Inquiry-Based Science Education in Secondary School Informatics – Challenges and Rewards

Nikolina Nikolova(✉) and Eliza Stefanova

Faculty of Mathematics and Informatics, Sofia University St. Kl. Ohridski, Sofia, Bulgaria
{nnikolova, eliza}@fmi.uni-sofia.bg

Abstract. The paper presents an application of the inquiry-based science education (IBSE) approach in the context of informatics, specialized classes, in the process of studying Java language by 11 graders. The experiment under consideration presents classes, performed in parallel in two mathematics high schools in Sofia, Bulgaria, in two consequence years.

The levels of IBSE as well as meta-levels of inquiry skills developed by students in process of learning are described. Next, the context of the experiment is presented.

Two different variations of the approach application are shown – *open inquiry* and *guided inquiry*. The products, developed by student as results of the education, are presented.

The analysis of the challenges, staying in front of the students and the teachers, in process of application of the inquiry-based science education takes special place in the paper.

In conclusion, the application of IBSE is analysed from the point of view of long-term effect of education.

Keywords: Inquiry-based science education (IBSE) · Design of education · ICT enchanced skills

1 Introduction

The *specialized classes in informatics* are real challenge for the teachers. There are approximately 30 schools having such classes in Bulgaria, three of them – located in Sofia. These classes deal with advanced object-oriented programming. The curriculum is similar to the curriculum applied during the first two years at the university. This means the learning process is quite heavy in terms of content.

The main efforts of the teacher in these classes usually are focused on acquiring some basic knowledge and skills in programming and data structures, as well as in algorithmic thinking development.

In practice, the training is often reduced to teaching the very language constructions, usually by lectures and uniform examples, which are not meaningful for the students. Our personal experience and the experience shared by other teachers in informatics strengthens our conviction that applying this widely used approach leads to a lack of motivation and to superficial skills.

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In harmony with the constructionist's spirit, we have been applying in our practice the credo: *learning by programming is more important than learning to program* [1].

Toward the elimination of the deficiencies of the traditional approach of teaching programming, we tried to apply project- and inquiry-based science education in the specialised classes of informatics [2]. Effectiveness of such type of education encouraged us, but in the same time placed in front of us new challenges. The main one was how to design the process of education, so that to cover state educational goals – the curriculum-related requirements (as defined by the state standards), and in the same time to increase the motivation of the learners.

In response to that challenge we decided to design the learning process, applying *I*Teach* methodology [3]. It is developed in the frame of the *Innovative teacher project* (*I*Teach*) [4], implemented under the Leonardo da Vinci program. Its characteristics are:

- The learning process is driven by students' interests.
- The students are faced with a challenge, which motivates them to participate actively in the process of learning.
- The students work in teams on a project, whose goals they formulate themselves.
- The *road to the goal* is a metaphor behind a specific educational scenario with *milestones* of intermediate objectives. The teacher guides the students to the ultimate project goal by interweaving his/her own pedagogical goals concerning the learning content with the building of ICT-enhanced soft skills (working-in-a-team skills, working-on-a-project skills, and information and presentation skills).

When we speak about the synergy between the I*Teach methodology and the Inquiry Based Science Education, we think about *fishing* – we just put the appropriate challenge in front of students and let them research, try, ask, and find their own solutions, getting better and better in the learning /discovered material (Fig. 1).

We already have provided an evidence of the effectiveness of the I*Teach methodology in series of trainings in ICT with teachers [5, 6] and students [7], but we had not applied it in the informatics education at school so far. In addition, it was

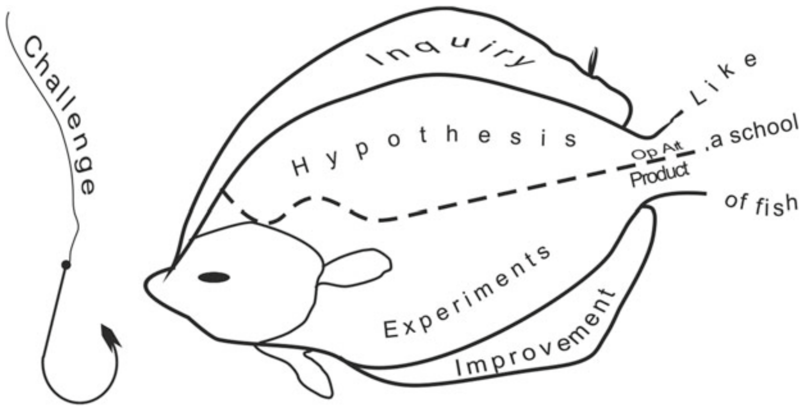

Fig. 1. Metaphor of the I*Teach methodology in the context of IBSE

necessary to think about the choice of the right level of the IBSE, depending of aiming students skills.

2 Levels and Skills, Developed Through Inquiry-Based Science Education

2.1 Inquiry-Based Science Education

The original idea for IBSE belongs to John Dewey [8] and includes concepts related to construction of the subject knowledge by student-centred learning based on student presented inquiries. It comes in contrast of the traditional approaches based on memorising contents, achieving basic problem solving skills in laboratory courses, where experiments mostly include not inquiry but verification of known principles.

