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EUROPEAN KEY COMPETENCES IN THE TEACHING OF MATHEMATICS AND SCIENCES

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ABSTRACT
This report has examined the nature of key competencies and related knowledge and skills. We share our experiences with opportunities for the integration of knowledge and activities to address the declining interest in studying math, science and technology in Bulgarian education.

Key words: Key competences, Mathematical competence, competences in science and technology.

INTRODUCTION

The interest in studying mathematics and sciences has been decreasing over the last fifteen years and this tendency is evident world-wide. To a very big degree this is true for Bulgaria too. The results obtained from TIMSS (an authoritative international comparative study) showed that in 1995 Bulgaria was 9th in mathematics and 5th in sciences, which are very high positions. In 1999 the same study showed that Bulgaria was 17th in mathematics and 16th in sciences. Despite the obvious decrease our students' results were better than the international mean value of all participant countries. In TIMSS – 2003 our position in mathematics was 25th and in sciences it was 24$^{th.}$ The most alarming finding from TIMSS – 2003 was that there was no other country with such big decrease in the achievements of the students both in mathematics and in sciences. This raises very big concerns and is a certain sign that the quality of teaching in these subjects is not on the necessary level.

In an attempt to find ways to overcome the decreasing interest towards the sciences a life-long learning strategy has been developed. The question now is: "What competences should a modern European citizen possess in order to be attractive for the labour market?"

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EUROPEAN KEY COMPETENCES

The word *competence* means a proven ability to use knowledge, skills and personal, social and/or methodological facts in work or learning situations and in professional and personal development.

Key competences are what all people need for their personal development, active citizenship, social integration and employment, and at the end of their initial education and training all young people should have developed these competences to a level which equips them with the knowledge they need for their mature life; and later on these competences should be built on, maintained and updated as part of the life-long learning process. (1) These are the key competences as outlined in the European Reference Framework: Communication in the mother tongue; Communication in foreign languages; Mathematical competence and basic competences in science and technology; Digital competence; Learning to learn; Social and civic competences; Sense of initiative and entrepreneurship; Cultural awareness and expression – expression of ideas, creativity, emotional and aesthetic understanding of the world through literature, music, painting, etc. (2).

The general framework of the competences is constructed according to the needs of the individual *to think and act reflexively.* The analysis of the competences gives ground to claim that the key competences should not be viewed in a hierarchical order and none of them is to be given priority over the others. In this sense the horizontal nature of the key competences is of enormous importance. They provide added value for employment, social cohesion and educational achievements of young people (European Youth Pact), which explains the significance of life-long learning in respect to adaptation to changes and integration.

In many European countries, including Bulgaria, the interest towards studying sciences and mathematics is low.
To a very big degree this is due to the lack of clear definition of the place that sciences and mathematics occupy in the whole educational paradigm. In order to overcome this situation the European Commission defined a separate key competence – mathematical literacy and basic knowledge in science and technologies.

Mathematical competence is the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations. Building on a sound mastery of numeracy, the emphasis is on process and activity, as well as on knowledge. Mathematical competence involves, to different degrees, the ability and willingness to use mathematical modes of thought (logical and spatial thinking) and presentation (formulas, models, constructs, graphs, charts).

Competence in science "refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to draw evidence-based conclusions. Competence in technology is viewed as the application of that knowledge and methodology in response to perceived human wants or needs."

The realization of all these ideas presupposes a connection between our educational system and the requirements of the European Qualifications Framework (EQF). The existing legislative framework was developed before these key competences were defined, which leads to a lack of direct correspondence with them. For example, in the State Educational Requirements (SDE) for the educational content concepts are defined separately, without providing the integrative essence of the knowledge about nature in the needed degree. Naturally, this leads to their absence in the relevant textbooks and school aids used in Bulgarian schools.

In order to restore the interest towards sciences and mathematics in the young generation it is necessary to direct the focus of school education to the details of the European dimensions – to provoke interest to natural phenomena, the environmental problems and human health. It is necessary to transform the strongly theoretical scientific information in the existing textbooks by going back to the almost forgotten educational experiment and to redirect scientific literacy to everyday realities. The knowledge acquired in the lessons of sciences and mathematics should be connected with understanding problems topical for society, with increased practical applicability and oriented to specific results.

The main words that renowned teachers used to characterize the teaching of mathematics and sciences during a survey of their opinion in interactive qualification sessions were *cooperation, inclusion, transfer of knowledge, applicability of knowledge, relations and interactions between subjects, integration,* etc. This gave us the idea to examine the integrative interactions as a basis in the teaching of mathematics and sciences.

INTEGRATIVE INTERACTIONS – A BASIS FOR TEACHING MATHEMATICS AND SCIENCES

The nature of the knowledge that the school subject gives is scientific information, which preserves its main qualities notwithstanding the didactic processing. The educational content is comprised of the following types of knowledge – empirical, of specific scientific nature, of general scientific nature and of philosophical nature. The empirical material should be selected on the basis of the universal principles existing in the phenomena to be studied, which are then to be fixed in the relevant concepts. This results in the students being able to rationalize certain scientific laws. Through these concepts the **inter-subject interactions** are realized.

One of the main tendencies in the modern development of science is the integration of scientific knowledge. **Integration** is a form of theoretical synthesis, realized within the

borders of the separate school subject and expressing itself in the form of interdisciplinary synthesis. The deepest meaning of integration is the achievement of qualitatively new knowledge.

