

New Factors in Teacher Training in Innovative Educational Methods Focusing on Inquiry-Based Science Education

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ABSTRACT

The effectiveness of teacher training, which is influenced by many limiting factors, is a significant issue when improving the quality of teacher preparation for new challenges in current and future education. The study is devoted to research into new limiting factors and methods for overcoming these factors in science teacher education. This research was carried out within the framework of teacher CPD courses within the PROFILES project aimed at the implementation of inquiry-based science education. Design-based research was the basic framework, with the use of specific research methods such as a curricular Delphi study, Kirton's Adaptation-Innovation Inventory, a case study, structured observation, a questionnaire, structured interviews, and analysis of teachers' products. The research sample consisted of science teachers from secondary schools, who were researched over the years 2012-2015. The main research outcome is determination of new limiting factors of the effectiveness of teacher training in inquiry-based science education: creativity styles of teachers, adult learning styles of teachers, and individual education of teachers. Teacher constructivism and motivation are the bases of the developed method for overcoming these limiting factors.

Keywords. Effectiveness, Inquiry-based Science Education, Limiting Factors, Teacher Training.

1. INTRODUCTION

Teacher training in innovative educational methods is the subject of many projects and other activities directed towards teacher continuous professional development (hereinafter CPD). A lot of innovative curricular materials are also available for teachers on websites for self-study. The effectiveness of this teacher training is an important issue which should be a priority for investigation.

Two main goals of this study are determination of new factors limiting the effectiveness of teacher training in inquiry-based science education (hereinafter IBSE) and the development of teacher educational methods for overcoming these limiting factors. The research on the effectiveness of teacher training was conducted in training courses on the implementation of IBSE within the project PROFILES (Professional Reflection-

Oriented Focus on Inquiry-based Learning and Education through Science) funded by the FP7 programme of the European Commission [29].

2. RATIONALE

The attitude of teachers towards CPD courses is affected by their beliefs. Teachers' beliefs are strongly influenced by their experience acquired as learners ([27], [24]). Teachers therefore subconsciously prefer to teach in the way they have been taught throughout their schooling to the way in which they have been trained in pre-service teacher education and in-service teacher CPD courses. Many studies ([20], [28], [31] and [33]) justify the close relationship between teachers' beliefs and their classroom practice. It is not possible to easily change teachers' beliefs to favour innovative educational methods. The inertia of their beliefs is very steady [31]. A group of teachers was monitored for four years after their teacher training to see if they implemented innovative teaching methods which they had acquired in teacher training. Most of them quickly reduced the frequency of implementation of these new teaching methods and went back to those ones used before their teacher training ([9], [13]).

A very important factor influencing the changes in teacher beliefs are the design and content of a teacher training course. To accept changes, teachers need to be not only theoretically familiar with an innovative method, but they also need to test it in their classroom practice. The gap between teacher training (theory) and teaching practice is a significant issue that limits the development of teacher professional competences [18]. The problem is that teacher training courses are often relatively short, with only a few hours of workshops, and follow-up activities. Such training courses have a chance of succeeding with teachers whose beliefs match the assumptions inherent in the presented innovative educational methods. Teacher training is usually successful in only about 15 percent of cases [23]. A further factor that can change teachers' beliefs is teamwork in training, which has an impact on their beliefs through close discussions with colleagues [33].

Many studies call for greater effectiveness of teacher training and also for the limiting factors to be overcome. These already known relevant limiting factors are:

- the short period of time of a teacher training course
- inappropriate content of the course
- inappropriate design of the course
- bad interconnection of course content with the experience of teachers from classroom practice
- non-systematic approach in the course
- gap between educational theory and classroom practice

Experience and previous research [40] confirmed that during teacher training in innovative educational methods, new, thus far unnoticed factors emerge and significantly affect the effectiveness of teacher CPD. These new limiting factors are teacher characteristics such as:

- creativity
- motivation
- ownership
- ICT competences

Some factors newly emerge, while others gradually gain in importance. It is necessary to take these new issues into account to increase the effectiveness of teacher training. After determination of the factors limiting an increase in the effectiveness of teacher training it is necessary to develop teacher educational methods for overcoming these limiting factors. It is also necessary to pay attention to the way in which teachers are trained, as research findings show that teachers are especially reluctant to accept changes in teaching methods and curricula which are forced on them by administrators and/or policy-makers [24].

IBSE is an appropriate innovative method in science education, based on constructivism. IBSE was based on a deep understanding of the process of science learning. The literature describes the characteristics of IBSE in detail ([3], [2]). The core principles of IBSE are the involvement of students in discovering natural laws, linking information into a meaningful context, developing critical thinking and promoting positive attitudes towards science [14]. IBSE seems to be a suitable method to encourage the interest of students in science education. The four IBSE levels (confirmation, structured, guided and open levels) are defined by the degree to which the teacher helps, asks questions and formulates the expected results [2]. It is important for IBSE, which is based on constructivism, that science teachers build up their pedagogical content knowledge, skills and competences using their own experience from teaching and thus connecting pedagogical theory and classroom practice, which can be defined as teacher constructivism [22].

