Creating a natural environment for synergy of disciplines

Evgenia Sendova[1], Pavel Boytchev[2], Eliza Stefanova[2], Nikolina Nikolova[2], Eugenia Kovatcheva[2]

[1] Institute of Mathematics and Informatics, Bulgarian Academy of Science, 8, Acad. G. Bontchev, 1113 Sofia, Bulgaria
[2] Faculty of Mathematics and Informatics, St. Kl. Ohridski University of Sofia, 5, James Bourchier Blvd., 1164 Sofia, Bulgaria
jenny@math.bas.bg, {boytchev, eliza, nnikolova, epk}@fmi.uni-sofia.bg

Abstract. The paper presents the authors' experience in stimulating the synergy of disciplines via active learning methods; the emphasis being on project based learning. Promoting this method is demonstrated in the context of teachers' training courses and developing a set of IT textbooks. Numerous examples are presented showing that the synergy of various disciplines is quite natural when integrating the study of IT with math & art & fashion design; math & language; history & crafts & math; electrical engineering & math. The project samples developed by teachers are inspired by ideas in textbooks and are accomplished by means of specially designed computer applications. The importance of working on projects tuned to the learner's interest as a decisive motivation factor is emphasized. In addition authors show that the *bouquet* of projects becomes more colorful with every new issue of the courses thanks to the learners' creativity and the collaborative knowledge building.

Keywords: Project based learning, learner's motivation, creativity, collaborative knowledge building

1 Promoting synergy among disciplines in teacher education

To meets the needs of contemporary society synergy between various frontiers of education is crucial. It is not easy to step outside of an individual disciplinary box, learn the language of another field and if necessary, alter the perception. Still, all this become essential in creating collaborative approaches when working on professional projects in science, industry and art. The fields of medical informatics, bioinformatics, bioengineering, design of micro-engineering machines by means of new materials, computer generated art and music provide just a few examples.

In order to prepare the young people to be ready to integrate knowledge from different fields we have to expose them to such an experience even at school level. And to achieve this we need teachers who themselves are doing this in a natural way and share their experience with the students.

1.1 Some previous positive experience

The idea of promoting interdisciplinary approach at school is not a new one. It implies a unified perspective on thinking – one that helps to knit together many areas of the curriculum without compromising the integrity of distinctness of each area [1].

But such an approach has been applied in Bulgaria in a natural way only in isolated educational experiments. One of them was designed by the Research group on Education (RGE) embracing Bulgarian scientists, educators and software developers with the ambition of facing the challenges of the information age [2]. The experiment was based on two main principles - the *integration of disciplines* and *learning by doing.* The RGE experiment ran for 12 years (up to 1991) in 29 schools. In the first four years informatics was introduced as a part of an encyclopedic education. Some notions as *algorithm*, *coding, decoding, table, graph, data*, etc. were applied to a variety of school activities. The educational software supporting the specially designed textbooks was also developed at RGE and included educational games, language- and music microworlds, text and graphic editors. The teachers in the primary school were prepared in specialized training programs but a lot depended on their creativity. For example a teacher of the integrated subject *I read, I write, I calculate* created a situation which called for decoding (matching numbers with letters), reading, writing and coding a return message in a context which was very motivating for the children. (They were expected to help Dr. Doolittle to communicate with the monkeys by means of secret messages.)

A very brave idea of integrating the study of mathematics, natural languages (Bulgarian, Russian and English) and a computer language (Logo in this case) was launched in fifth grade. Designed to show the intersection of language study with mathematical thinking in the context of informatics, the experimental textbook *Language and Mathematics* included problems on translating from a natural to a formal language, algorithmic description of basic grammar rules and ways to extend the Logo turtle vocabulary in several languages. Applications of informatics notions (e.g. *cycle* and *recursion*) were shown in mathematics, physics, music, graphical design, so that every student could choose a problem according to his/her interest. Such an approach implied a good co-operation among the teachers including joint teaching.

A smaller scale experiment was *Dante, Data and Today* project initiated by the Education Department at the Institute of Mathematics and Informatics with the idea of teaching 14-15-year old students in an integrated context [3]. The specific task of solving a riddle posed by Dante in his *Divine Comedy* by computer modeling of planetary motion was only a pretext to demonstrate how to harness the available modern technology in solving problems of various nature, both old and new. A team of mathematicians, informaticians, teachers in English, Bulgarian, literature and history were involved in a playful excursion into Middle Ages, guiding the students and encouraging them in investigations.