The integrative processes in the education have different strategic aims. The final aim is to achieve the higher knowledge of specific scientific nature. In this sense integration is realized with intra-subject interactions, which are a powerful regulator of the overall pedagogical process.

The interdisciplinary interactions take place in several directions:
- "on the basis of inter-scientific concepts, which are used in the cross informational fields in the respective school disciplines: information, symmetry, probability, algorithm, module, sign, etc.;
- on the basis of synthesizing disciplines: mathematics, cybernetics, theory of systems, etc.;
- on the basis of interdisciplinary scientific methods and methodology: transversal, etc.;
- on the basis of interdisciplinary study skills and general learning strategy;
- on the basis of general requirements and parameters of human activity: algorithmization, creativity, purposefulness, motivation, etc."(3)

Mathematics is one of the integrative sciences and school subjects, because the knowledge it gives influences to a significant degree various sides of human activities and also various school disciplines. In this respect there is a lot to be reconsidered with the aim of building such a structure of the educational content that projects in an ordered and unambiguous way the integrative possibilities that mathematics can provide.

The integration of physical, biological and chemical knowledge is implemented in the frame of one and the same skills. The inclusion of mathematical knowledge too provides an opportunity for creating an integral image in the mind of the student about structures, phenomena and processes. In this way benefits are gained for science, because knowledge is presented fully; for pedagogy - because within one lesson inter-subject relations are implemented; and also for practice - because skills are formed early and there is an opportunity of their application. It follows from the above that there is an obvious necessity of pointing out opportunities for inter-subject interactions in the educational content on the basis of general science concepts and approaches between mathematics and sciences. The full presentation of the hierarchy in the structure of natural objects and their interdependencies provides conditions for adequate intellectual activity of the students on the basis of the multidirectional but unified base which makes the cognitive process efficient and instructive, tangibly influencing their versatile development.

OUR EXPERIENCE

The practical experience described in this article is connected to the formation of mathematical competences and basic competences in sciences and technologies. In the course of four successive years the Department for Information and In-service Teacher Training has been participating through various projects in the U*Night initiative - part of the Seventh Framework Programme of the European Commission. These projects aim at promoting the job of the scientist/researcher, sciences and technologies in general and also raise the public awareness to the contribution of scientists to the development of society. The aim is to attract young people to scientific and research activities. The scientists' night is an initiative that is organized simultaneously in over 300 European towns, which makes young people all over Europe active and open to acquiring new knowledge in various fields – physics and astronomy, history and architecture, chemistry, biology and environmental studies, etc.

The projects that we have worked upon during the last three years are: **Researchers as Guides to Glory of Ancient Europe; (REGGAE – 2007) FP 7; Researchers Careers and e-Motions (RE*CAME) FP7-2008; STAR NIGHT FP7-2009.**

The team responsible for the initiation and implementation of the projects in Bulgaria have chosen various scientific fields and activities to attract the attention of the public and direct it to the job of the researchers and to the new technologies supporting the development of the sciences and thus to make them popular among the young people. There is an opportunity for dialogue between the scientists, high school and university students and the general public and the visitors are encouraged to ask questions to the researchers,

to observe the attractive sides of their job and their personalities. These are some of the most interesting initiatives:

- Quiz on the topic of ecology and environmental preservation named *Nature Borrowed*;
- Lab for fun science experiments and demonstrations;
- Visit to an eco-laboratory (automatic measuring station) and to the Regional Inspectorate for Preservation of Environment and Waters;
- Showing of a film specially prepared for the projects by the Eco-Center in Stara Zagora named *Transport in the Big Town – Environmental Problems;*
- Discussion in the form of a game named *Modern Aspects of Agrarian Science – Genetic Engineering and Biological Agriculture;*
- Exhibition of photos from archeoastronomical expeditions;
- Competition for multimedia products called *The Telescope – Eyes towards the Universe* in which the participants present their own products and these are assessed in terms of originality, quality and creativity;
- Competition in the form of a quiz called *Become Rich in Stars* with the participation of children of various age groups. When giving a correct answer they receive a star and in this way accumulate a wealth of stars as a result of their knowledge.
- Workshop of the young and talented (a demonstration experiment called *Let's Make a Megalith Observatory!);*
- Exhibition of technologies (an exhibition of high technology achievements, presentations, discussions, etc).
- A fun game named *Find the Treasure* which requires a creative approach in solving an archaeological problem – putting together pieces of an antique inscription, decoding of information and "finding the treasure";
- Scientists' café – provides an opportunity for dialogue between scientists, high school and university students, businessmen and citizens and promotes the development of harmonious relations between scientists and the community, creates conditions for recognition of their efforts and for attraction of young people to scientific careers.

These activities are suitable for out-of-class work with students of various age groups – from primary school to university and post-doctoral students. They show only a small part of the many opportunities that exist and can be used for forming an interest to mathematics and sciences through interdisciplinary educational activities on the basis of a general strategy for learning. A complex of key competences and human values is formed through them.

CONCLUSIONS

The implemented projects provide good practices for working in and out of schools.
They equip teachers with tools with which to organize the educational process and to direct teaching to solving practical tasks or activities that involve research and in this way to develop investigation skills, creative thinking, key skills and competences like basic skills in sciences, mathematics and technologies.

These skills do not exist in isolation and contribute to the development of communication skills in the mother tongue, digital competences, independent learning skills and information gathering; social and civic competences and all that is achieved in an emotional and creative atmosphere.

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