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THE TRAINING MODULES FOR IMPROVING QUALITY OF SCIENCE TEACHER PREPARATION: METHODOLOGICAL, PROCEDURAL, AND DIDACTICAL ISSUES

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Abstract

The constructivist perspective is becoming a dominant paradigm in the field of the science education. While a great deal has been written in recent years about constructivist learning theories and their applications to elementary and secondary school classrooms, much less has been said about these implications of these ideas and practices for teacher education. This approach in the initial science teacher training is not still too common at many European teacher training institutions. It is a reason why a group of science teacher educators from five European countries (Bulgaria, Czech Republic, Cyprus, Lithuania and Turkey) focused on this topic. These countries cooperate on the Project IQST Improving Quality of Science Teacher Training in European Cooperation – constructivist approach (the Socrates – Comenius 2.1 programme of the European Commission).

Key words: science education, teacher education, cooperation, constructivist approach.

Introduction

In majority of the European countries one can observe a lack of science teachers, mainly of physics and chemistry teachers, as well as a lack of students in this teacher training. There is not doubt that science teaching has a crucial role to play in shaping the future development of EU. Added to the momentum of the greater integration of EU, there is a need for the exploration, discussion and exchange of educational ideas, analysis of common problems, implementation of European dimension in initial science teacher training, with the aid of joint projects.

There is not doubt that science teaching has a crucial role to play in shaping the future development of EU. Science education has become an important prerequisite for a vital economy especially with the emerging global economy. Many industrial nations are seeking to improve the quality of science education because of the vital role science and technology play in a nation's economy and standard of life.

One of the burning problem is professional competence of science teachers. Regular investigations of these issues are conducted by various international organizations and groups of scientists. Education literature (Raven, 1999; Sjøberg, 1997; Naidenova, 2002; Namsone, 2002; Pak, Solomin, 2003; Belova, 2003; Sormunen, Aaltonen, 2003, etc.) suggests that undivided attention has to be paid to natural sciences teachers' in-service training and refresher courses and ads that in general, the role of the teacher changes – from an imparter of information to an expert-adviser. A teacher is the most important epistemic actor when we are thinking e.g. science education (Sormunen, Aaltonen, 2003) and teachers are recognised as the central determining factor in successful science education (Keinonen, 2003).

Research in the field discloses that natural science teacher training determines the approach of the young generation to natural sciences in general. Thus, natural sciences teacher training has to be efficient and permanently investigated (Lamanauskas, 2003). For the successful education it is important to have an attentive ear to the science teachers problems, their expectations, to respect them as well as give scientific and didactical assistance for mating their profession meaningful.

People use scientific principles and processes in making personal decisions and to participate in discussions of scientific issues that affect society very often. Science education strengthens many of the skills that people use every day, like solving problem creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning. And the economic productivity of our society is tightly linked to the scientific and technological skills of our work force. A new way of teaching and learning about science reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world. Teachers must have theoretical and practical knowledge and abilities about science, learning, and science teaching. The quality of science teacher training and its relationship with improving the quality the education systems generally have become key issues of public concern across the world in recent years.

The comparative analysis of the works of scientists from different European countries shows that there are many similarities in science teachers education problems among all countries, for example, lack of integration between pedagogical theory and practice, too little effort to teach the future teachers to teach effectively and use modern science teaching and learning methods and strategies, the role of practice work in science teacher education is often underestimated and other problems. One of the possible ways how to solve these common problems was to implement constructivist theory to science teacher training. In all participating institutions was possible to realize main goals of the IQST Socrates Comenius project: to design and implement constructivism modules in science teacher training and to improve its quality within their national contexts.

Methodology of Research

The analysis of scientific literature, training modules has been applied. All training modules were analysed by four main aspects: general methodological background, didactical approach, structure, and usefulness for students. There were used comparative analysis and quantitative analysis as the main research methods. The questionnaire was applied to find usefulness for students. The reflection of students and students´ essays supported these findings.

Assessing Science for Understanding – Constructivist Approach

General background

With the release of the constructivist approach to science teaching, the issues of why, how, and what we, as teachers, assess in our classrooms will become a major challenge in the science teaching and learning.

Assessment can be defined as a sample taken from a larger domain of content and process skills that allow one to infer student understanding of a part of the larger domain being explored. The sample may include behaviours, products, knowledge, and performances. Assessment is a continuous, ongoing process that involves examining and observing student's behaviours, listening to their ideas, and developing questions to promote conceptual understanding.