Even with these isolated experiments the lesson learned was valuable – the teachers' creativity can be enhanced when provided with an appropriate environment.

What is the most drastic change of today? – The existence of IT provides unlimited access to information, communication, and collaboration. They provide rich spectrum of means of expressing oneself. Being aware of this the policy makers have promoted the idea of ubiquitous use of computers at school. But the availability and the number of computers (even when they justify the name *personal*) are not sufficient conditions for an effective learning process. Of course, much depends on what "effective" means in this context – for some *the biggest effect of the computers on education has been the computer-scorable multiple choice test*. Whereas the original intention of bringing the computers in class setting was to prepare the students for real-life situation in which the problems are neither related to a single discipline, nor just to facts and answers. Therefore, the effective computer use in education should stimulate and support thoughtful analysis, expressing oneself in creative ways, seeing and making the connection among various fields.

Unfortunately, nowadays we often observe that the integration of subjects in the teaching materials is done very artificially, e.g. finding the average of several mountain peaks, drawing the graph of speed of growth of the elephant grass (?!), to mention just a few examples.

The policy makers feel very proud with reshaping the Bulgarian school – producing every year multiple sets of textbooks for each grade, introducing a new subject (IT) in the 5^{th} grade, providing a sufficient number of computers for each school. But the essential questions for us are: *Do we use technology so as to improve those features of education which we consider important? How do the teachers teach by means of technology? How could we define an* innovative teacher*? Do the teachers get appropriate education for their new role of facilitators in the learning process, of research partners of their students?*

In our capacity of people involved in developing computer environments, teaching platforms and materials, as well as ICT-enhanced teaching strategies we will share an aspect of our work, related to ways of encouraging teachers' creativity in multidisciplinary context.

2 Specifics of our natural environment for synergy of disciplines

The natural environment for synergy of disciplines we try to create during our teacher education courses is based on a specific *I*Teach* (*Innovative teacher*) methodology. It is based on developing the so called *ICT-enhanced skills* defined as a synergy between the technical and the *soft* skills – transferable skills in the Life Long Learning society. Putting the emphasis on such skills in the context of ICT education has been addressed in the frames of Leonardo da Vinci *I*Teach project* [4]. The *I*Teach* methodology [5], [6], [7], [8] has been proposed based on active learning methods – the student is in the center of the learning process, the teacher is a guide and a partner in a project work based on didactic scenarios encouraging learner's creativity.

We shall first illustrate how the *I*Teach* methodology has been implemented in a set of ICT textbooks and teacher's handbooks for the junior high-school so as to allow teachers and students to enhance the underlying ideas in their field of interest.

It is typical for the structure of the textbooks that there is a common thread linking: the tasks in a lesson; the lessons in a common ICT theme; and the ICT themes in the whole textbook [9]. The unifying theme of the final book of the series is the *coding*, which passes as a *red thread* through the whole content. Each lesson deals with ideas and tools for solving problems considered as milestones towards a final goal (Fig. 1). The *grand finale* is a project (*Decoding the past*) requiring the students to put together all the subject knowledge and skills acquired during the school year and to work creatively in teams and present their results (Fig. 2a). For the purpose they are expected to decode a message and to create computer models of ancient Greek vessels, figure out their function (Fig. 2b) and thus - to help a local museum to restore them. And, similarly to all real-life projects, the multidisciplinary elements in the project scenario are interweaved in a natural way.

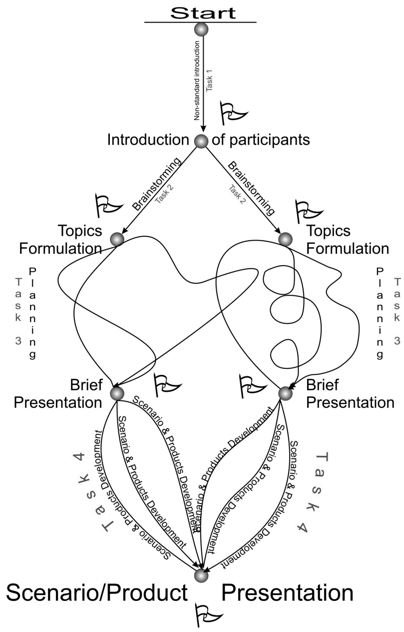


Fig. 1: A typical *I*Teach* map of a project scenario

Let us note that the *soft* skills expected to be developed when working on this project include team work (planning, task distribution, communication skills, conflict resolving), information skills (looking for and selecting relevant information, critical thinking), presentation skills (selecting the most appropriate tools for a specific task, preparing written and oral presentation of the milestones and the final product). Furthermore, the project output is expected to be "put on the table", i.e. to have a finalized appearance and to be sharable with others.

