CONSTRUCTIVISM IN SCIENCE TEACHER EDUCATION

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Abstract

The constructivist perspective is becoming a dominant paradigm in the field of the science education. This approach in the initial science teacher training is not still too common at many European teacher training institutions. In this article the constructivist approach in science teacher training is described. Science teacher training in five science teacher training institutions in five European countries (Bulgaria, Czech Republic, Cyprus, Lithuania and Turkey) is compared in this article. These countries cooperate on the project which in the main goal is to implement constructivist approach in science teacher training.
Key words: *science teacher training, teacher training institution, science education, constructivism, constructivist approach.*

Introduction

The constructivist perspective is becoming a dominant paradigm in the field of the science 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 five European countries (Bulgaria, Czech Republic, Cyprus, Lithuania and Turkey) cooperate on the Project IQST Improving Quality of Science Teacher Training in European Cooperation – constructivist approach (under the framework Socrates – Comenius 2.1 programme of the European Commission).

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.

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.

An important task of science education is making science more relevant to students, more easily learned and remembered, and more reflective of the actual practice of science. Science education in EU has many proposals how to improve quality of science education. The science teacher training is very important part for the future quality of science education. Students should be taught in ways that they recognize knowledge as a powerful means for solving problems and that it can be useful also in everyday life. Therefore learning and instruction should be anchored in meaningful situations and connected with important events (Brandsford et al., 1990).

Science teacher training has to provide new frameworks to pre-service teachers and to seriously consider new teaching practices. New perspectives on teaching tend to conflict with the pre-service teachers' previous and dearly held conceptions of teaching. Every pre-service teacher is itself an insider concerning the future profession due many years of experience as a student in school. Therefore, any implementation of new teaching strategies tends to face conflict. However, changing teaching practices at any point of a teacher career is a difficult and stressful process due to complex social and intellectual frameworks that both enable and constrain efforts to change. However, the pre-service training as an individual struggle period for an formation of an own professional identity as a particular kind of teacher might provide the most likely time period to achieve the higher quality of science education. In all cooperating countries teacher training is in the process of transition and most turbulent, but interesting times, with new challenges seem to be ahead.

Constructivist Teacher Education: Theory and Practice

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. It is a reason why a group of science teacher educators from five European countries (BG, CY, CZ, LT and TR) focused on this topic.

Science Education Research has shown the existence of striking differences between the goals of curriculum developers and what teachers actually practice (Cronin-Jones 1991). Those differences have called attention to the influence teachers exert in the implementation of science curricula in high schools. The issue is a major one in a field such as for instance physics that foresees drastic curricular changes (some of which have already been implemented) on this level. On the other hand, there is a high percentage of students who fail in physics and students' negative attitudes towards science and science learning grow steadily (Yager and Penick 1985).

Those results have broken simplistic views about science teaching as an activity which demands just a sound scientific knowledge and some experience. In other words, those results have made clear that teacher training can not be reduced to just scientific courses, as it has been usually. A possible solution which has been tried in many countries is to complement the scientific courses with other courses about Education. Which are the results of this orientation?

As McDermott (1990) has shown, university physics courses generally do not provide the type of preparation that teachers should have:

- the lecture format of the classes stimulates passive learning; the prospective teachers are more accustomed to receiving than to imparting knowledge;
- the standard problems developed in the classroom lead to algorithmic, repetitive, solutions, and fail to stimulate the type of reasoning necessary to approach new situations such as unforeseen issues that students may raise;
- laboratory work calls for sophisticated material not available in secondary schools, and above all, it is restricted to mere verification, like cooking recipes, which gives a reductionist and distorted view of scientific activity.

On the other hand, courses on Education are totally separated from instruction in content, and teachers can not see the interest of those courses in the treatment of their specific teaching and learning problems. No one questions the need for teachers to have in-depth knowledge of what they are to teach. It may seem superfluous to state this point if we take into consideration that, in many countries, teacher training is virtually limited to science courses plus some pedagogical disciplines (Carvalho and Vianna, 1988).