The increasing focus on the development of conceptual understanding and the ability to apply science process skills is closely aligned with the emerging research on the theory of constructivism. This theory has significant implications for both instruction and assessment, which are considered by some to be two sides of the same coin. Constructivism is a key underpinning of the science teaching and learning.

Critical to educators is the use of assessment to both inform and guide instruction. Using a wide variety of assessment tools allows a teacher to determine which instructional strategies are effective and which need to be modified. In this way, assessment can be used to improve classroom practice, plan curriculum, and research one's own teaching practice. Of course, assessment will always be used to provide information to students, parents, and administrators.
In the past, this information was primarily expressed by a "grade". Assessment is changing for many reasons. The valued outcomes of science learning and teaching are placing greater emphasis on the student's ability to inquire, to reason scientifically, to apply science concepts to real-world situations, and to communicate effectively what student knows about science. Assessment of scientific facts, concepts, and theories must be focused not only on measuring knowledge of subject matter, but on how relevant that knowledge is in building the capacity to apply scientific principles on a daily basis. The teacher's role in the changing landscape of assessment requires a change from merely a collector of data, to a facilitator of student understanding of scientific principles.

The assessment is learner-centred, teacher-directed, mutually beneficial, formative, context-specific, ongoing, and rooted in good teaching practice. In the context of constructivist approach, assessments need to gauge the progress of students in achieving the three major learning outcomes of constructivist approach: conceptual understanding in science, abilities to perform scientific inquiry, and understandings about inquiry.

Teachers have a very challenging role to play in assessment process. Assessment can foster development of the kind of knowledge frameworks that are needed for effective science teaching. So prospective science teachers must seek on their own initiative to build this kind of understanding of their field. Constructivist approach to assessment is formative rather than summative. Its purpose is to improve the quality of student learning, not to provide evidence for evaluating or grading students.

Didactical approach

The goal of this module is to implement newer pedagogical theories into initial science teacher training. These new pedagogical methods are based on constructivist approach in science teacher training. Module can be used by lecturers with their students at science teacher training institutions.

The didactical approach is deeply characterised in *Description of the Units for Direct Teaching* which contains the description of the units for direct teaching in initial science teacher training in higher education institutions. Each unit has the similar structure: number, topic, goals, time, materials, strategy/method, reflection/comments, developed competencies of constructivist science teacher. This material is only recommendation for trainers of prospective science teachers. The aim of this material is only to help trainers in their teaching.

Structure of training material

The training material was prepared for the module Assessing Science for Understanding – Constructivist Approach. Each chapter in the training material has the following structure:

- Title of the Chapter
- Chapter Objectives
- Training text (divided in parts)
- Tasks (assignments)
- Case study
- Questions to Case Study
- Summary
- Frequently Asked Questions

The training material entitled "Assessing Science for Understanding – Constructivist Approach" consists from 6 units:

1. Purpose and characteristic of classroom assessment.
2. A constructivist approach in assessment.
3. Planning and implementing classroom assessment projects.
4. Techniques for assessing knowledge and skills.
5. Techniques for assessing learner attitudes, values and self-awareness.
6. Assessing learner reactions to instructions.

European Dimension in Integrated Science Education

General background

A central concept of integration is underlined in the training material. Science education is an integral phenomenon that can be grasped as a whole science. It is disintegrated in the substantial parts such as ecology, environment education, etc. The parts of any of the units advance and finally settle in the complete wholeness. In order to understand the problems of science education, they have to be investigated complexly embracing different fields and levels. Different trends have formed considering a question of integrated teaching in foreign pedagogy: technocratic, pragmatic, cognitive, humanistic, etc. Learners' science education is given scrupulous attention as the content of natural sciences provides all opportunities to make the educational process dynamic, classified and harmonious. W.Gräber and other scientists (2001) maintain that science teaching can be described in three dimensions: teacher centred – student centred, teaching facts – teaching processes, and discipline oriented – daily-life oriented. The modern approach requires to combine the knowledge of related sciences (for example, natural sciences) into the entire system and to establish conditions for learners to investigate, conclude, analyse broad and diverse information, to improve, change and broaden their knowledge, i.e. to eliminate the traditional barriers of subjects, to refuse insular empiricism and finally, to be critical.

> „Trying to avoid the fragmentariness of nature study, the educational process must classify the knowledge of sciences and their content, to look for, find and show the correlation between separate facts and phenomena of natural science inside every single educational subject when discussing individual topics, connecting them with the content of all subjects of science and

integrating all related knowledge into the system. „The attachment" of learners' consciousness to separate natural objects and phenomena can be evaded as it prevents from the embodiment of the schoolchildren's world outlook" (Vaitkevičius, 1996; p.109).

