# ACHIEVEMENTS AND PROBLEMS IN THE IN-SERVICE TEACHER EDUCATION IN INQUIRY BASED STYLE

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***Abstract**: The paper deals with the experience of the authors in promoting the Inquiry Based Learning (IBL) in mathematics and science education within international and national projects. The emphasis is on in-service teacher education. Various types of activities and resources in support of all levels of IBL are considered, e.g. professional development courses, seminars, workshop, and performances; implementation of resources stimulating students to behave like working mathematicians. The first visible positive effects and potential problems in the implementation of IBL in the Bulgarian schools are discussed.*

***Keywords**: inquiry based mathematics and science education, in-service teacher courses, e-resources, dynamic geometry software*

## 1. Introduction – are in-service teachers not able or not motivated "to learn new tricks"?

Recently an interesting sign over a computer drew our attention [1]:

*OLD DOGS **CAN** LEARN NEW TRICKS.*

While this is certainly true, the question is how many more new tricks **we are motivated to learn.** Isn't it easier to be outdated but still master in what you are doing? Such an attitude to innovations is often faced by teacher educators especially when working with math teachers who feel they have been successful without using digital technologies and without applying student-centered educational strategies.

Being aware of this, our work with in-service teachers was based on the understanding that for the teachers to be motivated they should experience the same intellectual pleasure we expect their students to do. In other words, *if we hope for a real positive change in education, we should bring […] teachers in situations in which they would stop thinking about the future in terms of tests, exams or teaching pupils only. We should rather enable them to experience what they are doing as intellectually exciting and joyful on its own right* [2].

Such a spirit is part of our heritage of the constructionism as an educational philosophy and culture [3] and there are various manifestations of its being alive and developed today in the context of a number of European projects. The inquiry based learning (**IBL**) is one of the approaches that are part of this heritage [4, 5].

## 2. Activities and resources in support of inquiry based mathematics education

A research team of IMI-BAS (of which the authors are part) has been involved in organizing various events, and in developing resources in support of all levels of IBL**:** Level 1 - *Confirmation Inquiry*, in which students confirm a principle through an activity such that the results are known in advance; Level 2 **-** *Structured inquiry*, in which students investigate a teacher presented question through a prescribed procedure; Level 3 **-** Guided inquiry, in which students investigate a teacher presented question through a procedure they designed/selected themselves; Level 4 - Open inquiry, in which students investigate a question they have formulated themselves through a procedure they designed themselves [6, 7].

Here follows a short description of such activities and resources:

- **PD courses (**from 2 to 128 hours)

These courses are being organized by IMI-BAS in the frames of European projects (InnoMathEd, Fibonacci, Mascil, KeyCoMath and Scientix), as well as by sections of the Union of Bulgarian Mathematicians (UBM), by the Ministry of Education and Science, by publishing houses for educational literature, and by PD centers. The main goal of the courses is in harmony with the most recent educational strategies for updating the math and science education in the EC countries: *the development of key-competences by implementing the inquiry based learning in integration with the world of work*. These PD courses are based on a team work (of the lecturers and the participants alike) and implement educational models adaptable to various school settings. The crucial part of the courses is for the participants to experience different stages and levels of IBL. The teachers work on pedagogical problems related with: reformulating of math problems in IBL style so as to enhance the development of specific key competences; formulating their own math problems reflecting real-life situations, not solvable with the current math knowledge of the students but allowing for explorations by means of dynamic geometry models leading to a *good enough* approximation of the solution; studying and proposing methods for tackling problems which are unstructured, or whose solutions are insufficient or redundant; solving "traditional problems" with "non-traditional" data, for which the use of a computing device is necessary; applying game-design thinking so as to engage better the students in the problem solving; formulating more relevant evaluation criteria for the students' achievements; assessment of learning resources in terms of formation and development of IBL skills and key competences; project-based work with presentation of the results [8, 9].

- **PD events (seminars and workshops) in the frames of conferences**

The key feature of these events is that the teachers have an active role and act as partners in a research team – they share their good practices in oral or poster presentations (sometimes jointly with their students), work in groups on specific tasks and present their ideas to the rest of the participants. Typical examples include the *Scientix National Conference* within the National seminar *Inquiry Based Mathematics Education* [10], the *Dynamic Mathematics in Education* conference [11] (Figure 1), the seminars within the Spring conferences of UBM, the regional conferences organized by UBM sections, the International UNESCO workshop *QED* [12, 13].