Recent research in science education shows that teachers have ideas, attitudes, and behaviors related to science teaching based on a lengthy „environmental" training period - the period in which they themselves were students (Hewson and Hewson, 1988). The influence of this incidental training is enormous because it corresponds to reiterated experiences acquired in a non-reflexive manner as something natural, thus escaping criticism. In fact, as Bell and Pearson (1992) have pointed out, it is not possible to change what teachers and students do in the classroom without transforming their epistemology, their conceptions about how knowledge is constructed, their views about science.

We have to refer here mainly to the constructivist approach, which is considered today as the most outstanding contribution to science education over the last decades (Gruender and Tobin 1991, Moutmer 1995), integrating many research findings. Educators need to understand, very particularly, that:

- Students can not be considered as ‚tabula rasa', They have *preconceptions* or 'alternative frameworks' which play an essential role in their learning process (Viennot 1979, Driver 1986), obliging guiding science learning as a 'conceptual change' (Posner et al 1982) or, better, as a conceptual and epistemological change (Gil and Carrascosa 1990, Dusch and Gitones 1991);
- A meaningful learning demands that students *construct their knowledge*;
- To construct knowledge students need to deal with problematic situations which may interest them;
- The construction of scientific knowledge is a social product associated with the existence of many scientist teams; this suggests organizing students in small groups and facilitating the interactions between these groups (Wheatley 1991) and the scientific community, represented by the teacher, by texts, etc;
- The construction of scientific knowledge has axiological commitments: we cannot expect, for instance, that students will become involved in a research activity in an atmosphere of 'police control' (Briscoe 1991).

The most important thing is that all these contributions constitute related components of an integrated body of knowledge which is generating the emergence of a constructivist teaching/learning model, capable of displacing the usual transmission/reception one.

We have already referred to the ineffectiveness of simple transmission of knowledge, through manuals or courses, in the training of teachers. Such procedures have failed to prepare teachers for new, constructivist oriented, curricula (Briscoe 1991). For many, this constituted an unpleasant surprise: How is it possible that motivated teachers, who participated voluntarily in seminars and courses with the intent of mastering new methods and renewing their teaching, go on teaching as they have always done adapting the innovations to the traditional ways? Teachers themselves are frustrated when they have to affirm that things do not work better than formerly, despite the innovations. This ineffectiveness of the simple transmission means that other strategies of training are required. Investigations into the learning of science provide valuable suggestions of what these strategies might be.

Teachers, like students, have preconceptions. Just as pupils' learning of science is conceived of as conceptual, epistemological and attitudinal change, so should teachers' learning of didactics. Teachers' knowledge, like students', must build on the previous knowledge they have. There is a close parallel between how change occurs in conceptions of science and how it occurs in conceptions of teaching.

There should not, however, be a mechanical transfer of strategies used with pupils. Constructivist theory led to some teaching strategies and addressed conceptual change explicitly and directly. Driver and Oldham (1986) summarized such strategies as sequences of 1) identifying pupils' ideas; 2) questioning those ideas, using confronting examples to produce cognitive conflicts; 3) introducing concepts elaborated by scientists, that resolve the conflicts; and 4) using the new ideas in various contexts to promote their full assimilation. If a similar procedure were applied in teacher training, we would elicit beliefs about teaching and learning, then create cognitive conflicts to prepare the teachers for new conceptions, which they would have to be shown are effective in practice.

Such a procedure can quickly produce positive results, as it relies on common sense ideas that many accept uncritically as evidence. After the first impact, however, it becomes an "evil" strategy. What is the consequence of having teachers make explicit their ideas and then questioning their validity? It generates a reserve that inhibits the desired change. In the same way, this argument allowed us to appreciate that the strategy is inadequate for changing pupils' conceptions of science (Gil et al. 1991; Gil & Carrascosa 1985, 1990, 1994), although with pupils the resistance to systematic questioning of their conceptions is not so obvious. There is another reason why such strategies can inhibit construction of knowledge. They focus on problems, in which prior knowledge and new ideas are brought together in a tentative way. In this process the initial conceptions might suffer change or even be questioned radically, but this is not the immediate objective - that remains the solution of the problem that has been posed.