The reconstruction of the content of sciences teaching reveals the relevancy of pupils' cognitive activities organization. One of the suitable forms of teaching is group work that is useful for bright and weak pupils and pedagogically important when combining learners' teaching and upbringing into a single process. Facilities for group work must be provided during practice, laboratory work and other kinds of practical activities.

Considering the specificities of pupils` age and the peculiarities of cognitive material, it is necessary to heighten the sense of individual responsibility for learning, to help with practise of the skills of personal work, to fulfil a responsibility for the knowledge and actions of yourself and other members of the group (for example, group work).

Thus, the issues of integrated natural sciences teaching should be complexly discussed. ***The system of personal values – theoretic and practic knowledge of the personality – practic skills of the personality*** is an undivided system closely interrelated and functioning only through specific, intensive, practical activities of a personality. The integrated natural science course helps pupils to convey the whole (***holistic***) world picture that encourages to easier realize the issues of ecology, nature (environment) protection, the implementation of modern technologies, etc., to link outcomes with reasons, obtained knowledge with socio-cultural life.

The key issues of integrated natural science education should be analysed during the module realization in initial science teachers` preparation process:

- General didactic and methodic integration of teaching;
- The system of the categories (concepts) of the integrated educational course;
- The essence, forms, principles and functions of integrated teaching;
- The consistent patterns of integration processes;
- The forms, stages and trends of teaching and educational process integration;
- Theoretic reasoning of the significance and opportunities of integrated teaching;
- The consistent patterns and models of applying integrated teaching in school practice;
- The integral results of teaching/learning and their evaluation.

Didactical approach

The didactical approach for this training material is described in *Description of the Units for Direct Teaching* which contains the description of the units for direct teaching in initial science teacher training (Descriptions of the ....2008). Each unit has the similar structure: number, topic, goals, time, materials, strategy/method, reflection/comments, developed competencies of constructivist science teacher. The authors of the training material tried to combine different teaching/learning strategies, for example, independent reading, group work, discussions, case studies, brainstorming, research projects etc.

Structure of training material

The training material was prepared for the module "European Dimension in Integrated Science Education". Each chapter in the training material has the following structure:

- Title of the Chapter
- Chapter Objectives
- Training text (divided in parts)
- Tasks (assignments)
- Case study
- Questions to Case Study
- Summary

- Frequently Asked Questions

The training material entitled "European Dimension in Integrated Science Education" consists from 14 units:

1. A Conception of Integrated Science Education.
2. Some philosophic, didactic and social aspects of integrated science education.
3. The main tendencies of integrated science education development.
4. & 5. Integrated science sducation in the context of the constructivism theory.
6. The models of integrated science education.
7. The integrated science education curricula and its designing principles in comprehensive school.
8. The science education tools and ways of producing them in the collaboration process.
9. & 10. A constructivist approach to integrated science education: teaching would-be teachers to do science.
11. & 12. Contextual teaching and learning of integrated science in lower and upper secondary schools.
13. The evaluation strategies of integrated science teaching / learning.
14. The collaboration peculiarities of science teachers.

Development Procedural Skills in Science Education – Constructivist Approach

General background

During the last years constructivism as an approach in education has had a central position in didactical literature. Constructivist theory is definitely accepted as a modern and leading theory in the teaching of science. Constructivism has become the most valuable guiding principle for the teachers of science, as well as for researchers in this field. Constructivist teaching fosters critical thinking and creates active and motivated learners. The constructivist theory has been incorporated into the curriculum, and advocates that teachers create environments in which children can construct their own understandings. There are different types of constructivism: cognitive, social, radical. The following principles of constructivism are important: active construction on the basis of the already exciting conceptions; arrangement of tentative constructor; checking its viability; acceptance of the social character of the construct. Constructivism changes the role of the teacher in the educational process and suggests a new model of teaching environmental.

Science and teaching students about science means more than scientific knowledge. There are three dimensions of science that are all important. The first of these is the content of science, the basic concepts, and our scientific knowledge The other two important dimensions of science in addition to science knowledge are processes of doing science and scientific attitudes. The processes of doing science are the science process skills that scientists use in the process of doing science.There are different classifications of process science skills; one of these classifications describes them as basic (observation, classification, measurement, conclusion, prognosis, communication) and integrated process skills (formulating hypotheses, identifying of variables, describing relationships between variables, designing investigations, experimenting, acquiring data, organizing data in tables and graphs, analyzing investigations and their data, understanding cause and effect relationships, formulating models). Physics education gives vast opportunities for formation of process science skills.