The idea has been developed during the further years and the IBSE has been more precisely defined according to the specific needs and goals. According to a definition by Linn, Davis and Bell, inquiry is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments [9]. As a consequence, Inquiry Based Science Education is *an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding* [10].

Although this approach is rather difficult and time-consuming for the teachers, it pays off in terms of effectiveness, and it is therefore worth applying, if not for the whole curriculum, at least to achieve in-depth understanding of critical, core concepts that are the cornerstones of scientific disciplines.

2.2 Levels of Inquiry-Based Science Education

According Tafoya [11], the following levels of inquiry-based science education could be defined (Fig. 2):

Five inquiry skills areas, which could be developed at the meta-level, could be defined, depending on the level of the inquiry-based science education (Table 2) [12].

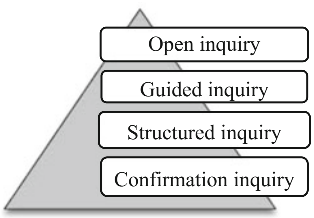

Fig. 2. Tafoya’s classification of levels of inquiry

Table 1. Meta-levels of inquiry skills (table adapted by Okada, 2008)

Level of inquiry	Inquiry skill area: 1. Scientifically orientated questions	2. Priority to evidence	3. Explanations from evidence	4. Explanation connected to knowledge	5. Communicate and justify
4 Open inquiry	Posing a scientific question	Determining what constitutes evidence, and collecting evidence	Formulating explanations after summarizing evidence	Examining independently other resources and forming the links to explanations	Forming reasonable and logical argument to communicate explanations
3 Guided inquiry	Selecting among given questions and posing new scientific questions with guided support	Collecting certain data with guided support for what constitutes evidence	Formulating explanations from evidence with guided support	Linking areas and sources of scientific knowledge to clarify explanations	Communicating explanations based on scientific reasoning with guided support
2 Structured inquiry	Sharpening or clarifying question provided by teacher, materials, or other source	Analyzing given data to select evidence	Selecting ways to use evidence with directed support to formulate explanation	Selecting possible connections to clarify explanations	Selecting broad guidelines to use sharpen communication
1 Confirmation/ verification	Engaging in questioning provided by teacher, materials, or other source	Analyzing given data to select evidence with directed support	Applying provided evidence to formulate explanation with directed support	Selecting possible connections to clarify explanations with directed support	Applying given steps and procedures for scientific communication

Table 2. Responsibilities depending on the level of inquiry

Level of inquiry	Problem	Procedure	Solution
Level 4 Open inquiry	**Student**	**Student**	**Student**
Level 3 Guided inquiry	Teacher	**Student**	**Student**
Level 2 Structured inquiry	Teacher	Teacher	**Student**
Level 1 Confirmation/verification	Teacher	Teacher	Teacher

As it is visible in Table 2 above, the higher inquiry level requires bigger responsibility to be taken by the students. This presumes that, in order to go from one level to another, they should have already developed enough cognitive and social skills, as well as previous meta-level inquiry skills. The teacher responsibility is to estimate the maturity of his students in advance and then – to make a choice of the level and to design the IBSE project (Table 1).

3 The Context of the Application of IBSE Approach in Informatics Education

3.1 Background and Methodology

In the described experiments the methodology I*Teach combined with IBSE approach were applied in two consequence years – 2010/2011 and 2011/2012, in four *specialized informatics classes* of 11th grade students from two mathematical high schools.

The main goals of the 11th grade specialized classes in informatics in the Bulgarian high schools as defined by the state standards, are: *mastering skills and knowledge about the syntax and the semantics of programming language*, *algorithms and basic data structures*.

The time determined for this is 108 academic hours (40 min each). The classes were taught in the context of the Java programing language. The students are expected to move from the procedure-oriented to the object-oriented programming paradigm and to acquire the concepts of classes and objects, data encapsulation, composition and inheritance.

The teacher diary, together with some observations and conclusions, were used to collect data, on the basis of which the phases of the experiment are described below. Unstructured interviews have been used for getting feedback from the students.

3.2 IBSE Assignment

Both pilots of the experiment were based on working on an inquiry project, related to the stream in the modern art named *Op Art*. The students had not only to examine carefully the art and its well-known representatives, but also to study technologies, through which such works are created: How the optical illusions are achieved? What are the types of optical illusions? – questions, related to physics, biology, psychology and other sciences.

After the study they were grouped in teams of 2 (in the National High School of Mathematics and Science - NHSMS) or 3 (in the First Private Mathematical Gymnasium - FPMG) members and had a programming assignment under the topic *It's a kind of Magic!*: to develop a simple Java application presenting Op Art graphics. Some of the requirements were:

- To show *Op* Art pictures – really based on the optical illusions;
- To create Op *Art* products – the resulting images should have aesthetic value. For validation of this requirement public final presentations were organized and visitors (other students) used evaluation cards to share their feelings.
- To develop Java *application* – the result should not be just a static drawing, but an application which allow users interaction.