This raises an issue concerning the cognitive conflicts: they will not mean an external questioning of the personal conceptions, nor the systematic recognition of the insufficiencies of one's own reasoning, with its consequent affective implications, but a confrontation of personal ideas, taken as hypotheses, with other hypotheses, as personal as preceding ones. We do not propose to eliminate the cognitive conflicts, but to prevent them from appearing as a confrontation between the personal wrong ideas and the scientific correct ones. Besides, it is important to take into account that the study of preconceptions has aimed, so far, to detect what pupils, and, now, teachers too, answer in an immediate reply to certain questions; more important than that is what they should have answered if they would have time to reflect critically. Actually, if a collective work of certain depth is facilitated, teachers and pupils are able to question those conceptions uncritically assumed and to construct knowledge consistent with that accepted by the scientific community.

The foregoing considerations suggest that a more fruitful strategy for teacher change consists in involving teachers and prospective science teachers in research in their own classrooms into teaching and learning of science. In this, teachers might be major members of autonomous teams involving researchers and innovators in the teaching of science. Such a strategy would have the following characteristics:

- Be conceived in an intimate connection *with the teaching practice itself,* as treatment of the teaching/learning problems posed by such practice.
- Oriented to favour the *experiencing* of innovating proposals and explicit teaching reflection, questioning "spontaneous" teaching reasoning and behavior, that is, questioning the "natural" character of "what has always been done".
- Incorporate teachers to the investigation and innovation in science teaching.
- Involve them in the construction of the specific knowledge body of science teaching and incorporate them to the scientific community in this field.

Constructivist teacher education is defined as working with teachers in a constructivist way, helping them to re-examine and reflect about the tacit ideas they bring to their education for science teaching. Two quite different forms of constructivist teacher education are being advocated: to teach students how to teach in a particular constructivist manner and how to apply these approaches to the teaching of particular subject matters. The challenge for constructivist teacher educators is to develop an approach to teaching that does not contradict the content of the course – that is, constructivist teaching – but acknowledges differences in the nature of constructivist teaching depending on the subject matter that is being taught.

The philosophy of science is a special informant about the nature of constructivism. Much of scientific knowledge consists not merely on the phenomena of nature, but also on the constructs advanced by the scientific community to interpret and explain nature. Constructivism is a way of thinking about the events of teaching and learning.

Structure of Science Teacher Education

The structure of the science teacher education programs has usually two parts:

1. Subject knowledge: academic studies in the license subjects;

2. Professional subjects: educational studies, professional studies, school practice.

Depending on whether the same institution is responsible for both academic training and the professional preparation of teachers, two basic models of program structure can be distinguished:

1. Two phases model of teacher training: There is a distinction between theory (what is taught at the University) and practice (what is taught by practitioners). The professional preparation is often provided by special institutes outside the university.
2. All programs contain both academic studies in one or more subjects and professional studies. Here the curriculum organization comes in three types:
    - An integrated program, which means that academic and professional studies are to a large extent integrated.
    - A parallel or concurrent program, which means that academic and professional studies are taking place concurrently.
    - A consecutive program, which means that at first academic studies are completed and then followed by the professional studies.

Content

The program prepares candidates to structure and interpret the concepts, ideas and relationships in science that are needed to advance student learning in the area of constructivist teachers. Content refers to:

- Concepts and principles understood through science.
- Concepts and relationships unifying science domains.
- Processes of investigation in a science discipline.
- Applications of constructivism in science teaching.

