DE GRUYTER OPEN

ICTE Journal

2016, **5**(2): 51–67
DOI: 10.1515/ijicte-2016-0008

INQUIRY BASED EDUCATION OF SELECTED INFORMATICS TOPICS – ANALYSIS AND RESULTS

Ľubomír Šnajder, Ján Guniš
Institute of Computer Science, P. J. Šafárik University, Jesenná 5, 040 01 Košice, Slovakia
{lubomir.snajder; jan.gunis}@upjs.sk

Abstract

In the paper we present the partial results of a qualitative research achieved in the project Innovation efficiency methods of teaching mathematics, physics and informatics (VEMIV). The project is aimed at developing inquiry skills of pupils and conceptual comprehension of the subject matter. In the first part we describe basic characteristics of inquiry-based education. In the second part we present two methodologies of teaching informatics. The first methodology is primarily focused on scientific research methods viable in school informatics. In the second one, we focus primarily on the content of school informatics. The methodologies were implemented and commented by teachers from partner grammar schools. At the end of both methodologies we summarize and analyze the results of inquiry-based education according to the presented methodologies. Our findings are supported by the results of pupils' works, the results of concepTest and evaluation feedback from teachers. In conclusion, we present recommendations for the implementation and evaluation of inquiry-based informatics education.

Keywords

informatics, inquiry-based education, methodologies, analysis.

Introduction

"Inquiry Based Science Education means pupils progressively developing key scientific ideas through learning how to investigate and build their knowledge and understanding of the world around. They use skills employed by scientists such as raising questions, collecting data, reasoning and reviewing evidence in the light of what is already known, drawing conclusions and discussing results". (IAP, 2012)

Inquiry Based Education (IBE) aim is therefore, besides the conceptual comprehension of the curriculum, developing pupils' inquiry skills related to various stages of exploration: The formulation of the problem and planning the research, the implementation of the research, analysis and interpretation of the research results, sharing and presentation of results, application and other use of the results (Berg, 2013) (Balogová & Ješková, 2016).

A pupil may not be, and generally even is not, capable of independently beginning to realize all stages of a research cycle. Depending on the quality and quantity of information provided to the pupil we distinguish different levels IBE. Banchi and Bell indicated in (Banchi & Bell,

2008) four levels of the IBE depending on the degree of research questions' determinacy, methods and results: from Confirmation Inquiry through Structured and Guided Inquiry to Open Inquiry.

To create a structure of inquiry lessons are used models, which serve for structuring the teaching to so-called teaching cycles. Model which is often used in the practice is 5E learning cycle by Bybee (Bybee et al., 2006) defined by five stages – Engage, Explore, Explain, Extend, Evaluate.

In the frame of the project Research on the efficiency of innovative teaching methods in mathematics, physics and informatics education (VEMIV) (Lukáč, 2016) we have focused on developing methodological materials for inquiry-based education of mathematics, physics and informatics at the secondary grammar school. The project also includes verification of the proposed inquiry-based methodologies in real school conditions and their implementation into educational curricula.

In this paper we present partial results of the ongoing project VEMIV for school informatics – the results of the implementation of teaching by two of our own designed inquiry-based methodologies. The first methodology is primarily focused on scientific research methods viable in school informatics. In the second one, we focus primarily on the content of school informatics.

ACQUISITION, PROCESSING AND PRESENTATION OF INFORMATION

This methodology is primarily focused on scientific research methods feasible in environment of school informatics. It is designed for pupils in 2nd grade of the secondary grammar school (ages 16-17) and its time consumption is about from 1 to 2 months. Pupils perform a substantial part of the work outside the school hours. The pupils' task is to choose a research area that is of interest to them and wherein they would like to gain new knowledge. Subsequently they plan and carry out own research in this area according to scientific framework of a relational research. According to (Banchi & Bell, 2008) we can include thus implemented activity to Open inquiry, in terms of the level of exploration.

In this activity pupils develop primary following inquiry skills (based on Tamir & Lunetta, 1981; Fradd, 2001; Berg, 2013; Balogová & Ješková, 2016):

- Conception, planning and design of experiment
    - Formulate hypothesis or expectation to be tested.
    - Design experiment (which variables, which relationship).
    - Design observation and/or measurement procedures (incl. lab-apparatus selection; experiment set-up) for each variable.
- Implementation
    - Observe/measure.
    - Record results.
- Analysis and interpretation
    - Transform results into standard form (i.e. tables, graphs).
    - Determine relationships between variables based on e.g. graphs, tables, text,
    - Compare experimental data to the hypothesis/expectation.

  - Propose generalizations of experiment results.
  - Draw conclusion.
- Communication
  - Share and present results in front of the class.
  - Discuss/ defend results/form arguments.
  - Elaborate formal report about the gained results.