The assignment was challenging for the students and required very well organized learning design in terms of milestones definitions, conducting students work, selecting additional learning resources and time management.

As a result, the main stages of the IBSE project were defined:

- Preliminary study about the Op Art, famous representatives, and technics and technologies for optical illusions creation. This stage finished with the class presentations and discussions. Duration: 1 week (3 academic hours).
- Forming teams. Students were grouped by themselves. Result: each group informed the teacher. Duration: 1 week out of the class doors.
- Choosing/creating a model and development an idea for further development, possible derivatives, opportunities for parameterization and interaction. At the end of the stage all teams reported and received feedback and ideas by other students and the teacher. Duration: 1 week in the class for preparation and presentation, and the last week out of the classroom to respond to the class requirements.
- Application development and improvement. At this stage the students should develop their plans and timesheets, to distribute the roles and responsibilities in the team, to design classes and their relationships, to determine desired functionality. They were asked to work mainly out of the class, and to use the face to face meetings to present intermediate results and problems to the teacher, to discuss their TODO list, to ask for assistance or additional sources of information. Duration: 3 weeks.
- Presentation of final products and evaluation. Duration: 1 week.

Requirements for the final presentation were closely related to the evaluation criteria. The teams should present the idea and the mathematical model behind it, to demonstrate the application, what problems they had met and how they solve them, and, the most important, to share what new knowledge and skills they had been acquired during the work on the IBSE project. They were appreciated to present all aspects of the evolution – new mathematical knowledge discovered and used, new programming concepts and algorithms learned and implemented, new Java-integrated classes familiarized with, new information from other sciences – biology, psychology, physics, etc., new skills in workflow management and control, new attitudes to the team members.

The evaluation process combined teacher's assessment as well as peer assessment. The evaluation criteria covered four rubrics:

– The initial model and related mathematical model assessment – does it provide opportunities for flexibility and reuse, does the appropriate mathematical lows were applied and how they were used, does the class design is appropriate and does in provides opportunity for implementation and further enlargement of the project.
– Project implementation – the use of appropriate programming structures, style of coding, effectiveness of algorithms, etc.
– Final presentation – covering the initial requirements, verbal and non-verbal communication with audience, presentation structure and design.
– Team work –the role of each member of the team, are tasks well balanced, how the team solved internal problems, are there "gaps" in the project because of the lack of communication among the team.

The detailed evaluation criteria were shared among all students. Each team was evaluated by all other students and the teacher using quantitative scale from 2 to 7 where the 6 presented the maximum expected achievement but 7 was a bonus – only if the team show much more. The students were asked to provide argumentation for each offered score.

In addition, the teacher assessed student arguments in the peer evaluation and if they correspond to the provided scores.

Finally, each team received five scores – for each rubric, and a feedback presented by diagrams of summarized results by rubrics and a list of the students and teacher argumentations, presented anonymously.

3.3 Pilots

The first experiment [2] was designed as an **open inquiry**. It was conducted in 2010/2011 school year in the two schools: NHMS and FPMG. Two teachers and three classes of totally 62 students – 52 from the NHSMS and 9 from the FPMG, participated in the pilots. There were two classes from the NHSMS which were separated in two groups by 13 students and taught in parallel by both teachers. The students from the FPMG were taught by one teacher.

Before stating the assignment the students were able to draw by means of Java only simple geometrical figures: circle, square, and rectangle. They have been introduced with the classes and object concept and they have been realized simple classes as a common group work.

Working on the project challenged them to discover, explore, analyse and apply additional learning materials, related to mathematical model and dependences as well as to object-oriented programming concepts (overload and override concepts, class composition, controlling access to the class members, etc.) and different programming technics – right parameterization of the functions, finding repetitive patterns, top-down and bottom-up approaches, through which to realize their ideas.

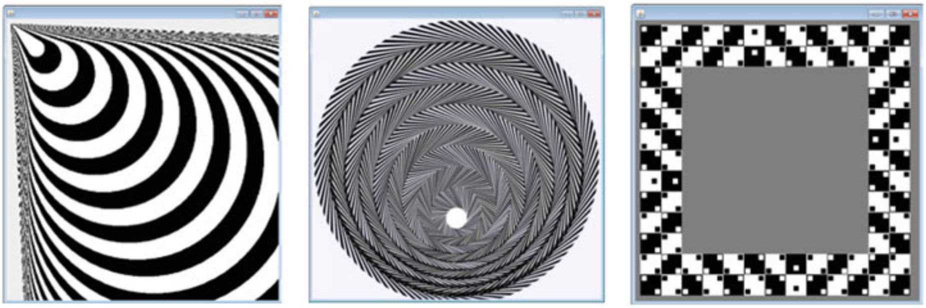

Fig. 3. Products of students, presented after the open inquiry

During the process of their studies on the project the students learnt and discovered themselves also a variety of Java language possibilities, especially the methods of the Graphics2D integrated class, and they were very proud to present developed by them as a result of their work on a project products (Fig. 3.).