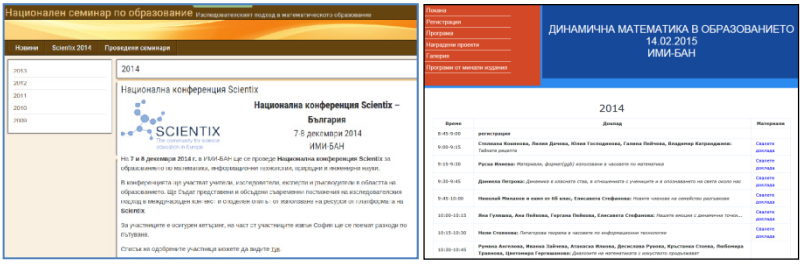


*Figure 1. The Scientix National Conference and "Dynamic Mathematics in Education" demonstrated good practices of teachers implementing IBL*

- The inquiry based learning, its connection with the world of work, good practices and problems in its implementation in a class- and out-of-class setting, have been the focus of our work with teachers, viz:

- **Using specific learning scenarios in support of IBL** – a good repository of such resources is the *Virtual School Mathematics Laboratory* (Figure 2) being developed by IMI-BAS [14, 15], which contains over 800 scenarios with dynamic files transparent for the users.

The way teachers are encouraged to use these resources is to stimulate students to behave like working mathematicians: to make experiments, to look for patterns, to make conjectures, to verify them experimentally, to apply "what-if" strategies so as to modify/generalize the problem, and even to use them as a preparation for a rigorous proof. To do this without leaving their comfort zone, the teachers enter the role of their students and experience the same type of activities during our courses, and when working on their own. They first use the dynamic files supporting the scenarios as a ground for explorations. The next step for them is to propose appropriate modification of the files for similar problems, or to use them as a model for creating one of their own from scratch. Thus, it would be quite natural for them to tell the

students: "I don't know the answer but I hope to find it together with you, thanks to YOUR efforts, to our joint efforts…"

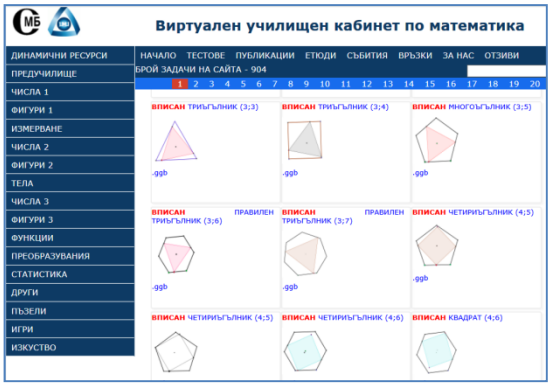


*Figure 2. Virtual School Mathematics Laboratory: dynamic files for tackling an open problem on finding the locus of a regular m-gon inscribed in a regular n-gon*

- **Joint research sessions on a specific problem** –for instance, face-to-face work on the *Problem of the Month* within the Mascil project [16] (Figure 3), possibly followed by a virtual meeting with teachers and students from the partner countries.

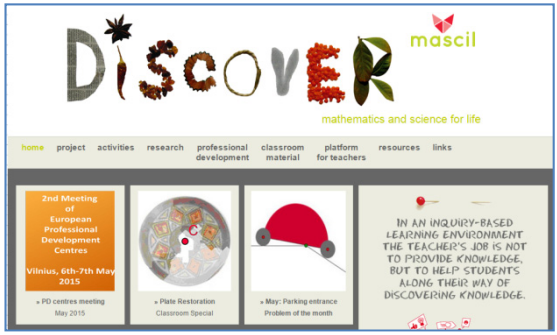


Figure 3. The homepage of Mascil – the *Parking Entrance Problem of May* is suggested by the IMI-BAS team of the project

- **Building and developing competences necessary for the students to participate in new types of mathematics contests,** e.g. *Mathematics with a computer, Theme of the month* [17-20].

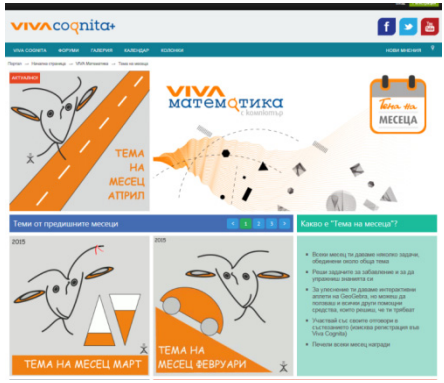


*Figure 4. "Theme of the month": an invitation for a long-term activity on a math problem modeling a real-life situation*

- **Mathematics performances** – events raising the awareness of the general public about the role of mathematics for enhancing children's scientific curiosity and endeavor to learn [21]. The examples include: Performance at the History Museum in Stara Zagora, organized by the UBM section in the town, performances during the Researchers' Nights (2011-2014), Science festivals (in Italy, Romania, Greece). It is important to note that the teachers act as multipliers of the IBL ideas during these events as well – they participate with their students, and occasionally lead the performance.

