МАТЕМАТИКА И МАТЕМАТИЧЕСКО ОБРАЗОВАНИЕ, 2017
MATHEMATICS AND EDUCATION IN MATHEMATICS, 2017
Proceedings of the Forty-sixth Spring Conference
of the Union of Bulgarian Mathematicians
Borovets, April 9–13, 2017

A EUROPEAN NETWORK FOR PROFESSIONAL DEVELOPMENT OF TEACHERS (AND THE ROLE OF IMI–BAS AS A CENTRE FOR INQUIRY BASED MATHEMATICS AND INFORMATICS EDUCATION)

Toni Chehlarova, Petar Kenderov, Evgenia Sendova

The authors present a new European educational project, PD STEM Net, in which the Institute of Mathematics and Informatics (IMI-BAS) is a partner from Bulgaria. They consider the first steps towards the establishment of an appropriate structure of collaboration among leading professional development (PD) centres and the role of IMI-BAS as a national PD centre for inquiry based mathematics and informatics education (IBMIE). An example of a PD course for work with teachers on the highest levels of IBMIE (*guided-* and *open inquiry*) is described.

1. The PD STEM Net European project. The *European STEM Professional Development Centre Network* [1] was based on the idea of connecting national PD centres having similar aims and agendas, viz.: investing in teacher professional development to substantially improve STEM education taking into account the most advanced strategies and innovative practices for overcoming the common concerns and challenges. The network aims at ensuring knowledge exchange in order to improve local practices in STEM professional development and strengthens the voice of practice when it comes to shaping STEM education in Europe.

1.1. The establishment of the Network. The first meeting of the European Professional Development centres involved in math and science education took place in the frames of the 2014 conference "Educating the educators – International approaches to scaling-up professional development in maths and science education". Hosts of the conference and the first PD centre meeting were the European project Mascil (mathematics and science for life!) [2] and the German Centre for Mathematics Teacher Education (DZLM). To date, five meetings of the European STEM PD Network took place: in December 2014 in Essen (Germany), in May 2015 in Vilnius (Lithuania), in December 2015 in Sofia (Bulgaria), in June 2016 in Hradec Králové (Czech Republic) and in November 2016 in Freiburg (Germany) as part of the second Educating-the-Educators conference [3]. The PD STEM network consist of 30 STEM PD Centres and other organisations with relevant aims, role and focus such as education institutes, education authorities or Ministries of Education from 13 European countries.

The Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences (IMI–BAS), is the only Bulgarian PD STEM Net project partner.

1.2. The role of IMI–BAS as a PD centre for Inquiry based learning at all levels. The IMI–BAS, which this year celebrates its 70^{th} anniversary, is recognised as a leading national organisation for research and applications in the field of mathematics and informatics. It welcomes annually more than 200 guest scientists, conducts about 25 international conferences, workshops and schools, 18 permanent open scientific seminars and 7 scientific and methodological journals thus providing opportunities for direct communication with the world scientific elite. In addition, IMI-BAS is the only institute of the Bulgarian Academy of Sciences with an Educational department. The education-related activities of the Institute include the professional development of teachers, mentoring PhD and MSc students, and developing the research competences of high-school students who have demonstrated great potential in doing mathematics and informatics.

It should be noted, that IMI-BAS is the main provider of scientific, methodological and technical support in inquiry based mathematics, informatics and IT education (IBMIE) at all levels and forms, in Bulgaria. This support is carried out by designing strategies and a system for implementing IBMIE in a national context, by organising various types of PD courses and by developing open access learning environments that enhance IBMIE with a focus on the acquirement of key competences. Thanks to the system for PD of teachers in mathematics, IT and informatics developed by IMI-BAS, a network of such teachers acting as multipliers of the IBL ideas has been established which facilitates and encourages teacher- and practitioner engagement at a national level. The current activities of the Institute of Mathematics and Informatics at the Bulgarian Academy of sciences (IMI-BAS) as a centre for inquiry based learning (IBL), and more specifically, for inquiry based mathematics and informatics education (IBMIE), include various types of PD courses and events, as well as open access learning environments (VirMathLab, VivaCognita, and BG Mascil) related to STEAM (science, technology, engineering, arts and mathematics).

1.3. What do we mean by IBL and IBMIE. It is sometimes believed that in order to be engaged in inquiry oriented activities students need to design scientific investigations from scratch and carrying them out on their own. In fact, there are different levels of inquiry that students can progress through as they move toward deeper scientific thinking [4, 5].

- 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 question presented by the teacher through a prescribed procedure;
- Level 3 – *Guided inquiry*, in which teacher provides students with an open research question, and students design the method to solve the problem with mentoring support;
- Level 4 – *Open inquiry*, in which students can act like scientists, formulating their own hypotheses, carrying out investigations and communicating their results.