Knowledge is a conceptual model through which the individual makes sense of the world (Sternberg, 1985). Shulman (1986) identifies three dimensions of professional knowledge important to the teacher: content, or subject matter knowledge; pedagogical content knowledge; and curricular knowledge. Content knowledge consists of the concepts and relationships constructed through professional investigations in the natural sciences, and the processes of scientific investigation.

Constructivism emerged from the realization that pre-existing knowledge influences the way new knowledge is added to the individual's conceptual model, modifying its subsequent meaning (Stahl, 1991). Educators increasingly understand that private knowledge - the true conceptual framework of the individual - may differ considerably from the public knowledge of science. Therefore the goals of formal education have shifted from the relatively straightforward process of transmitting information to the more complex task of facilitating development of a meaningful conceptual framework (Brophy, 1992).

Stalheim-Smith and Scharmann (1996) and Stoddart et al. (1993) found that the use of constructivist teaching methodologies and learning cycles-methods often emphasizing concrete learning-can improve the learning of science by candidates in science education. A second major problem in many courses taught traditionally is their emphasis on rapidly learning large amounts of un-integrated factual information. Major concepts are poorly delineated from less important concepts, and few concepts are learned in depth. This is in contrast with an approach in which fewer, well-selected integrating concepts are carefully linked to form a framework for further learning. A third problem lies in the division of knowledge, for convenience, into disciplines and fields. Such divisions may constrain the development of linkages among concepts across fields and so inhibit the development of an integrated cognitive model.

The content knowledge of the prospective science teacher is developed primarily in science courses taught by science faculty. Assigning the development of the skills and knowledge required to one or even several science methods courses is unlikely to produce the depth of understanding needed for effective teaching practice. All science teacher candidates should be provided with a carefully designed, balanced content curriculum leading to a demonstrated knowledge of the concepts and relationships they are preparing to teach. To the greatest extent possible, science content should be taught in the context of investigation. Opportunities should be provided for all constructivist science teacher candidates to participate in a range of laboratory and field investigations, and to complete one or more projects in which they design and carry out open-ended, inquiry research and report the results.

In the constructivist science teacher preparation programs, content is integrated with pedagogy and includes considerable laboratory instruction, including inquiry. There is a clear justified rationale for selection of content based on a careful analysis the needs of practicing teachers. These programs integrate science instruction across fields and prepare candidates with a broad unified science background, in addition to specific preparation. In the best programs, science instruction includes deliberately planned linkages among related concepts in chemistry, physics and biology. Experiences with the analysis and interpretation of data are regularly provided in content courses, as are opportunities for engaging in conceptual development through open-ended inquiry and research in the context of science (rather than science education). The best programs develop a variety of science-related skills, engaging students in active science learning in a variety of contexts. Candidates from these programs have a demonstrably strong conceptual framework in science grounded in experience, are confident in conducting research and inquiry, and can collect and interpret data meaningfully.

Science teacher preparation is described very widely. It is necessary that new science teachers gain applicable knowledge and appreciation of each of the aspects of science teaching with competencies of constructivist science teacher. Without competency in and subscription to constructivist science teachers, new teachers will not successfully teach all students for understanding and application utilizing a broad vision of science. We believe a constructivist model better reflects the challenges and consequences involved in science teaching.

Science Teacher Training in Cooperating Countries

To compare science teacher training in the five cooperating countries (BG, CY, CZ, LT, TR) is not so easy because of all existing cultural differences. To summarize approaches to the science teacher education three sets of variables are of importance:

Context variables, representing the influence on teacher training of the educational system, as its customer, and of the educational policies in the cooperating countries.

Institutional variables, representing the various aspects of the institutional constraints of the teacher training programs.

Curriculum variables, representing the various aspects of the content of the science teacher training program.