3. RESEARCH QUESTIONS, SAMPLE AND METHODOLOGY

This study attempted to solve the research problem of how to determinate new factors limiting an increase in the effectiveness of teacher education and how to develop teacher educational methods for overcoming these limiting factors. The research questions were phrased as follows:

- (1) Which new factors limit an increase in the effectiveness of teacher training in IBSE as a part of teacher CPD?
- (2) Which methods are appropriate for overcoming new limiting factors?

This research was carried out under the PROFILES project, which was aimed at teacher training with the educational

method IBSE as an important innovation in STEM (Science, Technology, Engineering and Mathematics) education [4].

The choice of design-based research (hereinafter DBR) as the basic research strategy was justified by its close connection between DBR and school practice and its developmental nature [32]. DBR can be described as a cycle: analysis of a practical problem, development of solutions, evaluation and testing of solutions in practice, and reflection on and production of new design principles:

- (1) Analysis of practical problems: identification of new limiting factors for teacher training in IBSE implementation.
- (2) Development of solutions: analysis of new limiting factors and determination of their positive and negative impacts on CPD; development of methods for overcoming the negative effects of new limiting factors in IBSE implementation.
- (3) Evaluation and testing of solutions in practice: testing and evaluation of the adapted teacher training courses containing the methods for overcoming the negative effects of new limiting factors in IBSE implementation.
- (4) Documentation and reflection to produce new design principles: determination of characteristics of the new limiting factors and the methods for overcoming them.

In the frame of DBR a combination of specific research methods were used, such as a curricular Delphi study, Kirton's Adaptation-Innovation Inventory, a case study, structured observation, a questionnaire, structured interviews, and analysis of teachers' products.

The research sample consisted of fifty Czech science (physics, biology, chemistry) teachers from secondary schools who were teacher-participants in the PROFILES project (see Tab. 1). This sample was investigated over the years 2012-2015.

Table 1. Sample selection of teachers-participants in the PROFILES CPD programme

Subject taught	N	Gender of teachers	N	Teaching experience of teachers (in years)	N
Total	50		50		50
Physics	16	F	41	0-5	6
Chemistry	16	M	9	5-15	19
Biology	18			More than 15	25

These teachers were chosen not randomly, but on the basis of their interest in being involved in the project. More data and a detailed description of the PROFILES project can be found in [29].

4. RESULTS

This research yielded many results, from which the core outcomes of the fourth DBR step were collected: determination of the characteristics of the new limiting factors and the methods for overcoming them. These research results are divided into two parts: new and increasingly limiting factors and methods of overcoming the limiting factors.

4.1 New and increasingly limiting factors

The study confirms a presumption about a topical issue, which is new and increasingly limiting factors in teacher CPD. In the first stage of DBR, using the curricular Delphi study, were

identified the expectations of STEM education stakeholders (students, teachers, teacher educators and scientists) in the form of comparison of their priorities for the future and the experience of the present stage at schools [38]. Comparison of these stakeholders' priorities (wishes) with the reality of teaching/learning in schools demonstrates that there are unnoticed factors blocking the transmission of educational innovations from teacher training into school practice. Three new significant factors have been found in the second and third stages of DBR research: creativity styles of teachers, adult learning styles of teachers and individual education of teachers.

4.1.1 Creativity styles of teachers: Teacher creativity is a significant factor in education ([6], [1], [21], [35] and [41]) and also in the development of teacher professional competences. The most important characteristics of creativity are that it can be developed ([12], [36]) and that everyone has the potential to be creative ([10], [11] and [25]). Creativity styles are based on cognitive styles, described by the Adaptation-Innovation theory [15]. The creativity style is a personality characteristic, which is relatively stable over time [15]. Kirton's Adaptation-Innovation inventory (hereinafter KAI) is a diagnostic instrument for the measurement of differences in creativity styles [16]. According to the KAI points individuals are divided into two groups: adaptors and innovators [15]. An individual can be located on a continuum ranging from highly adaptive to highly innovative. Innovators prefer to do things differently and bring radical solutions to problems. Adaptors improve things while working within the given structure, with personal characteristics such as precision, reliability, discipline and conformity. Innovators "do things differently" and adaptors "do things better" [30]. Individuals have both styles; however, each of us prefers one style to the other. Each style has its own strengths and weaknesses. One style is not better than the other; both styles are useful.

The important outcome of DBR was determination of the characteristics of teacher creative styles meaning that teacher training courses have to accept teacher creativity styles.