The textbooks, as a whole, and the *Decoding the past* project, in particular, are designed so as to foster the creativity of both teachers and students. In the case of the teachers, they are encouraged (in their handbooks and during the training courses) to develop variations on the project theme taking into account their own expertise and students' interests. As for the students, their creativity is stimulated by offering them a freedom of choice: 1) of a path towards a specific milestone; 2) of a tool representing their ideas, and 3) of a manner of presenting the results. The two aspects of the project work, viz. the generation of creative ideas and their implementation in a sharable product, could lead to innovativeness – an important characteristics of the creativity based society.

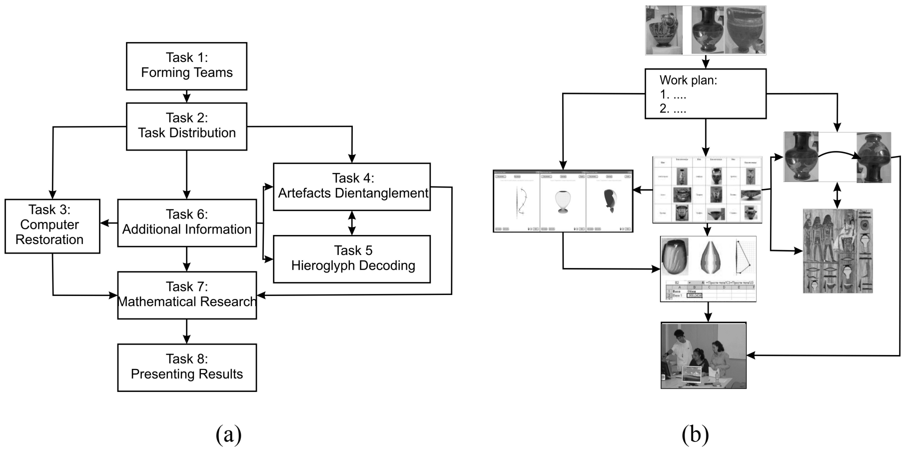


Fig. 2. From abstract I*Teach Scenario to concrete *Grand finale*!

3 Multidisciplinary projects

3.1 Preparing the ground

During the last 3 years in many courses with in-service teacher in which we have taught teachers how to use IT as a means of expressing oneself, as a natural environment of integrating knowledge, interests and skills form different domains.
What proved to be a very valuable idea was to start with an informal introduction of the participants addressing questions of the kind: *In which field do you feel an expert and how do you know that? Who was your teacher? What else would you like to learn well?* This would give a valuable feedback not only to us but to all of them in terms of interests, background and expertise. Then we would offer a rather general theme offering a lot of room for interpretation and reflection (*Be my guests*, *School out of doors, Which way now?*, *The Art of Communication*). Next, we would group teachers in teams according to their interests. Usually the teams embraced experts in more than one field – a good ground for a multidisciplinary project. Then the teachers would start working on a project formulated by their team after a discussion. They would solve problems of various type in a natural way based on their own experience, involving consultation in- and out of the team when needed. The IT were just an element of the environment and thus were used when necessary.

One of important point is the teachers' trainers and participants to be open-minded to all coming ideas. Of course, not all participants ware ready for such an approach and at the beginning some of them refused to work in teams and to share their experience. But looking at the results of the team work they reconsidered their initial attitude.

After sharing ideas some of the teams reformulated the topics of their projects to make it more in harmony with the rest, as complementary to a more general theme. For instance one of the teams had chosen the topic of “games” as recreational means for learning (out of school).