The trend to follow the models of the founder of the Op Art stream – Bridget Riley, was visible in the students' products: use of well-known simple geometrical figures, work in black-white tonality or just with plain colours.

Although the students created very attractive products and they achieved exiting results, there were observed also some difficulties:

- Team work – in both schools there were teams which members were not able to work together. Some of these teams were destroyed (2 of 29) and members continued individually, other were reformed (3 of 29) but met a lack of time to finish the project because new teams started later than others.
- Project work – there was a clearly manifested difference between students in both school. While the managers (principal, head teachers) of the FPMG promote the inquiry-based science education and the project-based learning (PBL) and required their application in almost all disciplines – chemistry, physics, biology, philosophy, etc., in the NHSMS the individual competitive style on working on a specific simple problems /tasks dominated. As a result the students from FPMG felt in *their own water*, while for the students from the NHSMS it was completely new situation. The most of them expect the teacher to organize their work, to prepare a plan, to say what and when should be done. When the time become shorter and they should present intermediate results, they started to panic and tried in chaotic way to catch up the lost time and missing results.
- Time management – all the teams met difficulties to finish their tasks in time and the deadline was prolonged with two weeks.
- Academic maturity –the students from the NHSMS were very well trained to search for, select, process and apply the needed new information and knowledge (they write science essays frequently in other disciplines), while the skills of students from the FPMG were limited to search for given keywords and to transfer the found information in their work without even any adaptation– the technique that usually does not work in programming.

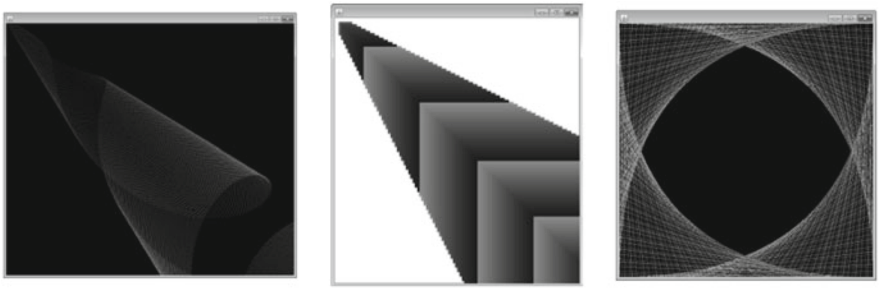

Fig. 4. Students products, presented after guided inquiry

The second pilot held a year later, in 2011/2012 school year. Only one class (8 students) from the FPMG continued the participation in the experiment. Considering the problems after the first application of the IBSE approach and having in mind the lower lever of the meta-inquiry skills of the new group, it was concluded that the **second application** of the IBSE approach - **the guided inquiry**, will be more convenient and it was chosen. The goal was: the students to be guided during the process of *discovery* of some mathematical models and methods of class *Graphics2D*, and in such a way to be well-grounded with regard to the programming concepts.

The results (Fig. 4) give evidence that this time the students really felt more self-confident. In that case, besides of use of set of simple geometrical figures with which they were already familiar, the students tried to experiment more with different settings and metric dependences, related to colours. Even more, some of them made a successful attempt to model through the use of affine transformation in the plane (*Java AffineTransform class*), developing by their own decision and their own hard work and experiments new mathematical knowledge and skills!

4 Challenges of IBSE in the School Practice

As it is visible by the provided examples, the IBSE implementation conceals a lot of challenges for both – students and teachers.

4.1 IBSE Challenges for the Students

For the students of one of the schools, the main challenge was to implement the IBSE approach for the first time. At the second school it was visible that, working on IBSE projects in other school disciplines, the students had been started already to develop inquiry-based science skills. So the work with them progresses far more easily. But for them the main challenge was to learn how to work efficiently with new information.

A serious challenge in front of all students occurred in combining together series of new *soft* competences: selection of reliable sources of information, organization of the tasks of the project, role distribution, time management, taking responsibilities, as well as in integration of knowledge from other school subjects, mainly from mathematics.

To learn how to learn – this was the biggest challenge for the students. It is true that they have enriched their knowledge and developed skills related to mathematical modelling and various concepts of object-oriented programming – became aware of notion on *Class*, *Object* and *Inheritance*. But they did not relay fully on teachers to receive it. They realized that they just should start and go through analysis of the sources and their evaluation, next to read *thick* (although some of them in electronic format) books, and become a part of professional forums. During the process of their work, the students felt natural need to respect the programming style standards (because without them it was not possible to program in a team) as well as to seek for the optimization of the programming code. In natural way they discovered *Top-down* and *Bottom-up* programming approaches. Last but not least – they got to know additional interesting and useful for them information, like Op Art for example.

4.2 IBSE Challenges for the Teachers

Most teachers do not dare to apply the IBSE and PBL approaches because they feel that the situation *spirals out* of control. They fear that there is no guarantee that they would ensure equal absorption of the learning material, that there will be students who will participate or not correctly interpret an experiments.