Pilot testing of the methodology took place in the school year 2014/2015. It was attended by 52 pupils and 3 teachers. We revised the methodology based on the results of the pilot testing. In ordinary run we have provided teachers improved methodology and also sample of research project realization with comments to its particular parts.

The methodology was followed by 42 pupils in 26 working groups. Overall, they were pupils from 4 classrooms and from 3 schools. The same teacher taught two classes. Until now there was comparatively low participation of pupils because of time consumption of teaching according to this methodology and also of difficulty of research work method itself.

We are aware that the number of pupils who have completed a specified methodology is too small for us to be able to generalize our findings. Thus, the following conclusions are valid only for this small group, although given the choice of schools involved in the research we can assume a certain degree of generalization.

Teachers gave us the final products of pupils' activities. In most cases, it was the spreadsheet document in which the pupils reported results and process of individual stages of their research on separate sheets. When analyzing the pupils' work, we observed how the pupils managed to meet the conditions imposed on this type of research (relational research problem), whether and how they were able to realize the various stages of research. We analyzed the results of each pupil (or of each working group) as follows:

- **Investigated area and research problem**
  - Did the pupils determine investigated area? Which?
  - Did the pupils define the research problem?
    - Is it clear, from formulation of research problem, what will be examined?
    - Does the research bring anything new?
    - Is the research problem trivial?
- **Research questions and variables of research**
  - Did the pupils define the research question?
    - How many research questions did the pupils define? Are they closed or open?
    - Are there variables in the research questions (or in research)? How many? Are they measurable?
      - Did the pupils distinguish between dependent and independent variables?

- Did the pupils verify the impact of the independent variable on the dependent? If so, how? (e.g. chart, picture, correlation coefficient, …)

- **Hypotheses**
  - Did the pupils formulate hypotheses? How many?
    - Did the hypotheses contain the relationship between at least two variables?
    - Are the hypotheses verifiable?
- **Data collecting**
  - Extent of research
    - What is the number of questions and number of respondents (researched objects)?
  - Did data collection ensure values for each variable?
  - Are the questions in the questionnaire open or closed?
  - Did the pupils describe the process of selecting respondents (researched objects)?
- **Final report**
  - Did the pupils compile the final report?
    - Does the final report include the interpretation and the explanation of results or just "retelling" of the graphs?
  - Does the final report contain pupils' statements about the hypotheses validity?
    - Is the pupils' expression of the hypotheses validity correct?
  - Did the pupils state some new, unexpected findings?

For completeness we point out, that we provided teachers the description and the justification of every research stage. The teachers also received the results of a fictitious research, which we used as a demonstration example of research. We added comments to each stage and each part of the research. Thus, by methodology with demonstration examples, we defined the framework which enabled to realize the research.

We explained in the table 1 some of the quantitative findings that we found by the analysis of pupils' works. In the analysis, we investigated the presence of individual stages of research, or the quality of their implementation. The table contains the percentage of answers to the above questions. We have put the answers to logical questions to one of the groups: yes, partly yes and no. The answers to quantitative questions are quantified.

Question \ answers percentage (the results are rounded to integers)	yes	partly yes	no
Investigated area and research problem			
Did the pupils determine investigated area?	77	23	0
Did the pupils define the research problem?	19	4	77
Does the research bring something new?	35	23	42

Research questions and variables of research			
Did the pupils define the research question?	15	0	85
Are there variables in research questions (or in research)?	96	0	4
Did the pupils distinguish between dependent and independent variables?	42	8	50
Did the pupils use the shape of chart as the evidence of the variables dependence?	58	0	42
Did the pupils use the correlation coefficient as the evidence of the variables dependence?	42	0	58
Hypotheses			
Did the pupils formulate hypotheses?	62	35	4
Average number of hypotheses (average / median / modus)	2.65 / 3 / 1		
Did hypotheses contain the relationship between at least two variables?	46	46	8
Are the hypotheses verifiable?	85	12	4
Data collecting			
Extent of research = number of questions * number of respondents (average / median / modus)	359.85 / 218 / 60		
Did data collection ensure values for each variable?	65	27	8
Did the pupils describe the process of selecting respondents?	27	12	62
Did the pupils describe the respondents?	0	42	58
Final report			
Did the pupils compile the final report?	100	0	0
Does the final report include the interpretation of results?	31	12	58
Does the final report include "retelling" of the graphs?	96	0	4
Did the pupils comment on the hypotheses validity?	92	0	8
Is the pupils' expression of the hypotheses validity correct?	35	23	42

Tab. 1: The analysis of pupils' works.

The following section attempts to explain some of the results.