After realizing that another team was planning a cruise, the game-team decided to concentrate on games with ropes and knots to make it more consistent with the trip on a ship. Thus the topic became more focused on knots in the context of *sea knots, knots in mathematics, secret messages with knots, etc.* The team members looked on the Internet, spoke with experts, etc. Finally they found how important the role of the knots has been in history, traditions, sending messages, safety in the sea, caves and the mountains, art, etc. (Fig. 3).

Fig. 3: Interweaving knots ideas

3.2 Math & fashion &arts

Our experience shows that technology enables the learners to approach geometry with a special enthusiasm when they work on projects tuned to their interests. For instance to explore the properties of geometric shapes in a computer environment becomes more motivated if made part of a visual modeling of some works of art. By building computer models of a given painting the students can gain deeper insight in its structure and elaborate their understanding in mathematics, informatics and art.

An inspirational synergy among these disciplines was achieved in the context of visual modeling [10] within the pre-service teacher education (4th year students in mathematics and informatics) at the Faculty of mathematics and informatics (Sofia University). The first topic for the students was to create variations on models of costumes designed by the great French artist from Russian origin Sonia Delaunay for the Diaghilev’s ballet (Fig. 4) With all the models we would start with a stylized version and then identify the geometric figures and transformation to be used in order to create a close enough approximation of the model. Various approaches were considered and one of the challenges was to use mathematical knowledge accessible for younger students. Another goal was to motivate students to apply their mathematics and informatics knowledge so as to generate a class of variations on a model by playing with parameters and controlled randomness. Some applied sophisticated informatics tools (e.g. recursion, procedures with parameter), others created tools of their own (e.g. filled-in polygons, hand-drawn-like parallelograms and curves). It was a pleasant surprise for the instructor to see the richness of ideas and the motivation of the participants regardless of their gender.

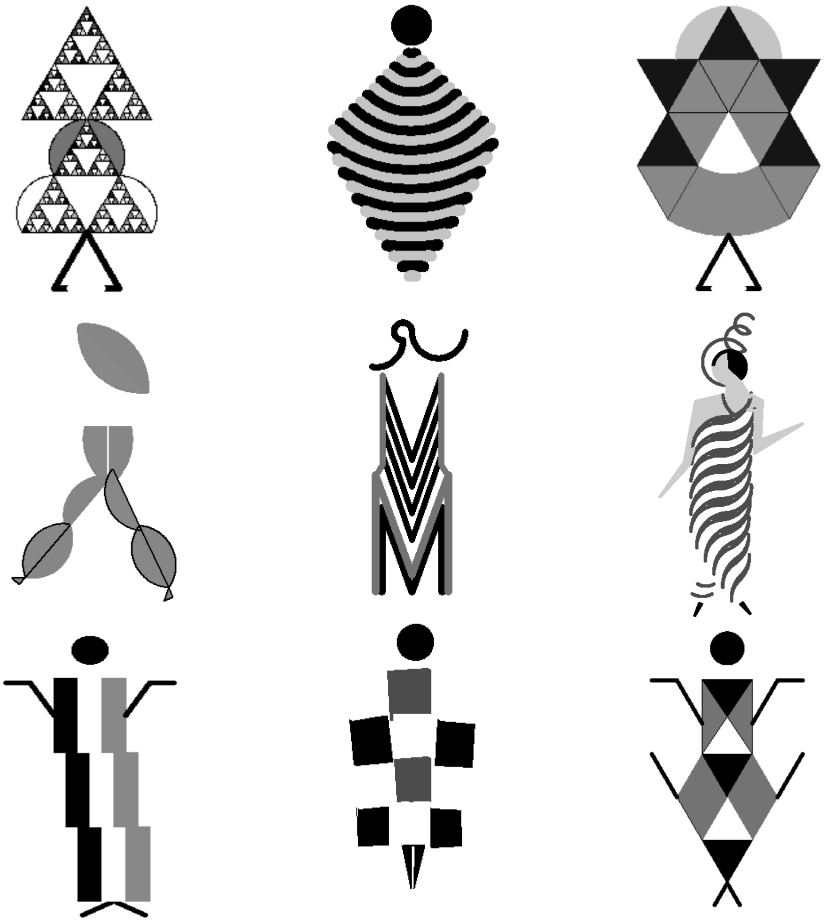


Fig. 4: Computer Models in the style of Sonia Delaunay

Products of the visual modeling should be judged with respect not only to the closeness to the original but also to their potential to generate works bringing the spirit of the original together with some new, unexpected ideas. After leaving the frames of the strict imitation the students we encouraged to explore new combinations of forms and colors and get new insight about the harmony and the balance of an abstract composition.