The highest IBL levels require experienced scientific reasoning and domain competences from students, which in turn poses specific challenges for the teachers and the teacher educators. With this in mind a research team of IMI-BAS (including the authors) has been involved in organizing novel PD courses and events in support of all levels of IBL as well as in developing relevant resources.

2. PD seminar on mentoring high-school students in their scientific research. Sometimes problem solving is defined as *what you do when you don't know what to do.* This phrase applies even more when one is looking for a topic in mathematics and informatics, which is doable by a high school student in a reasonable amount of time and contains elements of original research. To encourage teachers to act as mentors of students who would like to work on open problems, is one of the causes of the IMI-BAS researchers involved in the activities of the *High School Students Institute of Mathematics and Informatics* (HSSI) [6, 7].

2.1. The context – a scientific conference where high school students are the main actors. Traditionally, IMI–BAS organises within the HSSI events PD seminars with teachers who have been long-term mentors of students working in open inquiry style, and some novices who have expressed their wish to work at the highest levels of IBL (guided- and open inquiry).

At the beginning of every January about 100 high-school students from all over Bulgaria participate in a conference organised by the HSSI. There they present their research projects in mathematics and informatics in front of a jury of experts, teachers and peers, answer questions, and get ideas for further development of their work.

This year (January, 2017) the 17th High-school student conference was held in the Mathematics high school in Vratsa, the North-West of Bulgaria [8]. The participants embraced teachers in mathematics, informatics and IT, as well as regional inspectors in mathematics and science. Here are some moments Evgenia Sendova shared from her involvement in the 3-day PD seminar "'Scientific guidance of high school student projects"' within the frames of the conference.

2.2. The first day – sharing of a researcher and a teacher. The first session was started by Emil Kelevedzhiev, a researcher in informatics at IMI–BAS, who has been a coach of the Bulgarian Olympic team in informatics for many years now.

The talk Emil Kelevedzhiev delivered was on *How to develop and present a project with elements of original research in informatics or IT.* He made a brief review of the main topics of research in the field of informatics and IT that have been developed and presented in the frames of HSSI: *algorithms, educational software, web design, educational games, applications for mobile devices, applications for control of mechanisms, robots*, etc. He commented on the difference and the similarities between the work behind mentoring students who do research and the preparation of students for informatics and IT competitions and gave examples of his own practice.

The next speaker, Eleonora Pavlova, a teacher in IT from the Mathematics school in Varna, shared her experience on *How to work with gifted students.* The audience was ready to challenge back Eleonora – *How do you define "gifted"?; Is there a single intelligence?*, etc. but the opening slides showed that she had posed similar questions for discussion with the audience: *Who are the gifted students? How to work with them? How to choose research topics? How to guide the process? How to keep the motivation?* She emphasised that her main task in mentoring students has always been to help them enjoy the process, not the result. Especially valuable for the participants were the instruments for generation and evaluation of ideas she had been using with her students (e.g. mind maps, De Bono's hats, Google forms for questionnaires). Her experience has shown that by means of mind maps the brainstorming remains documented and could be used in further stages of the project's development. As potential sources of ideas for projects

Eleonora Pavlova pointed at the resources within international projects and programs, conferences, PD courses, teachers networks, clubs of entrepreneurship as well as mentors coming from the industry. Concerning the Scientix platform [9], she shared her being shocked to see its richness of resources – projects, didactic scenarios, courses, virtual communities. Eleonora ended her talk with a statement by the famous Bulgarian bass Nikolay Gyaurov that *strong individual performances could appear only within a strong ensemble.*

One of the final conclusions was that everybody is gifted – our role of educators is to show the students that we are not afraid to admit that we don't know the answer of something and we are ready to work with them as partners in a genuine research team. An important piece of advice of Eleonora based on the practice in her school was that the teachers should integrate their efforts and expertise when guiding the research of their students. She reminded the audience that some useful techniques of how to form teams had been already demonstrated at a previous PD seminar by Susan Feimova, a teacher in "Baba Tonka" math school in Ruse, an experienced mentor of research projects in informatics.

2.3. The second day – a "tableless" round-table discussion. The second day of the seminar was in the form of a round-table discussion (without a table) at which the participants were expected to share good practices of IBL at 4th level – the open inquiry (Fig. 1).

Jenny Sendova was the chair of the discussion and opened it with a joint presentation (with Petar Kenderov and Toni Chehlarova) on projects in support of IBL in which IMI-BAS has been involved in the recent years – Mascil, Scientix, PD STEM Net and VirMathLab [10]. The role of these projects for the PD of teachers was illustrated with specific examples of good practices in implementing IBL in a school setting, and of various PD events organised by the IMI-BAS team. She showed examples of how teachers and students have been using the resources developed within the VirMathLab platform – both in class and during the *Theme of the month* contest [11]. Jenny Sendova discussed with the participants that the chain of problems in each issue of this contest could be used as a generator of project ideas. A special attention in this presentation was paid to the most recent project, PD STEM Net, the opportunities it offers to the teachers in Bulgaria, and the first activities planned for the beginning of June in Varna.