We can find reasons for such a view in some scientific papers [13], where inquiry based science education and project-based learning are associated with minimal guidance during instruction. Most educators still underestimate the fact that really effective IBSE and PBL approaches need careful design to be successful and that the role of the teachers remains one of paramount importance, even if it isn't any more that of the knowledge source. The teacher role becomes even more difficult with these approaches, because the aim is no longer that of transferring content knowledge, but rather that of facilitating its appropriation, development of confidence with epistemic practices and mastery of soft skills such as collaboration and self-regulation [14]. Especially the more learner centred types of IBSE, where the students gain the ownership on the research question, the research process and the outcome demand an often unfamiliar and challenging role from the teachers [15]. To do this, teachers also need to consider differences between pupils and, at the same time, promote cooperation among them.

However, the motivation to learn and the success of inductive learning processes depend on the gap between the challenge and the knowledge needed to address it.

In addition, the design and organization of an interdisciplinary inquiry-based science education project requires wide general culture and knowledge in different areas of science, art, social life, etc. However, is there such a teacher, who is an expert in everything?! With what quantity of additional information should he be familiarized prior to design such a project? How much time should he sacrifice for his preparation? Is there anyone whom to ask for help? Moreover, the teacher usually is the elder than his students and he is not able to adopt process and memorize new information as quickly as the students can.

The crucial points are the selection of the problem and the guidance that teachers give their students when they are inquiring a problem; such guidance helps students to elaborate proper concepts, and to meet troubles and difficulties arising during the inquiry process. Planning for an inquiry learning process is a challenge for the teacher's ability to understand students' unanticipated questions, and his reasoning ability to handle them.

Regardless how well designed the inquiry-based science education project is, the challenges related to its implementation remain:

- What questions will arise by the students? Will he find the answers?
- How to manage in the same time several teams, working in parallel on different projects? What will happen if they fail to complete their projects in time? Shall he give them additional time? Is it acceptable to grand them such time?
- Is it possible he do not be able to react on time, because of rising of great number of many-sided questions, for some of which he can be completely unprepared?
- How **to guide the process** instead of **to teach**, as he used to do?
- How to organize differentiated education, so to reach the maximum with each student, regardless of the complexity of the project he/she undertook and his/her current capabilities, knowledge and skills?
- What approaches and tools for assessment to be used in order to stimulate the students to continue their development, instead just to do *an autopsy* of them.

The challenge, the teacher is most unfamiliar with, is **how to design the inquiry-based science education project**. It requires the teacher firstly to select attractive for the students topic, then – to perform preliminary study, including selection of sources of information, resources and activities, to define a clear formulation of the project and assessment criteria, to define the key milestones, and to intervene during the implementation only if it is necessary (during the experiment the next question often appeared: *To help or not to impede?!*).

5 Prerequisites for National-Wide Spread of IBSE

On the base of our practical experience and observations we try to summarize the prerequisites for wide spread in teachers' practice of the inquiry-based science project education.

The necessary conditions for national-wide spread of IBSE could be divided at three levels: micro level (teachers), mezzo level (schools), macro level (national education system). There is close relation between them: the prerequisites at national level are condition for flexibility and opportunity of the schools and the teachers to apply IBSE effectively and efficiently.

Existing experience in some European countries – we focused especially on Ireland, Northern Ireland and Finland, seams also to prove summarised below prerequisites as *necessary and sufficient* condition for national-wide spread of IBSE and the other innovative approaches.

5.1 Prerequisites at Micro Level (People – Teachers, Parents)

The change in the *teacher's attitude toward the IBSE* is the first important prerequisite at micro level. In most of the cases teachers are trained to teach how to use traditional (deductive) methods of math and science teaching, and lecturing is widely spread in teacher education courses. As teachers tend to teach as they were taught, it is likely that they also teach through lectures even if it doesn't lead to appropriate understanding. McDermott et al. [16] point out that instructional strategy is content specific. "If it is not learned in the context in which it is to be implemented, teachers may be unable to identify the critical elements". The results, as they have been reported by High Level Group [17], are that science subjects are often taught in a much too abstract way: "It is abstract because it is trying to put forward fundamental ideas, most of which were developed in the 19th century, without sufficient experimental, observational and interpretational background and without showing sufficient understanding of their implication."

The practice shows that teacher's attitude is related to teacher's self-confidence. That is why next prerequisite is to change the *teacher's self-confidence* with respect to his abilities.

For some teachers an obstacle to introduce IBSE is their vision that students are not capable to face challenges of such complex project. Because of that, it is important *to change the teachers' mind* – the teacher should be ready *to give the credit to his students*.

The *support and understanding* of *parents* for the importance of inquiry-based science education is last but not least prerequisite. That prerequisite is crucial especially in countries, like Bulgaria, where parents are taught in traditional (lecturing) style and expect teacher to use the same style.