This was well illustrated in the modeling of some works by Kandinsky (Fig.5):

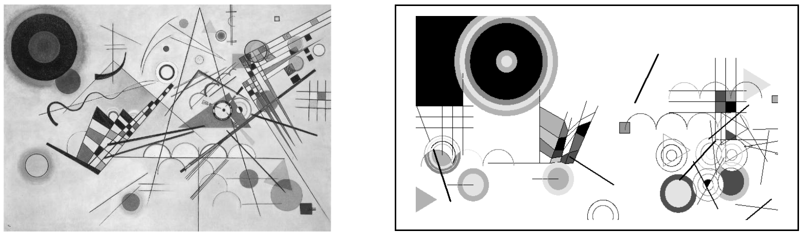


Fig. 5: A computer variation of Kandinsky's *Composition VIII*.

Here are some opinions expressed at the end of the course:

- *Projects bring the spirit of something interesting and diverse in contrast to the monotony of the classical exams…*
- *I am looking at Kandinsky's paintings with new eyes already…*

A very important mathematical concept – the shapes producing tessellation could be perfectly demonstrated by numerous Escher's works and then explored in a computer environment.

An example of such an activity is demonstrated in Fig. 6 – by cutting a certain piece of the regular hexagon and using appropriate geometric transformations we get a reptile as a motive of tessellation. What is left is to determine the angle of rotation so as to generate the reptile tessellation.

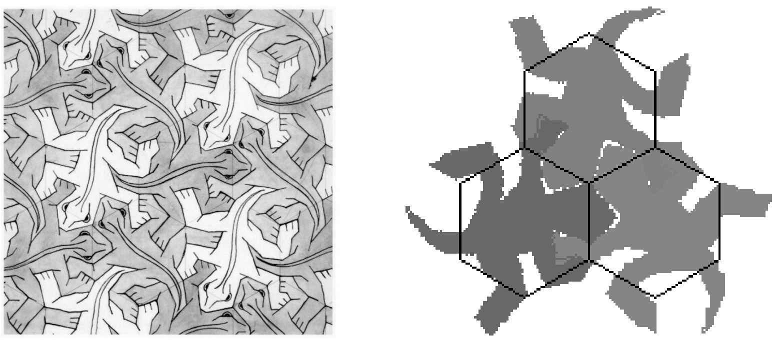
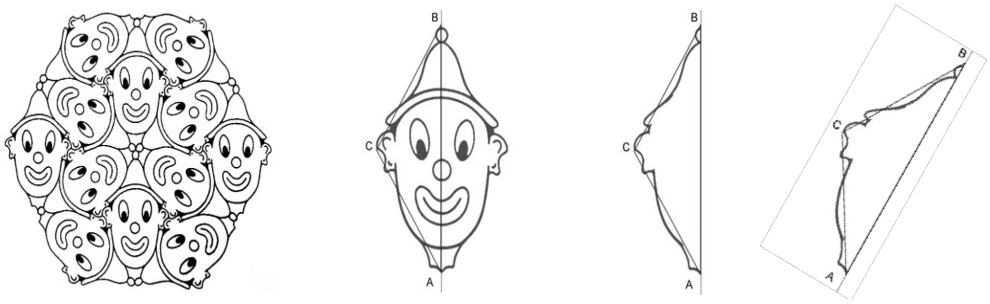


Fig. 6: A Logo model of Escher's reptiles

The same idea has been implemented in our IT textbook for 6 graders in a lesson for integrating activities by means of a graphic editor. The students are expected to apply their technical and mathematical skills in tessellating the plane with a clown's face (Fig. 7) and then - to demonstrate their artistic imagination by generating their own tessellations after Escher [11].



a) b) c) d)

Fig. 7: A tessellation challenge in an IT textbook for 6-graders

During the in-service teacher education the participants managed to design computer models of objects closely related to their professional orientation and/or hobbies. For the purpose they integrated not only various IT environments (Paint, Comenius Logo, Elica [12], [13] applications) but also knowledge in mathematics (symmetry, rotation in 2d and 3D, fractals), informatics (procedures with parameters, recursion) art (repetitive motives), hat- and jewelry design (Fig. 8), folk embroidery motives (Fig. 9), dress patterns (Fig. 10), decoration balls after Escher (Fig. 11).

