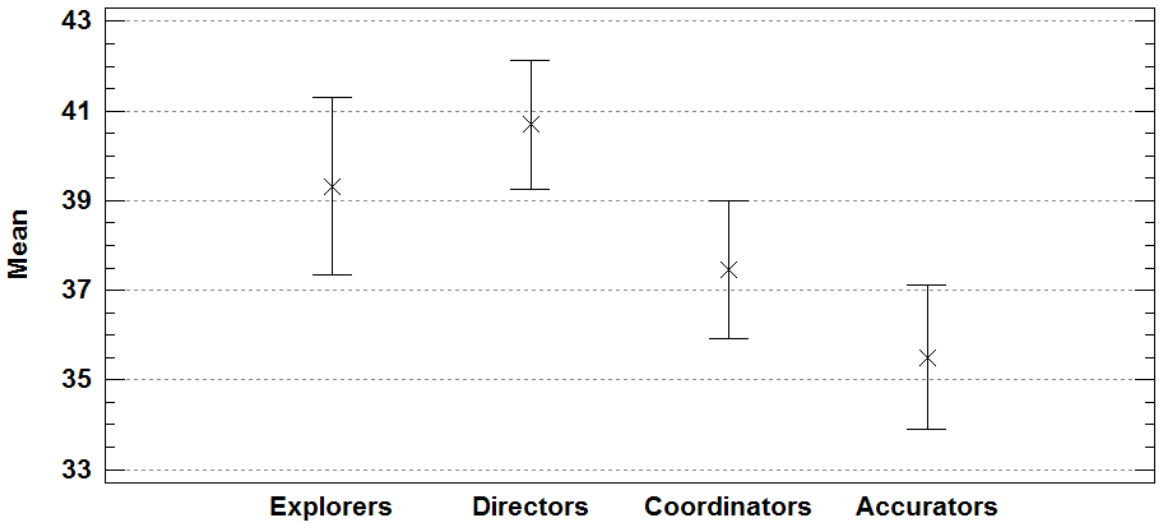

Figure 2: Means and 95 percent Tukey HSD intervals (Post-test1).

Reflecting the statistical differences in three pairs of motivation types, the hypothesis H_{02} was rejected. Directors reached the highest test score of all groups (55 points, i.e. 100 %) whereas accurators had the lowest test scores, none of them reached 100 %; two learners reached 50 points).

In October 2014, i.e. four months after the experimental inquiry based instruction and the post-test1, the post-test2 was administered to detect the level of long-time fixation of knowledge in Science subjects. The post-test2 test scores were subjected to the ANOVA test in single groups of motivation types with the following results: F (F-Ratio) = 3.56; p (p-value) = 0.0146, and the statistically significant difference was detected. Therefore, as in the previous post-test, further statistical analysis was applied through the Tukey HSD test to identify statistically significant difference in means of four groups of motivation types. Significant differences in means were detected in groups of explorers and coordinators (3.352) and coordinators and accurators (- 2.814). The results are displayed in figure 3.