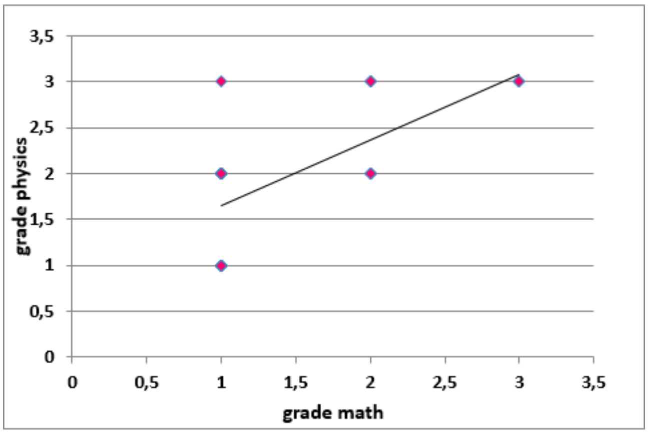
Pupils chose the area of research according to their interests. We consider as a positive element that the chosen area of research is in most cases (19 of 26) beyond the content of school informatics. Among the areas of research has emerged (free translation) e.g.:

- Alcohol consumption by adolescents.
- Sporting activities and obesity.
- Young people lifestyle (active life, time spent at the computer, eating, ...)
- The impact of gender on preferences in partnership.

- Artificial Intelligence, its perception and possible threats.
- Relationship between average of grade and the numbers of hours of absence.
- Weight of woman before and after her wedding.

We assume that the pupils' little experience and fear of failure caused that up to 58 % of research was previously almost clear that the results only confirm the already known facts.

Most pupils do not consider research questions necessary, or rather they replaced them by the question of whether there is a relationship between two variables. Half of the pupils do not distinguish between dependent and independent variable. This is probably a consequence of the previous pupils' experience. A typical school informatics task in the spreadsheet calculator environment is to create a chart. When doing so, teachers generally do not mention which variable is independent (defaults to the first row of the table data) and which is dependent and what this property of variable means. The fact that pupils prefer the shape of the chart as proof of dependency may be related to their mathematical background. It is interesting to note, that only in 42 % of cases pupils use the correlation coefficient (Fig. 1). In 36 % of these cases its use was incorrect (e.g. correlation between eye color and IQ).



Hypothesis:
There is a relationship between the mark of mathematics and physics.

Correlation coefficient:
0,67294

Conclusion:
Hypothesis is confirmed.

Fig. 1: The part of pupils' research: Correlations between the grade of mathematics and physics.

Hypotheses are quite clearly the identifiable part of investigations of this type (97 %). But at the same time it is not so easy to formulate hypotheses correctly (46 %).

The pupils did not pay too much attention to describe the selection of respondents (researched objects). However, this could lead to erroneous interpretation of the results, and/or to incorrect generalization of the research conclusions.

Every research includes some final report, but in most cases it was just a retelling of numbers from the chart. However interpretation and explanation of the results are not so simple. Similar conclusions can be found in commentaries of the final report "The main results of PISA testing in 2012" (Šiškovič & Toman, 2014). Among the mathematical problems the tasks aimed at interpreting the results and work with charts and tables ended up as the worst. A relatively large percentage of incorrect conclusions (42 %) is probably caused by the vague formulation in research (pupil meant something and said something else), perhaps by the desire to show that the hypotheses are valid (I am right). Another reason is that pupils do not use the exact tools that would unequivocally rule on the validity of hypotheses.

When analyzing pupils' work, we found that the results of the pupils can be categorized according to their teacher. Influence of teacher to pupil was strong. We explain it by the fact that such activity is new for pupils and teachers. Pupils thus have lack of experience to build their own way, preferring to abide by what the teacher submitted to them. Since neither the teacher had a lot of experience with this type of activity, either did not comprehend or did not realize the importance of the individual stages of research. Similarly, then followed his pupils. Subsequently, his pupils proceeded similarly.

We also note that teachers slightly underestimated this subject. The realization of such research is a complex and demanding activity. It is not possible to focus on only some elements of research and neglected others. Despite the fact that pupils carried most of the work outside school hours it is necessary for teachers to keep control and guide pupils in their work. However, teachers indicated in the questionnaire that pupils were working mostly alone (Fig. 2).

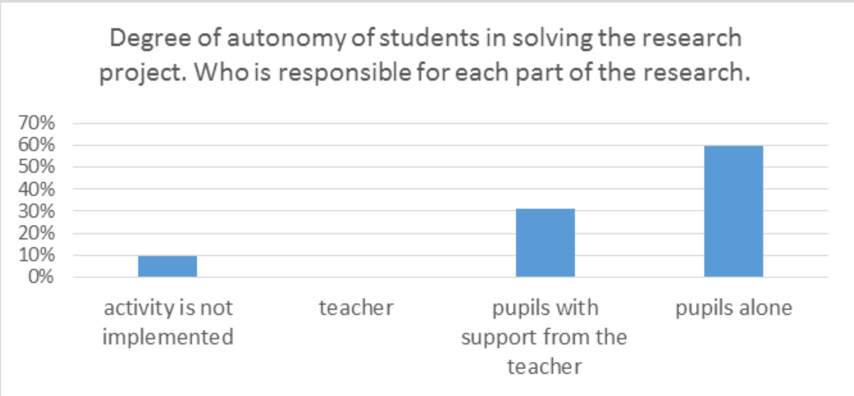


Fig. 2: Degree of pupils' autonomy in solving the research project.