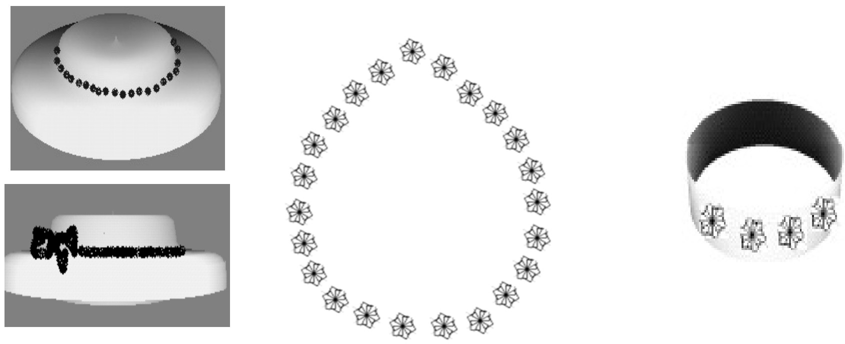
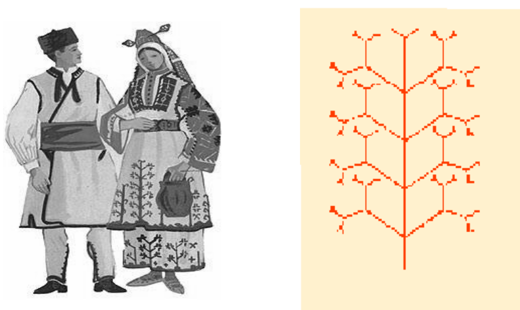


Fig. 7**:** Computer models of hats and jewellery
(*Hats: teacher Boyanka Atanasova; jewellery: teacher Diana Cvetkova*)



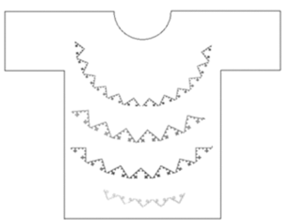


Fig. 8: Computer models of Bulgarian em

Fig. 9: Computer models of dress patterns with explanations in Bulgarian

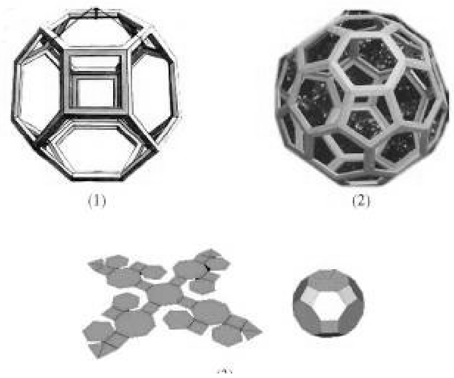


Fig. 10: Decoration balls after Escher

Following the idea of the *Decoding history* project, some teachers implement it in a new context combining their knowledge in history, mathematics, and information technologies (Fig. 12).

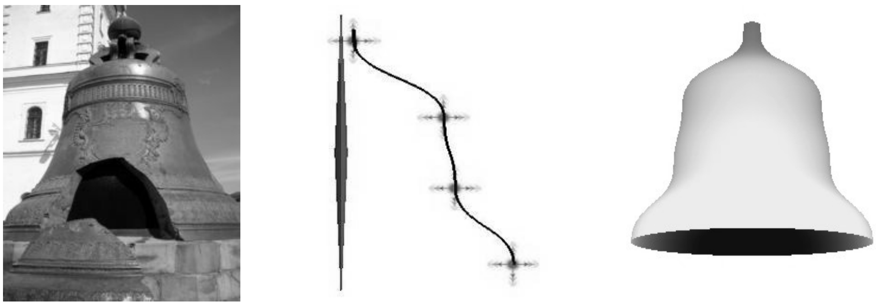


Fig. 11: Tsar Bell and a computer model of it (*teacher Tania Monova*)

A teacher coming from a field of electrical engineering developed series of electrical light sources (Fig.13)