5.2 Prerequisites at Mezzo Level (School Level)

The *strong support at the school level* is really important for wide application of new approaches in the daily school practice. To facilitate the change in teacher's work, it is needed to build a *team* which *to manage and support the IBSE implementation* at each school. A good practice, shared by schools in Northern Ireland during the Peer Learning Activity (PLA) *Thematic Working Group for Mathematics Science & Technology*, shows that such team has very positive effect on teachers willingness through its regular discussions with teachers on the ways of introducing and applying the new approaches and improvements of established practices.

In addition, *team work of teachers* and *sharing developed resources and experiences* among the same subject area teachers and between inter-subject teams is enabling IBSE implementation factor. As it was shared by Irene Stone, Maths coordinator at St Marks Community School, Ireland*, collective intelligence makes easier to overcome challenges and to develop better materials*.

Without *information and communication technologies* it is very difficult even to imagine that the IBSE implementation can be successful. They are needed to support spreading and sharing of resources, experiences, and so on. Moreover, they enlarge the space, the time and the possibilities in front of the students, teachers, schools and educational systems, providing flexibility, communication, permanent support, etc.

The last condition is related to accessing sustainability in the IBSE approach application. In order to ensure long lasting systematic use of these new approaches, they should be *built in* and become *integral part of the whole school practice*.

The school principal is responsible for the development of constructive environment, in which IBSE could be applied.

5.3 Prerequisites at Macro Level (National Level)

One of the most imperative prerequisite for wide spread of inquiry-based project education is a *reform of curriculum and assessment*. The curriculum itself should give enough freedom to teachers to have flexibility in time and distribution of the learning content. In the same time the assessments approaches and tools should consider new knowledge and skills, aiming to develop in process of learning. A good practice is presented by the project Maths [18] implemented in Ireland, where the new teaching approaches correspond with new assessment system.

In addition, the *consensus building* is important for successful application of the IBSE.

In North Ireland the idea is realized during the development of new national educational standards (2010), the North Ireland Educational Department worked extensively with teachers, school leaders, unions, inspectors, and policy makers to understand what they would expect young people to be able to do. It has also worked to build parents', business leaders' and politicians' confidence in the quality and appropriateness of the standards.

We saw the other way to implement the idea for consensus and cooperation at national level in Finland, where the government, research institutions, teacher training institutions and business organizations established together the national LUMA centre [19]. The aim of the LUMA Centre is to promote the learning, studying and teaching of natural science, mathematics, computer science and technology on all levels. The LUMA Centre works together with schools, teachers, students of education and several other cooperation partners in order to achieve its goals (Fig. 5).

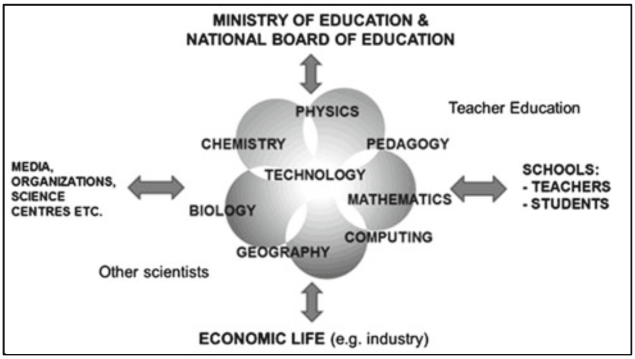

Fig. 5. LUMA is an umbrella organisation coordinated by the Faculty of Science of the University of Helsinki to bring schools, universities and industries together

But just a reform in standards, curriculum and assessment system is not enough if the teachers do not feel well prepared. That is why the *professional development of teachers* and *wide teachers' trainings* should take place in parallel with the educational system reform. Although there have been some successful but sporadic experiences with IBSE, today's teachers, in most European countries, do not have a consolidated and extensive experience in implementing it at all school levels. The uneven distribution of experience in the use of IBSE suggests that massive teacher training activities at European level are needed, and can take advantage of experience transfer from more advanced and successful contexts to others where uptake should be fostered. In addition, IBSE should become a school culture.

A good example of how to build IBSE culture in school could be found again in North Ireland experience in introducing new standards and spreading widely systematic application of formative assessments: North Ireland apply in-service training for the school staff on the place, building the school capacity in common and forming the school culture. Such trainings give positive results and support the spreading of new approaches in the school.

The training of teachers is not enough if there is no *continues teachers support. Support by experts* (face-to-face, online) as well as by *the resources* developed by teachers' trainers and by teachers themselves, available and shared online, increases the chance for application of the new approaches in the school practice.

5.4 Assessment for Learning

In order to apply widely inquiry-based science education, special attention should be paid to the assessment.

Traditionally, schools and teachers emphasize student assessment through final exams, rather than through on-going assessments. In recent years the focus moved to the assessment for learning.

The assessment should guarantee that students are well informed about their current achievements and next steps to the goals, as well as to identify these next steps and needs of new knowledge.

The student's engagement in the assessment process is also important. Assessments should support student's motivation and interests, rather than to discourage learners. Students may set learning targets with teachers, and may assess the quality of their own work. In this way, students and teachers develop a mutual trust.