We wondered how teachers assess the course of their teaching. According to the teachers this activity was quite interesting but difficult for pupils. Teachers considered their teaching as inquiry oriented with positive impact on understanding the acquired knowledge (Fig 3).

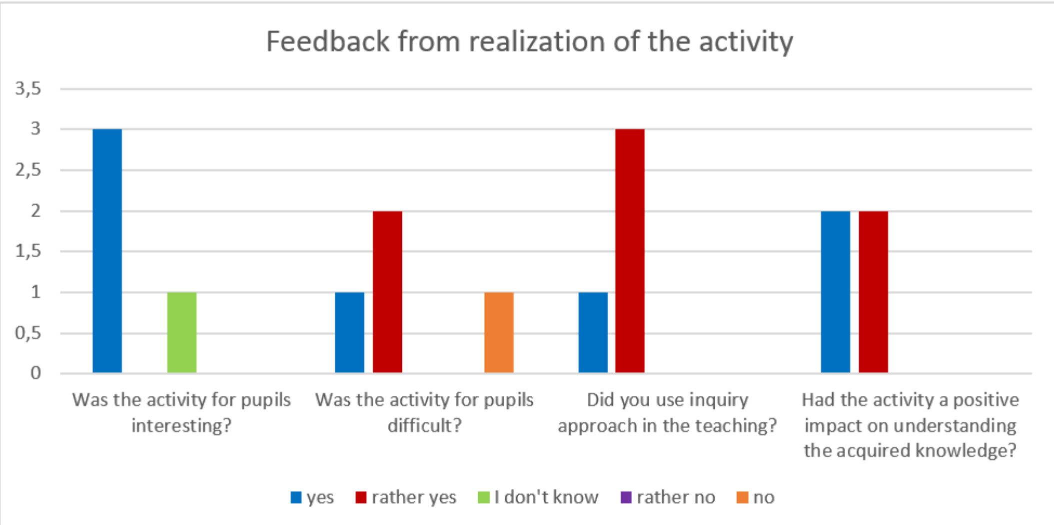


Fig. 3: Teachers' feedback from realization of the activity.

If we look at individual stages of the research problems solution, we find that the teachers realized similar activities (albeit isolated) with their pupils. E.g. the pupils are finding some values and write them to tables. Subsequently they statistically evaluated these values at the appropriate level. In most cases, however, the variables are given, the pupils only discover their values. But it is only rarely about complex problem (research problem) which requires to solve all parts in a single unit.

Although the current version of the methodology is the result of several iterations (Šnajder & Guniš, 2016), we consider that checklist appropriately guiding pupil while solving the research problem could become a part of the methodology in the future.

THE TEACHING METHODOLOGY OF THE TOPIC: THE BIT – UNIT OF INFORMATION

Next presented methodology is focused on teaching topic **The bit – unit of information**. This topic is reduced very often to the definition of the bit and the byte and calculations with byte and its multiples in our secondary grammar schools. We have updated and expanded the original version of the methodology published in (Šnajder & Guniš, 2012) to the current version that was verified at four secondary grammar schools in the school year 2014/2015 and at three secondary grammar schools in the school year 2015/2016. We suggest to teach the mentioned topic using the inquiry approach. This approach is more time-consuming in comparison to the instructive approach, but it allows pupils to understand the topic more deeply and to develop their inquiry skills by means of problem solving activities.

The structure of an inquiry methodology

Taking into account aspects of the IBE and iterative development of teaching methodologies, we proposed a specific structure of a teaching methodology (Šnajder & Guniš, 2016), that we used also for the teaching methodology of the topic The bit – unit of information.

In the section **Basic information** in addition to the standard items (e. g. topic name, target group, time allocation of a lesson, prior knowledge and skills, cognitive and affective objectives, didactic means) there is mentioned also the list of expected inquiry skills to be developed, the didactic problem, the names of the reviewers and the version of the methodology. **The didactic problem** of the topic is fact that there is insufficient space in teaching of informatics for deeper understanding of the bit as a unit of information, its identifying with the notion of a binary digit, as well as a simple calculation the amount of information in a message. Expected **inquiry skills** developed by this methodology are: experimentation, exploring the relationship between variables, justification of experimental findings, drawing conclusions.

The preparation section includes necessary teaching aids, tasks for verifying the level of prior knowledge and eventually a description of teaching methods. In the methodology we stated references for two worksheets, two applets, nine diagrams, table, concepTest (Šnajder, 2016) and set of tasks for verifying the prior knowledge of pupils.