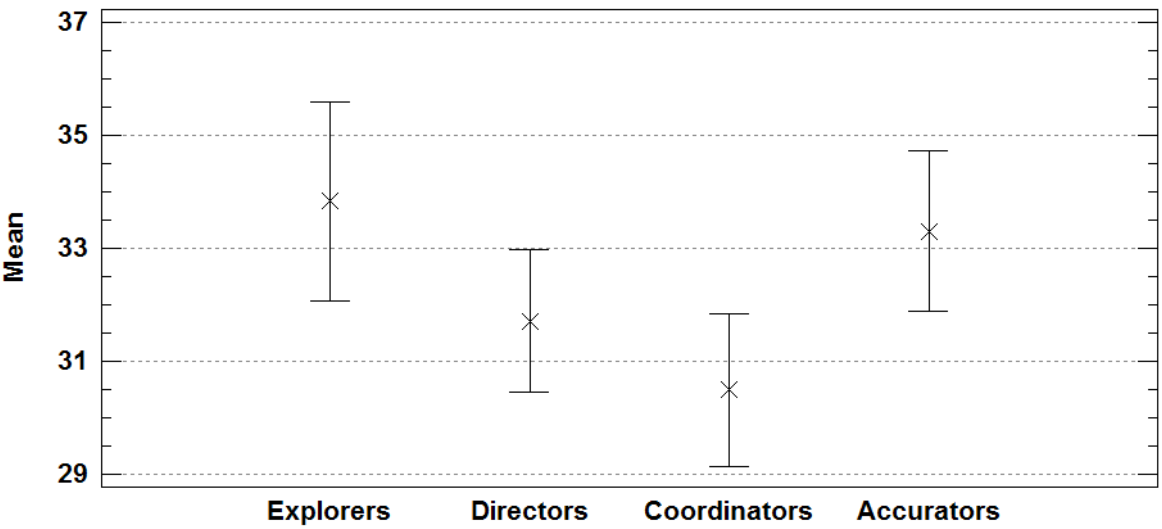

Figure 3: Means and 95 percent Tukey HSD intervals (Post-test2).

As the statistically significant differences were detected in single motivation types, this criterion provides impact on the results of post-test2. Therefore, the hypothesis H_{03} was rejected. The highest test scores were reached by explorers, the lowest scores by coordinators.

The mean values collected in single phases of the didactic test (pre-test, post-test1, post-test2) may not reflect the state to adequate extent because they operate with various input (pre-test – post-test1) and output (post-test1 – post-test2) levels of single motivation types. The comparison of differences in two levels in relation to learners´ motivation types provides more valuable results. First, the differences in pre-test – post-test1 were compared, i.e. how the test score increased from the pre-test to post-test1. This difference can be interpreted as a direct result of the IBSE approach. Differences in pre-test – post-test1 in single motivation types were subjected to the ANOVA test with the following results: F (F-Ratio) = 7.28; p p-value) = 0.0001. The detected difference is statistically significant. Therefore, another analysis was applied using the Tukey HSD test for identification of statistically significant differences in pre-test – post-test1 differences in single motivation types. The results are displayed in figure 4.

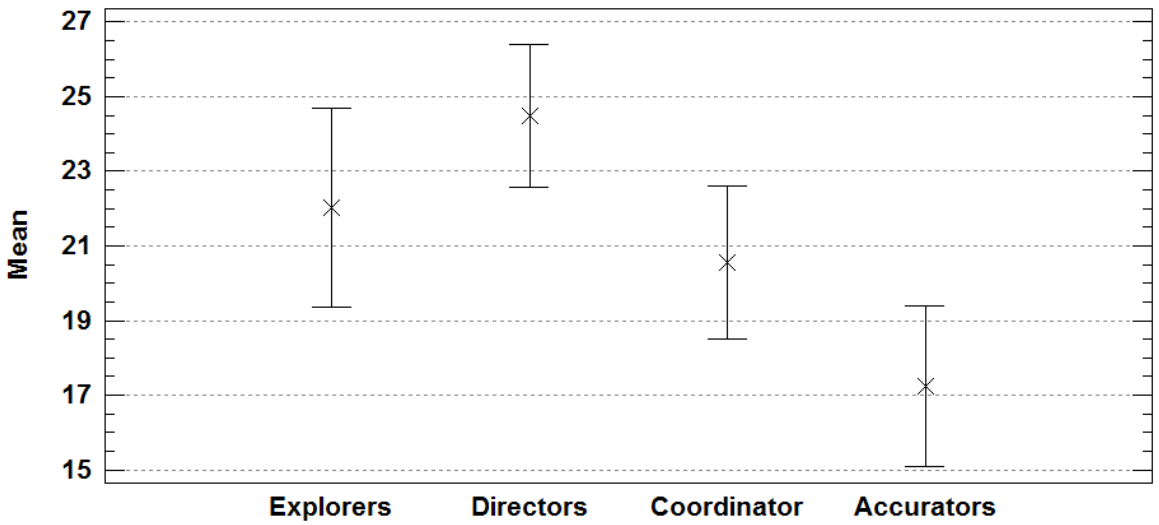

Figure 4: Means and 95 percent Tukey HSD intervals (difference in pre-test – post-test1).

The highest pre-test – post-test1 increase was detected in the group of directors, the lowest one with accurators. Statistically significant differences in differences were calculated in directors and accurators (mean difference in differences = 7.248) and explorers and accurators (mean difference in differences = 4.798); this is the boundary value. The hypothesis H_{04} was rejected.