After this introduction all the participants shared problems and challenges they have been facing in their practice. The thoughts expressed by two of them, a teacher who is a novice in the open inquiry, and an experienced one, deserve a special attention.

Fig. 1. Taking the floor in turn – the participants in the "tableless" round-table discussion

2.3.1 Lilyana Valcheva (Fig. 2, left): "The math community gave my students wings!" Lilyana started with the way she had formed a team of a girl (11^{th} grade) and a boy (10^{th} grade) – knowing their characters and their passion for mathematics she was sure that they could collaborate well when doing mathematical research. She was pleased that the students found an interesting theorem [12] and began investigating possible modifications and generalisations. The students contacted the author of the theorem (Marion Walter) and encouraged by her decided to work on a 3D analog of it.

Fig. 2. Lilyana Valcheva (in the middle) emphacises on the important role of the teacher when "the things do not seem to work" (left) and dsicusses the next steps of her students with Prof. Jordan Tabov (right)

This turned out to be a real challenge (not only for them as we'll see...). At a certain moment the students were ready to give up, but Lilyana Valcheva convinced them that they are not alone in their struggle... She was absolutely right and Jenny Sendova is completing her story below:

Soon after the students decided not to give up I got an e-mail by the girl asking for advice. In this case I was happy to play the role of a go-between... Incidentally, I had previously received an e-mail by an American mathematics- and informatics educator (Prof. Paul Goldenberg) who is an old friend of mine and happened to know and work with Marion Walter. He had been shown by her the power-point presentation of their work (with the kids' permission) and wrote in his e-mail:

"The extensions the students suggested are lovely. I'm particularly intrigued by their idea of moving to the third dimension. I've thought about that a bunch.(...) There's a fair amount of thinking to do just to define the trisection in 3-D (there's more than one sensible way to think about it), quite apart from then understanding and measuring the regions of space bounded by each such trisection. It's a super-interesting problem! "

Excited by this reaction, I consulted Prof. Jordan Tabov, a well-known geometer and colleague from IMI-BAS, who gave precious directions to the students for the next steps. The results they presented at the Conference in Vratsa were recognized with a diploma of excellence – the highest award at this event.

The thank-you card sent by the young mathematicians was a dynamic 3D construction of their problem. When I also thanked my colleague, Prof. Tabov said: "Their teacher had a key role in the success of the project... " Soon after that the young geometers, together with their teacher, visited Prof. Tabov in the IMI-BAS to discuss the next steps of their research (Fig. 2, right).

Fig. 3. Valcho Milchev demonstrating how he asked about what didactics was...

2.3.2. Valcho Milchev (Fig. 3): What's that "didactics"? The next to take the floor was Valcho Milchev, an experienced mentor of mathematic projects, whose students have achieved remarkable success such as having their results published in the math journal *Kvant*. Here is what he shared with the participants in the round table discussion:

What matters is the motivation of the students. If they are lacking solid mathematical background we could start with easier topic so that they could handle the problems with just a little help. If the problem is something completely new to them and you know the right road to the solution you could give them more specific direction trying not to deprive them of the ownership of the solution. We, as teachers, should always look for ideas from the leading world journals, such as Kvant and Crux Mathematicorum.

In fact I started my carrier as a math teacher long after I had graduated from the Faculty of Mathematics. At a regional math competition 3 of my students took the first three places and my colleagues started treating me with a great respect. At the first Counsel of teachers it was very noisy but I heard the word "didactics" being mentioned pretty often. "What does didactics *mean?" – I tried to ask my neighbor whispering but at that moment a complete silence occurred and everybody was literally frozen with surprise from my ignorance...*

What I would like to express with this sharing is my belief that everybody could be a successful mentor – it does not matter if you are young or old, experienced or a novice, provided you are enthusiastic about tackling problems and you can inspire you students with your enthusiasm... In fact what I am implementing in my work is the military pedagogy – give the solders as difficult problems as they could solve with a very little help (if at all). The solder should feel confident that he could solve the problem and keep that self-confidence in the real battle...

2.4. The third day – ideas for mathematics research and forums to present it. The final day of the seminar (Fig. 4) started with a lecture by Prof. Emil Kolev, Director of the HSSI since 2015, who considered exemplary topics for research projects in mathematics.

He commented on the projects presented in the Mathematics section of the Conference, considering some interesting special cases of the problems and some ideas for further extensions, modifications and generalisations.