The course of instruction is structured according to the 5E learning cycle (Engage, Explore, Explain, Extend, Evaluate) using a variety of teaching tools support (scaffolding) as recommended by IBE researchers (Bybee et al., 2006). It is defined by the following outline:

- Description of the game Guess the card (Engage) and playing the game in pairs (Explore).
- Heuristic discussion focused on discovering an effective method of determining a card (Explore) and the introduction of the concept bit as a unit of information (Explain).
- Demonstration of game with parallel guessing of 4 cards aimed at: to binary encoding of cards, to demonstrate the understanding the bit both as a unit of information and also as a binary digit, to prove the uniqueness of cards' binary encoding (Engage, Explore, and Explain).

- Practice the learned subject matter using a binary tree and its generalization at the N-ary guessing numbers or cards and extending to other information units as decits and trits (Extend).
- Summary and evaluation of the learned subject matter by self-assessment scales and concepTest (Evaluate).

The unique parts of the methodology are **The observations and findings** from teaching, which provides case studies of teaching of the author (Šnajder & Guniš, 2012) and teachers from partner schools of the VEMIV project containing percentage of particular task solutions, interesting pupils' solutions of tasks, and typical misconceptions in pupils' thinking.

The alternatives of the methodology allow a teacher to adapt the methodology to the particular conditions of teaching (e.g. his/her style of teaching, level of pupils' knowledge and skills, time allocation), and that in both direction i.e. narrowing or extension of this methodology version. It is up to teacher's competency to choose the appropriate set of tasks, levels and forms of scaffolding for pupils and level of pupils' inquiry. This methodology can be reduced to the teaching the bit as a unit of information without teaching other units (trit, decit) with fewer training tasks. The methodology can be expanded by several ways, e.g. adding tasks for other unit of information (trit, decit), pupils' programming a game for guessing number using specially prepared cards (using a binary system), discovering the relationship between the number of posed Q-nary questions and the number of cards, discovering the connection between the number of digits of Q-nary number, depth of Q-nary tree and logarithm with the base of Q, eventually to the introduction and practicing Hartley-Shannon's formula.

The methodology also includes the annex, i.e. worksheets, tables (Fig. 4), diagrams (Fig. 5), applets (Fig. 6), working files, concepTest, which are accessible for teachers on the web.

hearts, bells?	I know	hearts, leaves?	I know	J, Q, K, A?	I know	9, 10, K, A?	I know	8, 10, Q, A?	I know	binary code	decimal code
0	acorns, leaves	0	acorns	0	7, 8, 9, 10	0	7, 8	0	7	00000	0
								1	8	00001	1
						1	9, 10	0	9	00010	2
								1	10	00011	3
				1	J, Q, K, A	0	J, Q	0	J	00100	4
								1	Q	00101	5
						1	K, A	0	K	00110	6
								1	A	00111	7
		1	leaves	0	7, 8, 9, 10	0	7, 8	0	7	01000	8
								1	8	01001	9
						1	9, 10	0	9	01010	10
								1	10	01011	11
				1	J, Q, K, A	0	J, Q	0	J	01100	12
								1	Q	01101	13
						1	K, A	0	K	01110	14
								1	A	01111	15
1	bells, hearts	0	bells	0	7, 8, 9, 10	0	7, 8	0	7	10000	16
								1	8	10001	17
						1	9, 10	0	9	10010	18
								1	10	10011	19
				1	J, Q, K, A	0	J, Q	0	J	10100	20
								1	Q	10101	21
						1	K, A	0	K	10110	22
								1	A	10111	23
		1	hearts	0	7, 8, 9, 10	0	7, 8	0	7	11000	24
								1	8	11001	25
						1	9, 10	0	9	11010	26
								1	10	11011	27
								0	J	11100	28

Fig. 4: Table with encoding package of 32 German cards into binary system showing also equivalence of both meanings the bit (binary unit, binary digit).

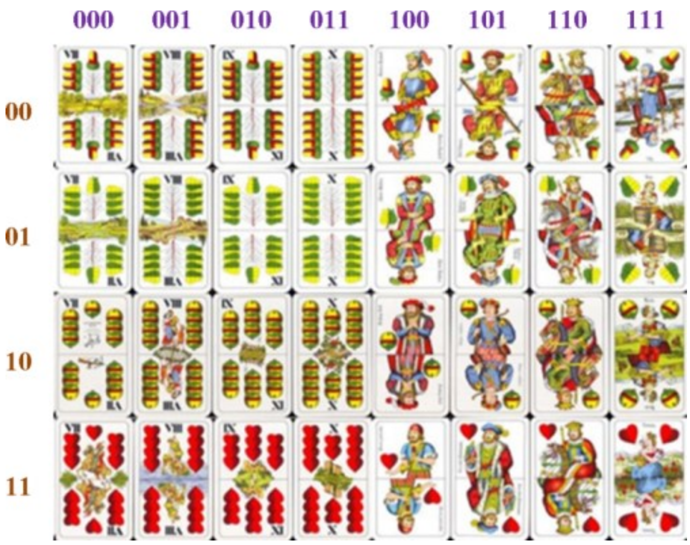


Fig. 5: Result of encoding package of 32 German cards into binary system (first 2 bits for card color, last 3 bits for card value).