The identical procedure was applied on calculating differences in post-test1 – post-test2. The time period between the post-test1 and post-test2 was four months; this was multiplied by the fact that two months of four were holiday months (July, August), when no school instruction was conducted. The post-test1 – post-test2 difference follows the forgetting curve by Ebbinghaus. Although the IBSE is expected to strengthen the development of learners´ autodidactic strategies, the forgetting, and decrease in test scores, is expected mainly in convergent questions focused on facts. Differences in post-test1 – post-test2 scores in single motivation types were subjected to the ANOVA test with the following results: F (F-Ratio) = 21.43; p (p-value) = 0. The detected difference is statistically significant. Therefore, another analysis was applied using the Tukey HSD test for identification of statistically significant differences in post-test1 – post-test2 differences in single motivation types. The results are displayed in figure 5.

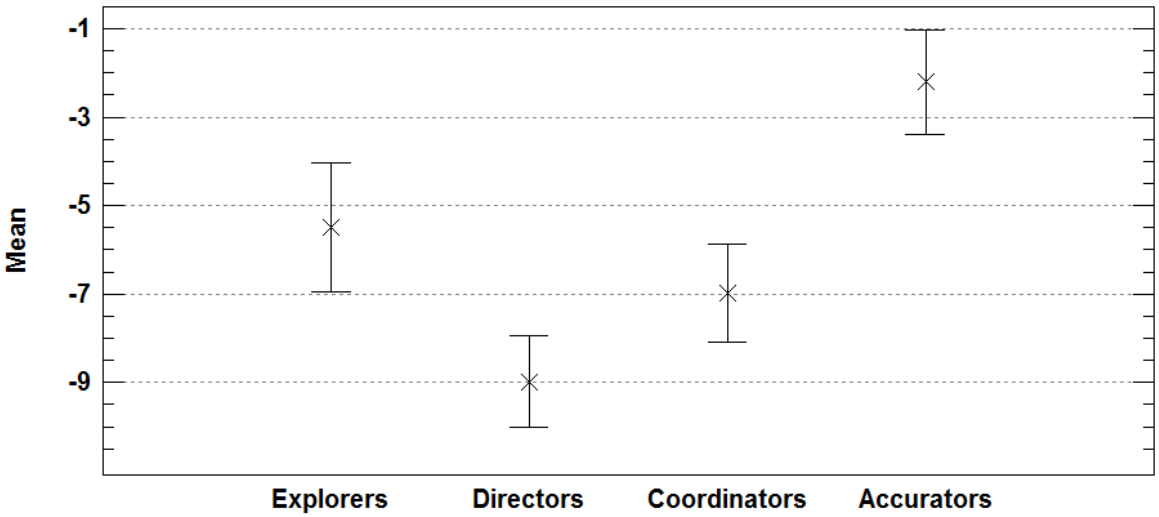

Figure 5: Means and 95 percent Tukey HSD intervals (difference in post-test1 – post-test2).

The highest decrease in these scores was detected in the group of directors, the lowest one with accurators. Statistically significant differences in differences were calculated in explorers and directors (mean difference in differences = 3.4904), explorers and accurators (mean difference in differences = -3.2885), directors and accurators (mean difference in differences = -6.7789), coordinators and accurators (mean difference in differences = -4.776). The hypothesis H_{05} was rejected. Differences in decrease of learning results (test scores) in relation to learners´ motivation types were significant.

Discussion

Reasons of the raised interest in IBSE in the past years are the results of the international survey PISA (Programme for International Student Assessment). These results show the decreasing tendency of learners´ Science literacy in the Czech Republic. Within its framework, PISA ascertains content, procedural and epistemic knowledge. The largest decrease occurs in the very domain of epistemic knowledge. That includes the knowledge of procedures dealing with verification and substantiation of scientific inquiry and hypotheses during the processes of scientific investigation. This very knowledge, or strategies of driving the learning activity are enhanced through IBSE. Although numerous studies (e.g. Kane, 2013) prove the high effectiveness of IBSE, this fact cannot be accepted without objections. The results of this study have shown that the IBSE effectiveness can be significantly impacted by learners´ motivation type.