The main factor for choosing one or another strategy is related to students, to their abilities and interests, to their number in class and to the problem that they should be active participants in the training. The inclusion of ICT in the teaching process changes its character and determines the choice of a certain strategy. Formation of process science skills such as to collect and process data and to present it graphically is related to a concrete organization of students' activity. Some integrated process skills related to assimilating of different structural elements of physics knowledge (physics phenomenon, physics value, physics law, and physics device) may be formed through an organization of students' mental processes in a certain sequence.

Didactical approach

The goal of this module is to introduce students into the topic „Development Procedural Skills in Science Education. In this module there are given different ways for putting into practice some these pedagogic ideas and theories. In this module the students will find some pedagogic methods, based on the constructivist approach, which can be used in training of science teachers to be. Constructivist perspective, to which the training material is dedicated, lately becomes dominant paradigm in the sphere of science training, which also determines the growing interest towards this problem.

Structure of training material

The training material entitled "Development Procedural Skills in Science Education – Constructivist Approach" consists from 5 units:

1. Scientific and technology literacy. Components and level of scientific literacy.
2. Constructivist approach in science education.
3. Building and developing process science skills.
4. Strategies for supporting process skills development and assessment.
5. Planning, organizing and delivering an active learning project.

Each unit in this module has its theme, and it contains theoretical material followed by given references. To the scientific texts in the training material are offered questions and tasks for students` self-training. There are also certain outlines for case studies on the subjects, and after them, there are sources of information for self-training. The training material is prepared in two languages – English and Bulgarian.

Using Laboratory to Enhance Student Learning and Scientific Inquiry

General background

Scientific knowledge is comprised of two distinct, yet interrelated, components: theory and empirical evidence. Understanding the interrelations between these two components is crucial to the understanding of what science is and how it works (Havdala and Ashkenazi, 2007; Kuhn & Pearsall, 2000).

Science teaching with a laboratory teaching method orientates the search for answers and coherent and correct explanations through learning processes in which students work and interact to gain the new knowledge that will allow them to read the cause of scientific phenomena or the explanation of observed situations (Berionni and Baldon, 2006). And also constructivist science teaching plays a crucial role in affective science teaching.

Students learn by fitting new information together with what they already know. Constructivists believe that learning is affected by the context in which an idea is taught as well by students' beliefs and attitudes. Effective teaching recognizes that meaning is personal and unique, and the students' understandings are based on their own unique experiences. ICT provides opportunities for science teachers to be creative in their teaching and for students to be creative as they learn.

Didactical approach

The training material was prepared to emphasis the importance of constructivist science and science laboratory teaching/learning approaches. Using laboratory to enhance student learning and scientific inquiry and some related factors are focus of this training material. Trainee science teachers and in service science teachers (physics, chemistry, biology) have been thought as the target group of this material. In order the people can get detailed knowledge the most of the data about the subjects were intentionally collected from the contemporary websites. Users of this training material can have possibilities to understand the subjects deeply using next readings and references at the end of units and also internet search engines. In order to be understandable easily a basic language were preferred on reporting the subject knowledge of the material much more than academic language.

Structure of training material

The training material entitled “Using Laboratory to Enhance Student Learning and Scientific Inquiry” consists from 4 units:

1. Constructivist science and laboratory education resources.
2. Constructivist science teaching techniques.
3. Scientific process skills and scientific inquiry.
4. Meaningful learning and nature of science.

The training material is prepared in two languages – English and Turkish.

Floating and Sinking of an Object in a Liquid - Based on Socio-cognitive Constructivism

General background

Research on student cognition has clearly demonstrated that students’ prior conceptions create a framework for understanding and interpreting information gathered through experiences. Learning results from the interaction occurring between an individual’s experiences and his or her current conceptions and ideas. The process of learning depends on the extent to which the individual’s conceptions integrate with new information. This integration is characterized as assimilation or accommodation and is guided by the principle of equilibration, whereby individuals seek a stable homeostasis between internal conceptions and information from the environment. The process of accommodation is, however, much more critical for the continuing conceptual development of the learners, because it requires a transformation of individual conceptions rather than integration of new information into the individual’s existing frameworks.