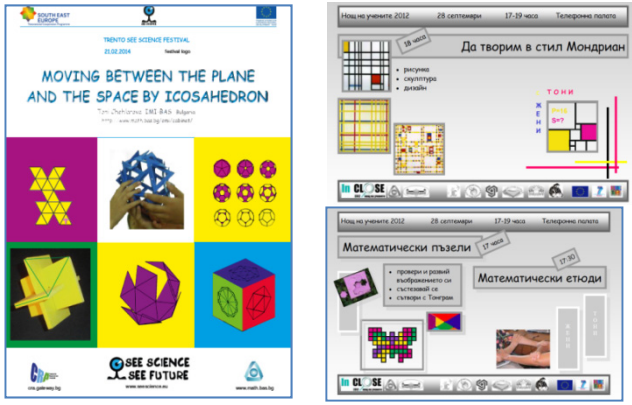


*Figure 4. Posters for math performances within Science Fairs and Researchers' nights*

- **Individual work with teachers** – it includes support for the development of a lesson, educational materials, mathematical fests, course projects, peer reviews, and preparation of a pedagogical experiment.

## 3. The main achievements

A community of teachers who implement and spread the inquiry based learning of mathematics and informatics has been created. They participate in pedagogical experiments not only as a reality-proof of researchers but as members of a research team. These teachers implement, modify and develop from scratch educational resources in support of IBL, share their good practices at seminars, conferences and in professional journals. Some of them organize public events at a school and regional level for popularizing the inquiry based mathematics education. Teachers are also key figures in organizing the new mathematics contests *Mathematics with a computer* and *Theme of the month*, in making them known to a broader audience.

More than 20 teachers have been identified and educated by our Mascil team as *multipliers* of the project ideas, viz. implementing the IBL with the world of work at a school level. New 40 will be educated by the IMI-BAS team in the summer of 2015 (in the frames of two courses organized by the Ministry of Education and Science). These multipliers will further educate new groups of teachers by the cascade method.

Some of the multipliers (Rumjana Angelova and Dinko Tsviatkov) have already developed resources at a level high enough to be included in the repository of the Bulgarian site of Mascil [22].

Problems, suggested by Neli Stoyanova, Galia Pencheva, Steliana Kokinova, Ruska Ilieva and Kremlina Cherkezova were included in the contests *Mathematics with a computer* and *Theme of the month* and published on the *Viva Cognita* portal.

Recent recognitions of our IBL multipliers include the *Konstantin Velichkov award* delivered to Boriana Kujumdzhieva (2011), *the Golden Feather award of the Union of the Bulgarian Teachers* delivered to Steliana Atanasova at the QED'13 UNESCO workshop, the honorable prize the *Heart of Sofia*, delivered to Elisaveta Stefanova (2013), the *Special award for sustainable and innovative ICT applications in education* delivered to Neli Stoyanova at the QED'14 UNESCO workshop, First award in the Seminars category of the 5th National *Science on Stage* festival (Sevlievo, 2014) won by Neli Hristozova with her presentation "Mathematics through experience" with which she will participate in the European *Science on Stage* (London, 2015). Several teachers (Steliana Kokinova, Neli Stoyanova and Rumjana Angelova) won a sponsorship for participation in the 2nd Scientix conference (Brussels, 2014) [23] where the focus was on the teachers' role in bringing change in the STEM education.

These awards reflect the attitude of the society to the dedication and the achievements of the teachers and their students. Their personal pride, the pride of their students' achievements, the feeling of being part of a community, are often expressed in their statements:

Elisaveta Stefanova: *The best is not the award itself but the fact that we, the teachers feel members of a community of soul mates...*

Neli Stoyanova: *When I decide to give problems appropriate for IBL, I don't think of the curriculum and the syllabus, I leave my students to inquire, to think, to combine, to create and to surpass me!... The award brings a great satisfaction since many colleagues expressed their wish for future collaboration, and their interest is not less important. The decision of the jury is recognition for my long-term activities, a confirmation that the IBL ideas are well-received in Bulgaria and abroad, and most importantly – that the resources developed by my students do matter.*