Fig. 6: Applet for parallel guessing of 4 mentioned cards.

For illustration there is presented sample of two items of designed concepTest:

A message "Value of a card is 9 (from a package of 32 German cards)":

a) is 0-bit information, because we don't determine card color,

b) is 1-bit information, because we have information about exact card value, no information about card color,

c) is 2-bit information, because we still need to find out value one of 4 (=22) possible values,

d) is 3-bit information, because mentioned value is one of 8 (=23) possible values.

A message "A number has binary representation 1??10":

a) is 0-bit information, because we don't exactly determine value of mentioned number,

b) is 2-bit information, because we still need to find out 2 binary digits,

c) is 3-bit information, because we know 3 binary digits,

d) is 5-bit information, because a number consist of 5 binary digits.

Several assessment tools (e.g. pupils' worksheets and concepTest filled by pupils, interviews and questionnaires filled by teachers after their inquiry lessons) were used for evaluation of the course and the results of inquiry lessons in partner schools (especially the level of conceptual comprehension of the subject matter and level of selected inquiry skills of pupils) as well as the development of a new version of the methodology.

Analysis of research results of teaching

The methodology was implemented in school practice during two years. During the pilot run in school year 2014/2015 there were involved 34 pupils from five classes from four secondary grammar schools who verified the methodology. During the ordinary run in school year 2015/2016 there were involved 39 pupils from four classes from three secondary grammar schools, including 16 pupils in 1^{st} grade (ages 15-16) and 23 pupils in 2^{nd} grade (ages 16-17).

Based on the evaluation of the worksheet with 13 tasks, filled by pupils during their inquiry lesson, we have come to the following findings:

- Task 1 is focused on writing a list of questions (and answers) for guessing a schoolmate's card from package of 32 German cards. Only 21 % of pupils during pilot run solved optimally this task. After adding of the picture with cards to the worksheet in ordinary run, percentage of pupils' solution this problem increased to 44 %. Some pupils by drawing to the picture with cards narrowed a set with potential card, which helped them to find the optimal solution. In pupils' solutions new types of questions based on the pictures of cards emerged, e.g. “Is it a color of vegetable?”, “Is there a man on the picture?”, “Is the card on an even position?”, “Is it at the third row?” or a very condensed formulated sequence of five questions “Y/R? G? >10? J/Q? A?” In another part of the task the pupils should find an optimal solution after discussion in pairs. The correct number of total questions was determined by 46 % of pupils, the number of questions for the card color by 74 % and for the card value by 59 % of pupils. It turned out that after discussions in pairs the percentage of solutions increased only slightly and also that it is easier for the pupils to determine the card color than the card value. From particular solutions of this task there can be identified certain differences among pupils in terms of their algorithmic thinking (discovering of the binary search algorithm), their systematic approach and thoroughness in their written solutions.
- Task 4, focused on the assignment of the binary code for chosen card using the same 5 questions, and was solved correctly by 97 % of pupils in both the ordinary and the pilot run. The second part of the task, focused on distinguishing both parts (for color and for value) of the binary code, was correctly solved by 53 % of pupils in the ordinary run and by 56 % ones in the pilot run. There were not registered any false solutions, but only the lack of distinguishing marks for color and value in the binary code. To obtain more accurate results about thinking of pupils, it is important to draw their attention to thorough filling of all items in the worksheet.
- Task 5 is aimed at identifying a card based on given binary code. This is a dual task for the task 4, which was suggested by pupils during the pilot run. Despite its high percentage (87 %) the task plays very important role in strengthening the subject matter.
- Task 6 focuses on declaring and proving the uniqueness of encoding the cards using binary numbers. Although 95 % of pupils correctly concluded that such encoding is unique, only 23 % of pupils approached to the correct argumentation who reported that each card has a different binary code. No pupil did prove the uniqueness of binary codes, e.g. by construction of the binary tree whose all vertices have different binary codes. This task and other ones showed very weak argumentation skills of the pupils, or low need to prove their arguments orally and all the more in writing form.
- Task 7 was aimed at constructing the binary tree as a guide for guessing an integer number ranging from 0 to 7. Only 23 % of pupils properly constructed the binary tree. 38 % of pupils did not attempt to draw a binary tree at all. This indicates that pupils not so often meet a tree structure in their learning and use it for solving problems. In further two subtasks only 44 % of pupils understood the need for asking the same number of questions for guessing integers in ranges <0, 7> and also <1, 8>. In the last subtask of task 7 and also in the task 10 only 39 % of pupils correctly determined the number of questions required for guessing a number (or a card) from set of 2K numbers (or cards). There was another pair of analogous tasks formed by the task 2 and the first three subtasks of the task 9 that increase the reliability of the results of the worksheet. In both groups of tasks 56 % of pupils correctly determined the amount of information for various messages about cards. It showed a higher percentage of pupils

in determining the number of bits concerning a card color (74 %) in comparison with a card value (56 %). A surprising finding was slightly lower success rate in solving the task 9 in comparison to analogous task 2, which was likely caused by more autonomy of the pupils in solving task 9.