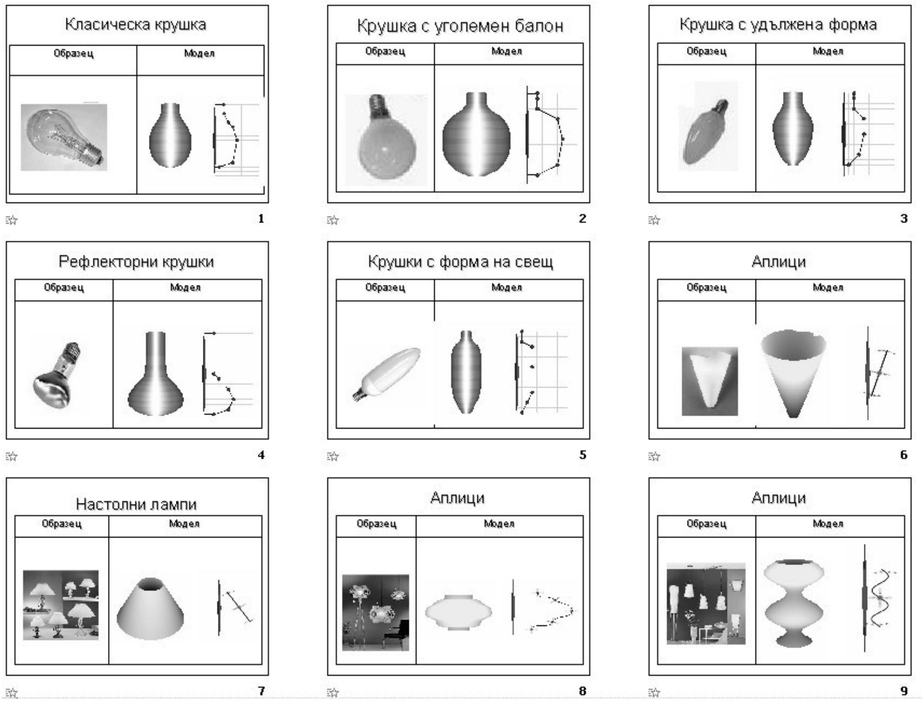


Fig. 12: Modeling light sources (*teacher Marian Radulov*)

The idea of the coding was also extended by a language teacher who illustrated in her project presentation that her students (after covering the standards for learning how to insert special symbols in a text document) could communicate in a new way - by means of a secret code (Fig. 14).

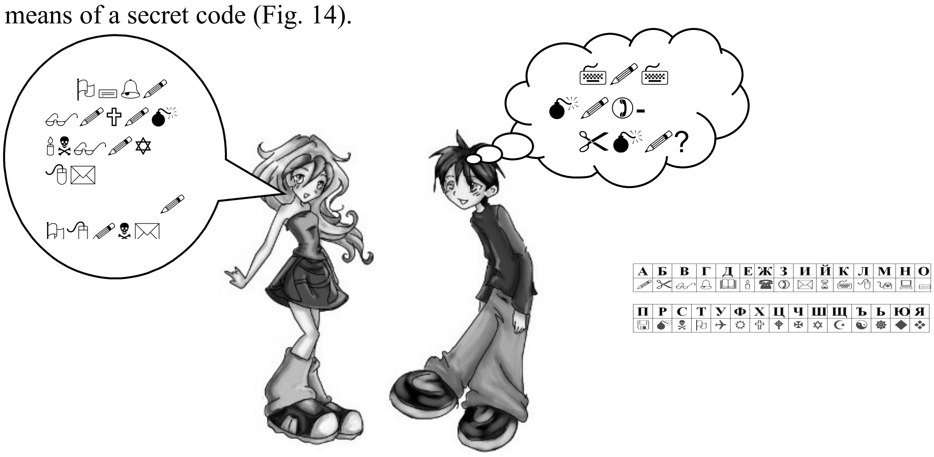


Fig. 13: Another look of pupils on coding

Our overall impressions were that the teachers felt uneasy at the beginning, but later were inspired by the freedom we gave the them concerning the theme of their projects. They came up with a lot of original ideas about various multidisciplinary projects embracing ecology, geography and even physical education.

A very rewarding experience for us was the invitation we received by the principal of a school in a small town (Rakovski) in Bulgaria which organized a science festival. The most interesting part was accomplished by teams of teachers in English, history, technology, literature, geography together with their students.

The initiator of all that was the teacher Ana Koyrushka, who after being exposed to the *I*Teach* methodology managed to demonstrate it to her colleagues and to stimulate them to work in teams on multidisciplinary projects reflecting their areas of competence and interests.