High-flying students may set more ambitious goals, while lower-achieving students may need to focus on achieving smaller steps (frequent milestones) toward learning goals, tracking their progress along the way as they check off items on a *can do* list. This is closely related to differentiated approach to each student and his progress.

In addition, the assessment should focus on the improvements, which the students could make, not just to do an *autopsy*, but rather show them what and how to change, so to become closer to their learning goals. And when the students *comes to their pick* (final goal), it is important to congratulate them.

The teachers should understand very well their responsibilities for the students' results.

All these statements are known in pedagogical science, but unfortunately they are not widely spread in the practice.

The school practice in Northern Ireland and Ireland practices show an evidence for a national-wide effectiveness.

For example, the Northern Ireland strategy supports teachers and students in taking ownership of learning and assessment. Teachers already pay much closer attention to learner motivation and progress.

The importance of identifying small successes through providing regular feedback on how to improve, and of celebrating students achievements is an accent in Ireland Project Maths [18].

5.5 The Sufficient Condition

The conducted and described experiment proves that *the teacher* really is a *sufficient condition*: when he has willingness, the teacher could manage to apply the IBSE regardless of the *lack of necessary conditions*. But is it necessary he to be jaded?

Even if the teacher is so self-motivated to make efforts to do everything along, at some point he becomes exhausted, with no energy for more. Moreover, he has no time and strength all-the-time to prepare along for the IBSE classes. In such circumstances the most of the teachers set the IBSE idea aside. If they begin using IBSE at all! Is it necessary to bring them in such conditions?! Because, as Neda Gerginova (teacher) says: *The truth is that students like to have hard time and challenges, while the teachers prefer the easy way*.

So, if there is no *necessary and sufficient conditions* for IBSE, as a result the natural students' motivation and desire *to have hard time* is not used, and with passing time students lose their enthusiasm, and finally, they take the *easy way*.

6 It is so Difficult! Is It Worth?

Below we would like to share what it is observed by us and what could happen even only *sufficient conditions* are available. Then just to open the door for the imagination what the results could be if all *necessary and sufficient conditions* for IBSE are available.

The attempts to implement the IBSE approach, not only in described experiments, but also in small groups of students and individual work with students during the last 15 years convincingly prove sustainability of the results over the time.

Only one year after the first experiment we observe that the students, who participated in the pilot, are more responsible, take independently initiative for new projects, show maturity in organization and management. For example, last year's eleven graders of First Private Mathematical Gymnasium, today already twelve graders, themselves proposed they to analyse and improve the school web site, defined their own assignment, distribute roles among the class, control the process, and finally, completed the tasks they put themselves.

When the next project in informatics classes was laid, they desired to take part in formulation of the assignments. As a result several projects were defined, provoked by students' interests and motivation:

– A project, serving the process of price-formation in the small private company owned by a student's father;
– A project, enhancing the Op Art ideas of the one of the previous teams by new interface and functionalities;
– An application of combinatorial games, based on early studied algorithms;
– An application, supporting his developers to train for other subjects (in that case - physics).

Two of the National High School of Mathematics and Science students, already admitted students at University of Cambridge, with self-confidence shared that during the entrance interview, telling the interviewers about the inquiry-based project they took part in, the students were delight to the special attitude: *They accepted us as real researchers!*

The evidence for sustainability of the results of the approach is given also by students, graduated National High School of Mathematics more than 5 years ago, and trained in the same style. For example, Kaloyan Slavov, already graduated Massachusetts Institute of Technology (MIT) shares: *I remember almost nothing of what I learned in school, but you taught us to learn and know how to prove own self ideas!*

But most touching award was the proposal of Ruslan Russev (graduated National High School of Mathematics 11 years ago, nowadays owner of a software company): *I would like to develop for you such a learning programming environment, so to be able to teach students in the best way you would like to!*

Looking from the distance in time, we could summarize: the results of the application of the approach give us reasons to conclude: **the efforts are deserved and many times rewarded – as for the student, so for the teacher**!

7 Let's Do It Together!

Keeping in mind the observation and conclusions of experiments as described above and other research results [2, 10], Bulgarian Ministry of Education, Young and Science (MEYS) started the reform, aiming to make the changes evidence and research driven.

The Bulgarian MEYS started a procedure of development of new national standards, curriculum and assessment. Through them the MEYS endeavours to put the accent on development of key competences. In order to consolidate as much as possible experience, research and different point of views, the MEYS involves into the developments researchers, university professors, and teachers. The authors of the paper contribute to the work of the MEYS experts' commissions for the development of national standards, curriculum and assessment for Informatics and Information Technologies. The authors bring to the commissions results their long-standing international research observations and conclusions as well as rich school and university experience. As consequence they search for approaches to build in IBSE in the nature of the curriculum, to stimulate and to integrate it as deep as possible, as well as to use it potential for synergy among disciplines. In addition, as members of stated examination boards for Informatics and Information Technologies, reflecting on international research, the authors work in direction to change the evaluation criteria and work towards putting the accent on the assessment for learning.