- **Differences in cognitive styles:** The main reason why creativity styles affect teacher training courses is the significant difference in the cognitive styles of the two groups - adaptors and innovators. These two distinct groups of teachers have different special educational needs and characteristics:

Adaptors: precision, reliability, seen as disciplined; concerned with resolving problems rather than finding them.

Innovators: undisciplined, unpredictable, approaching tasks from unsuspected angles.

- **Different cooperation:** Teachers-adaptors and teachers-innovators collaborate with difficulty in learning teams, which is a source of potential interpersonal conflicts:

Adaptors: more loyal, provide stability, order, sensitive to people, cooperation.

Innovators: less respect for others' views, provide task orientations, insensitive to people, often threatening cooperation.

- **Different communication with the lecturer:** Communication with lecturers of teacher training courses has a different shape in the case of teachers-adaptors and teachers-innovators. The implementation of the teacher training course basically depends on the professionalism and personality of the lecturer:

Adaptors: conformity; vulnerable to authority; compliant.

Innovators: take control in unstructured situations, lack of consensus, face opposition.

- **The difference in the potential for dissemination of knowledge:** teachers-innovators have greater potential to disseminate competences acquired in the teacher training course among other teachers out of the course:

Adaptors: adopt ego avoidance orientation.

Innovators: adopt mastery goal orientation.

These research results confirmed the advisability of examining the impact of teacher creativity styles in the implementation of their education, including teacher CPD. This DBR of teacher creativity styles confirmed that teacher training courses should be adapted to the creative style of teachers.

4.1.2 Adult learning style of teachers: One of the main weaknesses of teacher CPD is lack of respect for the principles of adult learning (a part of andragogy). It is necessary to know and remove barriers which teachers as adult learners have to participating in their education. When preparing the teacher training course it is necessary to take into account that it is necessary to respect the learning principles of andragogy. The Canadian Literacy and Learning Network [5] has classified a set of rules of adult learning which distinguish adult learners from children. The DBR analysis of teacher training courses resulted in these rules:

- **Adults cannot be made to learn. They will only learn when they are internally motivated to do so.** The teacher whose aim is teaching others accepts being educated by someone else with difficulty. Emotionally they are often set negatively against the lecturers with a high degree of subjective criticality. The reason is that teachers enter a training course often by external social motivation (e.g. to improve qualifications), which may be positive but also negative. It is necessary to design training courses where the teacher is motivated by internal cognitive motivation, i.e. by interest in an increase in his/her competencies.

Preventing this problem: The teacher-participants should be selected on the basis of interest (intrinsic motivation). Their external social motivation should be minimized.

- **Adults will only learn what they feel they need to learn. In other words, they are practical.** The education of today's NET-generation of students [26] brings teachers a number of problems, the biggest of which is the lack of motivation of students in learning using traditional methods. Therefore teachers look for innovative teaching/learning methods and tools.

Preventing this problem: The content of the teacher training courses should be very pragmatic and the teachers-participants are encouraged to use action research for testing innovative educational methods.

- **Adults learn by doing. Active participation is especially important to adult learners in comparison with children.**

In teacher training courses teachers were spontaneously interested in being actively engaged in the presented activities and testing them using their own experiences in classroom practice. They were also willing to participate in the modification of these methods and tools.

Preventing this problem: The activity of teacher-participants should be an essential pre-condition for their participation in the project.

- **Adult learning is problem-based and these problems must be realistic. Adult learners like finding solutions to problems.** Solving practical problems is one of the main motives for participation of teachers in the training course.

Preventing this problem: The creativity of teachers should be significantly expressed [39].

- **Adult learning is affected by the experience each adult brings.** To achieve the desired outcomes the experience of teachers was the basic source of many alternative solutions and ideas. Teachers' wrong beliefs caused complications.

Preventing this problem: The teachers-participants should have had sufficient experience (practice) of teaching in schools.

- **Adults learn best informally. Adults learn what they feel they need to know whereas children learn from a curriculum.** Quality teacher training courses have a formal part; however, they should also incorporate the informal part, which is especially collaboration and exchange of ideas between teachers and between teachers and lecturers.

Preventing this problem: The informal part of education should be an integral part of the training course.

- **Children want guidance. Adults want information that will help them improve their situation or that of their children.** The training course leaders' guidance of teachers must be sensitive and high quality. Course leaders and lecturers should be more mentors or partners than instructors.

Preventing this problem: The course leaders and lecturers should be chosen and prepared very carefully; the best teacher-participants became lecturers in future training courses.