- Extensional tasks 11 to 13 were solved only by a few pupils with very low success rate. Individual degree of the knowledge was denoted in self-evaluation card by about 30 % of pupils for the extensional subject matter in comparison to 50 – 60 % of pupils for the basic subject matter. In the evaluation card 49 % of pupils said that the tasks were interesting for them in comparison to 14 % of pupils for whom these tasks were boring. For 35 % of pupils were the tasks difficult and for 11 % of pupils they were easy. We recommend the teachers to include 3 extensional tasks to their lesson only after their pupils successfully solved first 10 tasks, which could reduce the complexity of tasks and increase their attractiveness.

Degree of conceptual comprehension of the topic **The bit – unit of information** was verified also by the concepTest containing 10 multiple choice questions. Its publishing in the form of web form (at http://goo.gl/forms/OMxlSkfGBf) allows its availability for1 many schools and rapid evaluation of its results. In early April 2016 the concepTest was solved by 58 pupils of 1st and 2nd grade of three grammar schools participating in the project VEMIV with an average success rate of 53 % and 28 pupils of 1st and 2nd grade of two grammar schools outside the project VEMIV with an average success rate of 12 %. It is quite natural that higher percentage of success was achieved by pupils who learned the subject matter in comparison to pupils who were not involved in the topic before. Interesting, however, is very low success rate of 12 % in contrast to about 25 % which would be achieved by random answering of the pupils.

For improvement of the new version of concepTest the analysis of the test distractors can be used. 9 from 30 distractors had a lower frequency than 10 %. The distractors with the lowest rates could be removed or replaced by other ones in the concepTest. A total of 7 distractors had a higher frequency than the correct answers, which draws attention to the subject matter which should be taught more carefully in future lessons.

Other sources for analysis of teaching were the web forms in which teachers from partner secondary grammar schools reported the following observations and findings from their teaching:

- The range of teaching 90 minutes is sufficient only for the basic subject matter (first 10 tasks in the worksheet), all teachers used worksheet in their lessons but only some of them used our applets.
- The teachers considered the subject matter as rather interesting and rather difficult for their pupils. The activities connected with guessing a card were interesting for pupils, as was exemplified by the question "Do also magicians with cards use that trick with binary codes?", which was asked by a pupil to her teacher, who played the role of a magician during the lesson.
- Some teachers reported dominance of group work of pupils, others individual work, e.g. in case of some talented pupils. The teachers provided support to the pupils by guiding questions as needed. In some cases, the pupils took their initiative, e.g. helping pupils from other group or programming a card guessing game.

Summary of research results of teaching

Based on the results of worksheets and concepTest solved by pupils and also written and oral feedback from teachers on their teaching, we came to the following conclusions:

- IBE is time consuming, requiring the involvement of the pupils' and teachers' higher cognitive functions. On the other hand, solving problems in the form of magic and games provides an incentive to solve interesting problems and develop their inquiry skills.
- In supporting IBE the worksheets are of the great importance, because they determine an inquiry way of learning and teaching, they are a tool for the diagnosis and development of selected inquiry skills and also are helpful for further educational interventions. In order to achieve the most accurate results, it is important that teachers requested pupils to complete consistently their worksheets.
- Since IBE of informatics is explored too little yet, we consider it important to provide methodological support for teachers in the form of methodological materials, which sets out specific outcomes, tools, course of teaching, etc. Unconventional but very useful parts of the methodology are The observations and findings from teachers after their lessons and also The alternatives of the methodology that provide teachers with relevant know-how and ideas for the methodology modification according to themselves.
- Results of worksheets and concepTest give teachers more information about pupils' level of understanding of the subject matter and their level of inquiry skills. We consider this approach to learning and teaching as more scientific in comparison with teaching without registering results of pupils' thinking, based only on teachers' observations and their impressions.

Conclusion

Based on the previous analysis, we conclude that the teacher is a very important factor in the IBE of informatics. Despite of thoroughly prepared methodologies for teachers there were not achieved expected pupils' results. Therefore it is not sufficient to provide only a methodology and pupils' worksheets for the teacher. For quality implementation of the IBE the teacher should have sufficient theoretical knowledge and practical experience in researching and with IBE too. Moreover, the teacher should have a positive attitude towards the implementation of the IBE in his teaching.

Aims of teaching informatics are not just concepts and facts, but also the scientific procedures and methods by which informatics achieved these concepts and facts (inquiry skills).