The entire implementation of IBSE is a significant intervention to the stereotype developed with learners during the years of traditional teaching. A shift in existing teacher´s and learner´s roles has been detected. The teacher is not a mentor any more but the facilitator of the process of instruction. The learner is not a passive recipient but an active element and to some extent an initiator of the process of instruction. Fast increase of scientific knowledge results in revising the generally and widely applied educational strategies, methods and forms of instruction (Lamanauskas, 2013). The co-operative learning is used to a larger extent, which calls for higher requirements on planning and driving (organizing) the learning activity, on the ability of efficient communication with other actors of the education process, and on the ability of auto-regulation of the learning process. The co-operative strategies also require to develop learners´ social competence, higher claims are applied to meta-analysis of the cognitive process (Dignath, Buttner, 2008), to the ability of critical analysis of own mind processes, to the process of getting, analysing and classifying information. Moreover, changes in curricula occur – the learning content is integrated, and the emphasis is shifted from low levels of the Bloom´s taxonomy of cognitive objectives to more complex competences on higher levels. All these changes brought by IBSE are demanding for learners´ adaptability and their ability to accommodate to other strategies of driving pupils´ learning activities. These changes do not have to be positively viewed by the learners! Numerous learners appreciate the time-tested stereotype of traditional

instruction because they are used to learning in such a way, when higher cognitive effort is not required from them as in case of the IBSE.

From the view of motivation types, accurators seem to be most resistant to the IBSE. They reached the lowest increase in pre-test – post-test1 score, but on the other side, the lowest decrease in post-test1 – post-test2 score was detected in this group. They are stability- and usefulness-oriented, requiring to get instructions and to keep them. Reflecting these features, they are rather conservative and do not like changes. They likely appreciate traditional transmissive – instructive instruction with stronger directive driving of pupils´ learning activities from the teacher´s side. They like working alone, they do not feel good in a group of people with different motivation types. They completely do not appreciate the group co-operative instruction in IBSE lessons.

On the other side, the highest increase in pre-test – post-test1 scores was detected with directors. Learners of this motivation type value the IBSE approach and it shows to be strongly efficient for them. As the directors are dynamic, they embrace changes brought by different strategies of driving pupils´ learning activities. But the question is what the role of newness effect is. Such a change itself activates the learners and increases their efforts, without considering what caused the change. This leads to gradual burn-out of the positive impact. Directors usually become easily enthused by an activity but the enthusiasm does not last a long time-period, it shifts to another, new activity; i.e. the consistency towards continuing the activity or finishing tasks is missing. This presumption is supported by the fact that after finishing the inquiry based instruction and starting the traditional approach again, the considerable decrease in test score was detected. It was the deepest decrease of all observed motivation types. As the IBSE approach compared to traditional instruction brings numerous different activities, it is suitable for directors but if applied consistently. The results show that mere time-limited experimental process cannot keep the positive IBSE effects in the long run.

Comparable to directors, the very high effectiveness was detected with explorers pre-test – post-test1 scores (the difference was not statistically significant). But, the decrease in post-test1 – post-test2 score was significantly lower with explorers (compared to directors). Thus, explorers seem to be the motivation type which best appreciates and accepts the IBSE. Unfortunately, this motivation type is of the lowest occurrence in population. Been independent and rational, they succeed in traditional instruction as well, if it is not led too authoritatively and directively. Therefore, the explorers appreciate strategies of driving pupils´ learning activities applied in IBSE because a considerable part of decision-making, checking and organizing of learning activities is shifted on learners, which works as a motivator with explorers; and the teacher facilitates the education process only.

Interesting are the results of coordinators, for they seem ambivalent in relation to the IBSE. The test scores of single motivation types are on average level and show only few statistically significant differences. This may mean that the IBSE both brings them positive stimuli (co-operation in the process of instruction, higher frequency of communication between learners, the emphasis on the class climate) and sets difficult tasks to them (interpretation of observed phenomena, deducing and verifying conclusions, explaining the collected data etc.). Considerably higher share of peer teaching, which the IBSE brings compared to the traditional approach, can provide positive impact on coordinators. The increase in pre-test – post-test scores is comparable to explorers. The decrease in post-test1 – post-test2 scores is the second highest with coordinators. It may be caused by the reversion to the traditional instruction where verbal methods prevail. Thus, the radical change in communication patterns appears compared to the co-operative instruction. Communication among learners is depressed. If we accept the thesis the IBSE arises from constructivist models of driving learners´ activities (e.g. Kirschner, Sweller, Clark, 2006), then coordinators are the motivation type the social-constructivist concept of shared cognition is typical for. Salomon (1997) states that all knowledge and skills are built in social context and they are inseparably connected to shared understanding. This explanation emphasizes the imperative aspect of group cognition and communication as a central mechanism changing the cognition. Within co-operative activities and team work a common vision is built and the learning is conducted through efficient communication.