## 4. The problems as seen from experts in mathematics and informatics

At the beginning of 2015 we delivered a 3-day course on the Inquiry Based Learning with the use of GeoGebra to experts in mathematics and informatics from the Regional Inspectorates for Education. The course was organized by the Ministry of Education and Science. At the end the participants were kind to answer the following two questions:

- *How do you see the potential of the IBL in a class setting?*
- *What are the main problems of its implementation?*

Here are their answers grouped accordingly:

**Regarding the IBL potential and the use of dynamic geometry software:**

*The IBL will enhance the motivation for thinking and learning of the students and the teachers alike; the IBL could be used in the IT classes and in integrated (binary) lessons; the IBL is applicable only partially in the obligatory classes, it could be used mainly in the selective classes, and in the context of work on projects; the IBL would have a very strong effect on the students' motivation, interest and endeavor to knowledge; the IBL could be successfully applied in the out-of-class activities, and especially in the vocational schools; the IBL should be disseminated among the teachers, among the students, by means of the social networks and the media; all the methods and tools by means of which the teachers could convey the beauty of mathematics to the children are useful; using dynamic geometry software is appropriate for modeling various real phenomena and processes; the use of dynamic geometry software is useful for preparing drawings for problems for math contests (?!); GeoGebra is a powerful tool for visualization and for exploration of complex situations; the IBL could be applied in mathematics classes* ***if wisely used;*** *the conditions for implementing IBL in school are: to change the existing syllabus, to educate the teachers to work in this style, to equip the schools with the necessary technical resources.*

**Regarding the problems of IBL implementation:**

*More practical seminars and workshops with teachers are needed; the literature with tasks and problems appropriate for IBL is not sufficient, or at least not well*

*spread; the main problem is how to motivate the teachers to get ready for implementing IBL in their practice*; a *significant problem is the lack of time; the qualification of the teachers is insufficient; there is lack of appropriate equipment; the relatively high average age of the teachers could be a serious problem and a reason for indifferent attitude to innovative approaches.*

For a comparison, let us through a glance on the findings of the organizers of an *Inquiry-Based Courses for Pre-Service Teachers* [24] who report essential difference of students attitude after one and after two courses in IBL style:

**After one course:** *Frustration of not knowing whether answers are correct; lack of structure and purpose; lack of clarity about grading; required to teach yourself; group work not always effective; O.K. sometimes, but shouldn't be only method.*

**After two courses**: *Learned much more about mathematics; in some ways more difficult than traditional (have to think more, do more active work); in some ways easier than traditional (no memorizing or cramming, no longer mysterious); more rewarding to find answers yourself; more confident about mathematics ability; can see how to use this in my own classroom…*

## 5. What next

If we agree with the great conductor and educator Zander [25] that the ultimate goal of education is *to create a world of shared commitment, shared involvement, open-mindness, contribution, love, health, collaboration, curiosity* we should help teachers to create an atmosphere where the students would not tell themselves: *I am a good student, because I got such and such grade, so many points on the test, I'll take the exam, I'll enter the university…* But they would rather think about the excitements the genuine learning offers: *How interesting, I wonder what will happen if… I feel like a real scientist! I am not afraid to try something nobody has tried before…*

Our impressions of the work with teachers make us optimists. Teachers let students discuss with peers, create and *support collaborative community*, become *technologically fluent* by using it wisely.

And instead of repeating that the math education is in crisis, let us (researchers, educators, policy makers) join our efforts to identify, implement and disseminate styles of learning which makes the teachers enjoy the explorations on their own righ, and the eyes of their students shine.

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## ПРОБЛЕМИ И ПОСТИЖЕНИЯ ПРИ КВАЛИФИКАЦИЯТА НА УЧИТЕЛИТЕ В ИЗСЛЕДОВАТЕЛСКИ СТИЛ

***Резюме**: За успешното широко внедряване на изследователския подход, основан на дигитални технологии, в математическото образование, важен фактор е подготовката и мотивацията на учителите. В статията представяме основни идеи, постижения и проблеми, свързани с обучения на учители, провеждани в изследователски стил. Предоставяме връзки към учебни ресурси със свободен достъп, подкрепящи образованието по математика и информационни технологии, като „Виртуален училищен кабинет по математика", състезания „Математика с компютър" и „Тема на месеца", конференция „Динамична математика в образованието", национален семинар „Изследователски подход в математическото образование", проекти Mascil, KeyCoMath and Scientix.*