Context variables

In cooperating countries a little bit different educational systems exist that influence teacher education in that countries. Generally, systems in these countries (Improving Quality of Science Teacher Training in European Cooperation – constructivist approach. Compendium, 2007) have primary, lower and upper secondary levels. The systems differ from the length of the levels. Primary education takes 4 (BG, CY, LT) to -5 (CZ, TR) years. There is a different training for primary and secondary science teachers in all cooperating institutions. Some of the cooperating institutions are more focused on the primary science teacher training (CY, LT, TR), others on lower secondary science teacher training (LT, TR) and the next on upper secondary science teacher training (CZ). In all these countries governmental control over the science teacher exist. In the context of science teacher training the various types of decision-making, however, become most evident in the extent of governmental influence on decisions with respect to:

a. The control over the admission to teacher training.
b. The control over the curriculum and the qualification.

In all these countries science teacher training is a part of higher education, a secondary general education diploma is the minimum entrance requirement. With the respect to the control over the curriculum and the qualification of science teachers, there are a little bit different models, but common for all cooperating countries is that government controls the curriculum through state examination and accreditation.

Institutional variables

These variables concern:

- The course length.
- The structure of the training program.

In primary teacher training the length differs between 3 (CY) to 4 (BG, LT, TR) and 5 (CZ) years. The teachers are trained mostly in schools of education (pedagogical faculties (BG, CY, CZ, TR) or pedagogical faculty and colleges (LT) which are part of universities. The course length of the science teacher training of lower and upper secondary school varies from 4 (CY, LT, TR) to 5 years (BG, CZ). All participating institutions implemented credit systems (ECTS).

The programs contain both academic studies and professional studies in all participating institutions. The integrated program, which means that academic and professional studies are to a large extent integrated, is realized in primary science teacher training in all five countries. A parallel or concurrent program, which means that academic and professional studies take place concurrently, is most frequent for participating institutions in CY, LT and TR. A consecutive program, which means that at first academic studies are completed and then followed by the professional studies, was implemented in CZ and BG recently. For instance in CZ (Faculty of Science) prospective science teachers at upper secondary schools finish bachelor degree in academic subjects. Then students can continue with academic studies in two subjects and professional studies to earn master degree. The subject combination of specialists depends on their choice at the beginning of the study and can be selected from a list of combinations or from a list of individual subjects set by the faculty.

Content variables

In all cooperating countries the curricula for the science teacher training contain subject-knowledge (academic studies) and three components of professional preparation: educational theory, didactics of the subjects and school practice. In CY, LT and TR the professional preparation is more stressed while in BG and CZ subject-knowledge is more important. In educational theory such topics as child psychology, learning psychology, philosophy of education, history of education, general didactics, culture of mother tongue, educational management, foreign languages is possible to find. The curriculum is strongly focused on the ICT using in all participating institutions. The topic of constructivism is implemented only in the curriculum in CY. Didactics of the subjects are focused on the problems how to teach science at school (teaching methods, school curriculum, methodology, research in schools, communication in sciences, planning of lessons, choice and preparation of materials, techniques of presentation, methods of assessment, classroom management, labs in sciences). School practice is a series of structured learning situations in schools, designed for prospective science teachers, in which they are confronted with concrete teaching and classroom management activities on a systematic basis, supervised by a cooperating teachers in schools. There is different length (but 6 weeks at least) of teaching practice in cooperating institution in the project.

Conslusion

In the institutions participating in the IQST project the different approaches of science teacher education are possible to recognize. On the other side these institutions have nearly the same problems: lack of prospective science teacher and strong common interest how to improve the quality of science teacher training. One of the possible ways is to implement constructivist theory to science teacher training. In all participating institutions would be 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. All cooperating institutions are willing and able to alter the structure of their programs to improve the quality of science teachers within their national contexts. One of the more significant challenges facing all countries is the not only the quality but the quantity of science teachers. Unfortunately, the new approaches to the contain of the programs does not seem to influence the decision by students to become science teachers. All science teacher training programs still need more students. In all institutions we believe that science teacher preparation will be able to meet confidently the challenges of the 21st century.

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