Fig. 4. The third day of the seminar – Prof. Kolev (left) and Konstantin Delchev (right) share with the audience ideas for topics of mathematics projects and where to present them

Emil Kolev demonstrated "what-if" strategies in the case of some classical logical problems – covering of boards with domino tiles, weighing puzzles dealing with coins one of which is false, the game of Nim. So **what if** the board is infinite, or the tiles are of different shape; **what if** there are three scales two of which are functioning correctly but the third one is not and we don't know which one it is. Prof. Kolev posed some open problems in this context and admitted he did not know how difficult they are... So, this makes the role of the mentor very challenging, viz. the mentor should have a general idea of possible roads to the solution, thinking at the same time about easier partial cases or interesting generalisations.

The final talk was delivered by Konstantin Delchev who presented a number of forums (in a national and international context) where the students could present their research projects. He emphasised on the importance of science fairs for developing the communication competences of the students and providing them with an early scientific experience. He also focused on the potential of science fairs at a school level for promotion of STEM careers and motivating inquiry based learning at all levels. In conclusion, he encouraged teachers to emphasise not on the competitive aspect of such events but on the community building, strong alumni connections and peer mentorship.

During the discussion, the participants agreed that in a long-term perspective such an approach creates more inclusive and positive educational environment.

REFERENCES

[1] European Network of STEM Professional Development Centres (STEM-PD-Net) http://stem-pd-net.eu (20.12.2016)

[2] П. Кендеров, Е. Сендова, Т. Чехларова. Европейският проект MASCIL – математика и природни науки за цял живот! *Математика и математическо образование*, **42** (2013), 183–186.

[3] Educating the Educators conference http://educating-the-educators.ph-freiburg.de/ (20.12.2016)

[4] H. Banchi, R. Bell. The-Many-Levels-of-Inquiry. *Science and Children*, **46**, No 2 (2008), 26–29.

[5] E. Sendova. You do – you understand, you explore – you invent: the fourth level of the inquiry-based learning. In: Constructionism and Creativity (Eds G. Futschek, C. Kynigos) Proceedings of the 3d International Constructionism Conference, August 19–23, Vienna, Austria, 2014, 103–112.

[6] O. Mushkarov, N. Dimitrova, E. Sendova. Math Research at School Age. In: Meeting in Mathematics (Eds V. Georgiev et al) 6th chapter, Sofia, 2008, 81–93.

[7] P. Kenderov, E. Sendova. Enhancing the inquiry based mathematics education. Proceedings of the UNESCO International Workshop: Re-designing Institutional Policies and Practices to Enhance the Quality of Teaching through Innovative Use of Digital Technologies, 14–16 June 2011, Sofia, Bulgaria, 56–70.

[8] 17th Conference of High School Student Institute of Mathematics and Informatics, 13-15 January, 2017, Vratsa, http://www.math.bas.bg/omi/hssimi/?page_id=738 (20.01.2017)

[9] Scientix – the community for science education in Europe, http://www.scientix.eu/ (20.01.2017)

[10] P. Kenderov, T. Chehlarova, E. Sendova. A Virtual Math Laboratory in support of educating educators in IBL style. In: International approaches to scaling-up professional development in mathematics and science education (Eds K. Maaß, B. Barzelet al.), 2015, 167–176.

[11] P. Kenderov, T. Chehlarova, E. Sendova. A Web-based Mathematical Theme of the Month. *Mathematics Today*, **51**, No 6 (2015), 305–309.

[12] Marion's theorem, http://mathworld.wolfram.com/MarionsTheorem.html (20.12.2016)

Toni Chehlarova
e-mail: toni.chehlarova@gmail.com
Petar Kenderov
e-mail: kenderovp@cc.bas.bg
Evgenia Sendova
e-mail: jenny.sendova@gmail.com
Institute of Mathematics and Informatics
Bulgarian Academy of Sciences
Acad. G. Bonchev St, bl. 8
1113 Sofia, Bulgaria

ЕВРОПЕЙСКА МРЕЖА ЗА ПРОФЕСИОНАЛНО РАЗВИТИЕ НА УЧИТЕЛИ (И РОЛЯТА НА ИМИ–БАН КАТО ЦЕНТЪР НА ИЗСЛЕДОВАТЕЛСКИЯ ПОДХОД В ОБРАЗОВАНИЕТО)

Тони Чехларова, Петър Кендеров, Евгения Сендова

Представен е PD STEM Net – един нов европейски проект, в който ИМИ–БАН е партньор от България. Разглеждат се първите стъпки към установяването на подходяща структура за сътрудничество между водещи европейски центрове за професионално развитие на учители по математика, информатика и природни науки (известни като STEM). Подчертана е ролята на ИМИ–БАН като национален център за внедряване на изследователски подход в образованието. Като пример на работа с учители на най-високите равнища на изследователския подход е разгледан 3-дневен семинар на тема: *Научно ръководство на ученически изследователски проекти.*