The results of the presented study should be considered from the view of limitations resulting from the entire experimental application of IBSE. First, learners should be imposed to long-time and complex impact of IBSE which is comparable to the traditional instruction, i.e. for several years. Moreover, the inquiry based instruction should not be limited to Science subjects. The IBSE principles can be also applied e.g. in problem instruction of maths, where they support learners ´abilities to solve mathematical tasks (Eisenmann, Novotná, Přibyl, 2014). As proved by Říčař (2014), some IBSE approaches can be also explored in humanities. Above all, only within the long-term impact of IBSE its contribution to the effectiveness of education process can be considered from the view of learners´ motivation types and also e.g. in relation to their learning preferences.

Another limitation of the research results from the fact that, similarly to the learning styles, neither motivation types are stable. Every individual tends to a certain motivation type but at the same time, reflecting the situation or the incentivity of surrounding environment, they can partly exploit stimuli characteristic for other motivation types. Hereby, it should be emphasized that the field of motivation types has not been worked out as the learning styles have been, including the empiric researches. Another factor which must be considered within the result interpretation is a relatively low amount of learners who were imposed to the experimental IBSE. So, the presented results are to initiate and inspire further research activities in this field.

Conclusions

The collected results show the IBSE effectiveness, besides other factors, depends on the learners´ motivation type. This individual characteristics decides on the way how the teacher activates learner´s inner motivation, which then the learner integrates to the education process. The research aimed at emphasizing the fact that strong attention should be paid to motivation strategies in the process of designing the lesson because they can have substantial impact on the whole process of instruction. In accord with the research aim it was proved the IBSE effectiveness significantly differs in four motivation types. The highest effectiveness was reached with directors and explorers immediately after the IBS instruction (post-test1). From the long-time view, i.e. four months later (post-test2), the strongest decrease was discovered in the group of directors and explorers reached the highest effectiveness. Accurators were least impacted by IBSE from all motivation types. The traditional approach with larger extent of directiveness and explicitness in directing accurators´ learning activities seems to be more suitable for this motivation type. However, the validity of these results should be considered through limitations of the conducted research which are reflected in two main factors. The first one is that the period learners were exposed to IBSE was relatively short (five months). The experimental character of IBSE in the research is the second factor. In previous phases (years) of schooling learners included in the research sample were taught by traditional methods which resulted in various learning strategies and approaches which were purposeful and learners were used to exploiting them. In IBSE these strategies do not work and even can be counter-productive. Therefore, in this research good results were reached by learners who are able to quickly adapt to changing conditions, which is more suitable for dynamic motivation types – directors and explorers. Reflecting this finding, it would be useful to research the long-time impact of IBSE applied as majority strategy directing learners' activities from the very beginning of their school education. Moreover, the "inquiry-based" concept should not be merely limited to Science subjects.

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Jiří Škoda	PhD., Associate Professor, Department of Pedagogy, Faculty of Education, Jan Evangelista Purkyně University in Ústí nad Labem, České mládeže 8, 400 96 Ústí nad Labem, Czech Republic. E-mail: Jiri.Skoda@ujep.cz Website: http://jiriskoda.webnode.cz
Pavel Doulík	PhD., Associate Professor, Department of Pedagogy, Faculty of Education, Jan Evangelista Purkyně University in Ústí nad Labem, České mládeže 8, 400 96 Ústí nad Labem, Czech Republic. E-mail: Pavel.Doulik@ujep.cz Website: http://paveldoulik.webnode.cz
Martin Bílek	PhD., Professor, Department of Chemistry, Faculty of Science, University of Hradec Králové, Rokitanského 62, 500 03 Hradec Králové, Czech Republic. E-mail: Martin.Bilek@uhk.cz Website: http://lide.uhk.cz/bilekma1
Ivana Šimonová	PhD., Associate Professor, Department od Applied Linguistics, Faculty of Informatics and Management, University of Hradec Králové, Rokitanského 62, 500 03 Hradec Králové, Czech Republic. E-mail: Ivana.Simonova@uhk.cz