All these make us to believe that the change is started and IBSE national-wide is possible, when all work in one direction together. It is a challenge, but the reward worth it!

References

1. Sendova, E. (2011) Assisting the art of discovery at school age – a Bulgarian experience, in *Talent Development Around the World,* http://www.cpti.com.mx/publicaciones/LIBRO.pdf
2. Nikolova, N., Stefanova, E., Sendova, E.: Op Art or the art of object-oriented programming (plenary talk). In: Bezakova, D., Kalas, I. (eds.) Proceeding of Selected Papers, 5th International Conference on Informatics in Schools: Situation, Evolution and Perspectives ISSEP2011, 26–29 October 2011, Bratislava, Slovakia, pp. 28, ISBN: 978-80-89186-90-7 (2011)
3. Stefanova, E., Sendova, E., v. Diepen, N., Forcheri, P., Dodero, G., Miranowicz, M., Brut, M., et al.: Innovative Teacher - Methodological Handbook on ICT-Enhanced Skills. Faleza-Office 2000, Sofia (2007)
4. Innovative Teacher (I*Teach) project. http://i-teach.fmi.uni-sofia.bg Accessed 12 June 2012
5. Stefanova E., Sendova E., Nikolova I., Nikolova N.: When I*Teach means I*Learn: developing and implementing an innovative methodology for building ICT-enhanced skills. In: Benzie, D., Iding, M. (eds.) Abstracts and Proceedings of the Joint IFIP Conference: WG3.1 Secondary Education, WG3.5 Primary Education: Informatics, Mathematics, and ICT: a 'golden triangle' IMICT 2007, CCIS, Northeastern University, Boston, MA, ISBN-13:978-0-615-14623-2 (2007)
6. Sendova, E., Stefanova, E., Nikolova, N., Kovatcheva, E.: Like a (school of) fish in water (or *ICT-enhanced skills* in action). In: Mittermeir, R.T., Sysło, M.M. (eds.) ISSEP 2008. LNCS, vol. 5090, pp. 99–109. Springer, Heidelberg (2008)
7. Stefanova E., Nikolova N., Kovatcheva E., Sendova E., Peltekova E., Hubenova N., Miladinova M., Katrandjieva E.: From a "Flap of a Butterfly Wing" to the "Wind of Change". In: Proceeding of Constructionism 2010, Paris, France, 16-20 August 2010, CD ISBN: 987-80-89186-66-2 (2010)
8. Dewey, J.: Science as subject matter and as method. In: Archambault, R.D. (ed.) John Dewey on Education: Selected Writings, pp. 182–195. University of Chicago Press, Chicago (1964)
9. Linn, M.C., Davis, E.A., Bell, P.: Internet Environments for Science Education. Lawrence Erlbaum Associates, Mahwah (2004)
10. National Science Foundation: Foundations. Volume 2: a monograph for professionals in science, mathematics, and technology education: Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom. Variation National Science Foundation US NSF 02084. http://www.nsf.gov/pubs/2000/nsf99148/pdf/nsf99148.pdf (2000) Accessed 29 July 2012
11. Tafoya, E., Sunal, D., Knecht, P.: Assessing inquiry potential: a tool for curriculum decision makers. Sch. Sci. Math. **80**(1), 43–48 (1980)

12. Okada, A.: Scaffolding school pupils' scientific argumentation with evidence-based dialogue maps. In: Okada, A.; Buckingham Shum, S.J., Sherborne, T. (eds.) Knowledge Cartography: Software Tools and Mapping Techniques. Springer, London (2008)
13. Kirschner, P.A., Sweller, J., Clark, R.E.: Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educ. Psychol. **41**(2), 75–86 (2006). doi:10.1207/s15326985ep4102_1. Lawrence Erlbaum Associates, Inc. 10 Industrial Avenue Mahwah, NJ 07430-2262 USA
14. Hmelo-Silver, C.E., Duncan, R.G., Chinn, C.A.: Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark (2006). Educ. Psychol. **42**(2), 99–107 (2007). doi:10.1080/00461520701263368. Routledge
15. Furtak, E.M.: The Dilemma of Guidance. An Exploration of Scientific Inquiry Teaching. VDM Verlag Dr. Müller, Saarbrücken (2008)
16. McDermott, L., Shaffer, P., Constantinou, C.: Preparing teachers to teach physics and physical science by inquiry. Phys. Educ. **35**(6), 411–416 (2000)
17. High Level Group on Science Education: Michel Rocard (Chair), Peter Csermely, Doris Jorde, Dieter Lenzen, Harriet Walberg-Henriksson, Valerie Hemmo, (2007), Science Education now: A renewed pedagogy for the future of Europe, Directorate-General for Research Science, Economy and Society, European Commission
18. Project Math. http://www.projectmaths.ie/. Accessed 12 June 2012
19. University of Helsinki. (n.d.). About the LUMA centre. From Finland's Science Education Centre LUMA: http://www.helsinki.fi/luma/english/. Accessed 3 Sep 2012

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