The existence and persistence of students’ alternative conceptions in science gave rise to different research efforts attempting to identify conditions that encourage or drive accommodation (e.g., Posner, Strike, Hewson, & Gertzog, 1982). Dissatisfaction with current conceptions acts as a catalyst for accommodation to occur provided that the new conception is intelligible, plausible, and fruitful. This approach tends to imply that learners behave like scientists, and that ontogenic change in an individual’s learning is analogous to the nature of change in scientific paradigms, ignoring the differences and disagreements about the nature of this change among philosophers, historians, and sociologists of science. Thus, each time students encounter a discrepant event, they search for new intelligible, plausible, and fruitful constructs in an attempt to balance the existing cognitive disequilibrium. Personal construction of knowledge occurs through the interaction between the individual’s knowledge schemes and his or her experiences with the environment. The primary mechanism for cognitive growth is the learner’s interactions with the physical environment, while the social interactions and language do not receive primary attention. Social interactions and talk with other people are, however, seen as aiding the process of accommodation by creating cognitive dissonance. This description focuses on the psychological process of equilibration and reflects the Piagetian perspective or the *cognitive perspective* in general.

Conversely, the Vygotskian perspective, or the *socio-cultural perspective* in general, considers the construction of knowledge as a social process, where social transactions and discourse are considered to be the basis for any subsequent learning. Representations of knowledge are viewed as patterned by social and cultural circumstances. This view "accentuates the social and cultural genesis and appropriation of knowledge" (Billet, 1996, p. 264). Learning is viewed as the appropriation of socially derived forms of knowledge. Appropriation is not restricted to the internalization of externally derived stimuli. It consists of a transformational and reciprocal constructive process (Rogoff ,1995) and results to a co-construction process of cognitive structures (Valsiner, 1994).

The cognitive and socio-cultural constructivism seem disparate, but they offer some basis for considering "*the mutuality between persons acting and the social and cultural circumstance in which they act*" (Billet, 1996, p. 265), and for building bridges between them. Even though both perspectives deal with the construction of knowledge, the cognitive constructivist perspective emphasizes the internal processes of knowledge construction, whereas the socio-cultural perspective focuses on children's cognitive development, as it occurs through social interaction, and details the negotiated nature of the reciprocal transformation with social partners. Thus, language, in the socio-cultural perspective, is considered essential in socially negotiating and constructing meaning. The widening interest in "*situated learning*" resides in the belief that learning is more closely linked to the circumstances of its acquisition, and that these circumstances influence the transfer of knowledge to other situations. This belief calls for a closer consideration of the contributions of socio-cultural constructivism in understanding the role of social transactions in shaping cognition and the complexities of the situated knowledge of the classroom.

Although the relationship between social circumstances and cognition remains opaque, our approach accepts the potential contribution of both perspectives to the construction of knowledge, and attempts to investigate how carefully designed individual or classroom-based discourse supports students' conceptual growth. The attempt aims at providing students with the opportunity to be involved in experimentation and discussions, or evidence-based argumentation, for the purpose of examining how the knowledge construction process is shaped and validated by students' interactions amongst them, the teacher, and the physical environment.

Didactical approach

The present training material is an attempt to familiarize primary school teachers, lower secondary school teachers, and prospective teachers for primary and lower secondary school with the basic assumptions of the *socio-cognitive perspective* of learning. The training material is also an attempt to provide a concrete example of teaching / learning, using a *sinking / floating scenario*. Thus, the training material represents an attempt to teach the different concepts regarding sinking/floating, using the described theoretical framework and involving the learners in an inquiry process (active learning/learning by doing). This approach focuses on the learners' initial conceptions and how to promote conceptual change. Within this framework, different ways for identifying learners' alternative conceptions and factors (cognitive and affective) affecting conceptual change are considered very important. Consequently, the learning environment should also encourage rich interactions among the learners and between the teacher and the group of learners.

Structure of training material

The training material entitled "Floating and Sinking of an Object in a Liquid - Based on Socio-cognitive Constructivism" is not divided into units. The content of the training material relates to the different factors affecting the sinking / floating of an object in a liquid. This content can be easily used for primary and lower secondary school students, and it takes into consideration that all, or some of, the students remain concrete thinkers and cannot use abstract concepts. It is thus important to provide observable evidence to the students that challenges their existing conceptions.

Summing-up

The aim of this article was to analyze and compare 5 different training materials for prospective science students prepared during international project "IQST" implementation. Lithuanian, Czech, Turkish, Bulgarian and Cyprus training materials were discussed and compared. Training materials of five countries were analyzed in comparison with Constructivism theory. The analysis of training materials was important because it allows further development and progress of university study programms in science education. On the basis of the preliminary observations we can state that all training materials are useful in the university teaching process. We hope that all training materials prepared during the project implementation will assist students, lecturers and administrators in their work. All training materials are good support for prospective science teachers training programmes. Another important thing is that all training materials can be used in many different ways by students and lecturers. Some customers will be able to point their users directly to our project website, others will be able to integrate the material with their own website or learning environment. Finally, we hope, that all users of these training materials will be able to match the different learning styles of prospective science students to really help them succeed.

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