We recommend the following three-stage process at university teacher training and further education of informatics teachers:

- a teacher in the role of inquiry pupil develops his inquiry skills,
- a teacher in the role of inquiry teacher analyzes and modifies presented IBE methodology and subsequently he implements it in his own teaching,
- a teacher in the role of the author of IBE methodology, which reflects his own experiences and suggestions for IBE of chosen informatics topics.

In this article we mentioned observations and findings from IBE of two topics of different character that do not use the same format of methodologies. We accept also other formats of methodologies. We consider formats of mentioned methodologies to be a framework for the preparation of teaching, on the other hand, these formats should not limit teachers to adapt their teaching according particular conditions.

Thanks to cooperation with didactics of physics and mathematics, which have rich knowledge and experience with IBE, we developed and implemented the mentioned methodologies into school informatics. This cooperation is very beneficial in research and implementation of IBE and STEM in education.

ACKNOWLEDGEMENTS

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-0715-12 Research on the efficiency of innovative teaching methods in mathematics, physics and informatics education: VEMIV.

References

BALOGOVÁ, B. and Z. JEŠKOVÁ. Analýza bádateľských aktivít: národný festival fyziky 2015. In: *Tvorivý učiteľ fyziky VIII*. Bratislava: Slovenská fyzikálna spoločnosť, 2016, **2016**(VIII), s. 14-21. ISBN 9788097145088.

BANCHI, H. and R. BELL. The Many Levels of Inquiry. *Science and Children*. 2008, **46**(2), 26-29.

BERG, E. V. The PCK of Laboratory Teaching: Turning Manipulation of Equipment into Manipulation of Ideas. *Scientia in Educatione*. 2013, **4**(2), 74-92.

BYBEE, R. W., J. A. TAYLOR, A. GARDNER, P. V. SCOTTER, J. C. POWELL, A. WESTBROOK and N. LANDES. The BSCS 5E Instructional Model: Origins, Effectiveness and Application. In: *BSCS* [online]. Colorado Springs: BSCS, 2006 [cit. 2016-09-14]. Available from:
http://www.bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Executive_Summary_0.pdf

FRADD, S. H., O. LEE, F. X. SUTMAN and M. K. SAXTON. Promoting! Science literacy with English language learners through instructional materials development: A case study. *Bilingual Research Journal*. 2001, **25**(4), 417-439.

IAP. Taking Inquiry-Based Science Education into Secondary Education. In: *Aktualni dogodki - Slovenska Akademija Znanosti in Umetnosti - sazu.si* [online]. York, United Kingdom: IPA the global network of science academies, 2010 [cit. 2016-09-14]. Available from: http://www.sazu.si/files/file-147.pdf

LUKÁČ, S. *Výskum efektívnosti metód inovácie výučby matematiky, fyziky a informatiky* [online]. Košice: Univerzita Pavla Jozefa Šafárika v Košiciach, Prírodovedecká fakulta UPJŠ, 2016 [cit. 2016-09-14]. Available from:
http://ufv.science.upjs.sk/_projekty/vemiv/projekt.php.

ŠIŠKOVIČ, M. and J. TOMAN. PISA 2012: Výsledky Slovenska v kocke. In: *Ministerstvo školstva, vedy, výskumu a športu Slovenskej Republiky* [online]. Bratislava: Inštitút vzdelávacej politiky, Ministerstvo školstva, vedy, výskumu a športu SR, 2014 [cit. 2016-09-14]. Available from: https://www.minedu.sk/data/att/6077.pdf

ŠNAJDER, Ľ. and J. GUNIŠ. Inquiry based learning of selected computer sciences concepts and principles. *International Journal of Information and Communication Technologies in Education* [online]. 2012, **1**(1), 28-39 [cit. 2016-09-14]. ISSN 1805-3726. Available from: https://periodicals.osu.eu/ictejournal/9_15_volume1-issue1.html

ŠNAJDER, Ľ. and J. GUNIŠ. Bádateľsky orientované vyučovanie informatiky - priebežné výsledky pedagogického výskumu. In: *DidInfo 2016*. Banská Bystrica: Univerzita Mateja Bela, 2016, s. 116-123. ISBN 9788055710822.

ŠNAJDER, Ľ. *Bádateľsky orientované vyučovanie informatiky: Bit – jednotka informácie* [online]. Košice: Univerzita Pavla Jozefa Šafárika v Košiciach, Prírodovedecká fakulta UPJŠ, 2016 [cit. 2016-07-14]. Available from: http://ics.upjs.sk/~snajder/bovi/2_bit/

TAMIR, P. and V. N. LUNETTA. Inquiry-Related Tasks in High School Science Laboratory. *Science Education*. 1981, **65**(5), 477-484.

VAN DEN BERG, E. The PCK of Laboratory Teaching: Turning Manipulation of Equipment into Manipulation of Ideas. *Scientia in educatione*. 2013, **4**(2), 74-92.