As many of the teachers shared with us after the courses, the most important conditions for using the multidisciplinary approach were:

- the use of an active learner-centered approach
- formulating the problem as a motivating challenge for the learner
- tuning the theme of the project in harmony with the learner's interests
- the team work (sharing and building knowledge)
- the use of IT tools for bridging knowledge from various fields4

4 Conclusions

We have never seen anybody improve in the art and the techniques of working on projects by any means other than engaging in a project. We cannot teach the art of working on multidisciplinary projects without engaging ourselves in such a work – with this in mind we encourage the teachers in expressing their creativity, knowledge and interests in a project chosen by them; we act as research partners of their teams and demonstrate during the work how we try to solve the occurring problems. Looking back at the challenges they have overcome, and being proud with the results they and their peers have received, these teachers enter the schools with newly gained self-confidence, ready to teach the way they have been taught.

Although good examples of teachers' creativity are not found in every school our endeavor is to spread their achievements through journals and conferences for teachers, and based on such achievements to enrich the in-service and pre-service teacher training. And we are not alone in this endeavor [14].

The main lesson for us as teacher educators could be summarized as follows: if we hope for a real positive change in education, we should bring today's and tomorrow's 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 experience what they are doing as *intellectually exciting and joyful on its own right*.

References

1. Boytchev, P. *Overview of Research Logo System*, in: P. Brna and D. Dicheva (eds.) Proceedings of the Eight International PEG conference, Sozopol, Bulgaria, 1997
2. Sendova E. *Identifying Computer Environments and Educational Strategies to Support Creativity and Exploratory Learning*, in Davies, G. (ed.) *Teleteaching'98 Distance Learning, Training and Education* , Proceedings of the XV IFIP World Computer Congress, 31 August – 4 September 1998, Vienna/Austria and Budapest/Hungary, p.889
3. Vassileva, A., Murhead, J. *Happy Birthday, Caciaguida!*, Mathematics and informatics Quarterly, 7/4, 1997
4. *Innovative Teacher* project site http://i-teach.fmi.uni-sofia.bg, retrieved on 5 March 2009
5. Stefanova E., Sendova E., v. Deepen N., Forcheri P., Dodero G., Miranowicz M., Brut M., et al: *Innovative Teacher - Methodological Handbook on ICT-enhanced skills*, Faleza-Office 2000, Sofia, 2007
6. Stefanova E., Nikolova N., Kovatcheva E., Boytchev P, Sendova E, *The discovery as a part of a teaching in an IT context*, Proceeding of XXXVIII Annual conference of the Union of Bulgarian Mathematicians 2009, Borovetz, Bulgaria, p. 319-328
7. 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. and Iding M. (Eds). Joint IFIP Conference: WG3.1 Secondary Education, WG3.5 Primary Education: Informatics, Mathematics, and ICT: a 'golden triangle' IMICT 2007 Proceeding, CCIS, Northeastern University, Boston, MA, 2007
8. Sendova E., Stefanova E., Nikolova N., Kovatcheva E. *Like a school (of fish) in water (or ICT-Enhanced Skills in Action)*, LNCS Informatics Education - Supporting Computational Thinking, pp. 99-109, July, 2008
9. Sendova E., Stefanova E, Boytchev P., Nikolova N., Kovatcheva E. *IT education – challenging the limitations instead of limiting the challenges*, Proceedings of CIIT 2008, Bitola, Macedonia
10. Sendova, E., Grkovska, S. *Vsisual Modelling as a Motivation for Studying Mathematics and Art*, In *Gregorczyk, G. et al (Eds.) Proceedings, EUROLOGO'2005* , pp. 12-23
11. Seymour, D., Britton, J (1989), *Introduction to Tessellations*, Dale Seymour Publications
12. Elica site http://www.elica.net, retrieved on 5 March 2009
13. DALEST project site http://www.ucy.ac.cy/dalest/, retrieved on 16 March 2009
14. Galabova, G. *Method of the Project for Interactive Training in Mathematical Didactics*, in Gagatsis, A. and Grozdev, G. (eds.) Proceedings of the 6th Mediterranean Conference on Mathematics education, 22-26 April 2009, Plovdiv, Bulgaria, p. 375