4.1.3 Individual education of teachers: An individual approach to students is currently implemented in teaching/learning. But this aspect is not usually considered in the preparation of teachers in their training courses. However, teachers-participants in teaching training courses are people with individual needs and different educational backgrounds. They have different learning styles, but the strategy of teacher training tends to be uniform and not to take these into consideration. Therefore, the individual approach for teachers in teacher training courses is necessary. The main individual characteristics influencing teacher education in CPD are presented below:

- **Social competence of teachers:** This influences teachers to interact constructively with the co-participants of a training course and with the lecturer, and it shapes their feelings and motivation connected with a training course. This characteristic is very important for teamwork and leadership. When creating a team, it is important to respect the specificities of the participants and possibly to allow them to work individually if they have problems with teamwork. Also, the leadership of the team should be based on social competence. Social competence is connected with styles of creativity, as mentioned above.
- **Learning styles of teachers-participants and teaching styles of lecturers:** Each individual has their own personal learning style which is connected with their personal characteristics and abilities. For example, according to the Kolb Learning Style Inventory [17] it is possible to distinguish four learning styles (diverging, assimilating, converging, and accommodating). Similarly, there are many teaching styles (methods or strategies). Most of the learning and teaching style components are parallel to one another. There could be mismatches between the learning styles of the learners (participants) and the teaching styles of the lecturers. To be successful, the lecturer should detect the learning styles of the teachers-participants, their preferences and needs and manage the training courses with respect to them.
- **Educational background:** Teachers have different knowledge, skills and experience. It is understandable that

beginning teachers have a lack of experience, which limits their professional competences. Lecturers in teacher training courses should implement different approaches depending on the other teachers' backgrounds. It is possible to use teamwork when experienced teachers share their experience with beginning teachers.

- **Individual motivation:** The reasons for participation in training courses are different. Motivation could be intrinsic (interest in issue, effort to educate, etc.) or extrinsic (the need for upgrading professional competences, which are forced by school management, etc.). As in the education of children it is necessary to foster the interest of teachers using motivational methods to transform extrinsic motivation into intrinsic.
- **NET-generation of teachers:** This characteristic may be a source of mismatches between teachers-participants of a different generation. Many young teachers are already members of the NET-generation, sometimes called generations X, Y or Z. Members of the NET-generation have other personal characteristics including learning styles [26]. It is also necessary to take into account "connectivism: a learning theory for a digital age" [34]. Educational strategies implemented in the education of "NET-teachers" have to respect these aspects. The most suitable method for teacher training courses is to use different sources of information and to implement an appropriate level of ICT with regard to teachers-participants' abilities and needs.

4.2 Methods of overcoming the limiting factors

The answer to the second research question, which seeks appropriate methods for overcoming limiting factors, is not easy. It is necessary to overcome this problem. The experience of teachers from their everyday teaching strongly influences their real beliefs about teaching/learning methods. By this principle, DBR suggested a possible solution to this problem. This solution is based on two core methods that can successfully increase the effectiveness of teacher education by suppressing the limiting factors. These two methods are motivation of teachers and teacher constructivism.

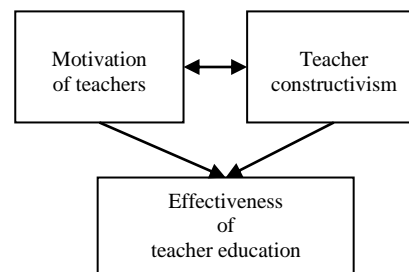


Figure 1. A diagram for overcoming limiting factors in teacher education

The diagram (see Fig. 1) shows the equivalence and mutual interaction of motivation and constructivism. These two methods must be closely linked in order to influence the effectiveness of teacher education in connection.

The first core method is the motivation of the teacher engaging in the teacher training course [19]. Teachers as adults have many responsibilities due to which they experience barriers and challenges when participating in their education. These barriers can be classified into three groups: institutional, situational, and dispositional [7]. Three specific types of motivation of students, but also of teachers in the role of learners, have been found in

education: cognitive, achievement, and social [37]. Cognitive motivation is intrinsic motivation; achievement and social are kinds of extrinsic motivation. If teacher education is induced by cognitive motivation (interest) it is an optimal situation. But very often the participation of teachers in training courses is induced by extrinsic motivation, which may be accompanied by negative emotions and lack of interest of teachers. If we want to suppress the limiting factors, the motivation should be focused on individual teachers' needs and their individual personalities. Such motivation accepts the creativity styles of teachers, the principles of adult learning, and the individual education of teachers. Through the use of action research and an analysis of teachers' portfolios in the PROFILES CPD course a strong increase in the motivation of the teacher-participants was found.

The outcome of this research is a proposal to implement teacher constructivism [22] as the second method appropriate for overcoming most of the limiting factors of teacher CPD. This means that during teaching training, teachers should be supported in building up their innovative pedagogical knowledge, skills and competences similarly to students (in constructivist learning), using their own experience and thus connecting pedagogical theory and classroom practice. Constructivism as a theory of "how people learn" is preferably applied to the education of students [8]. In the context of teacher CPD they are acting in the role of teacher-learner, so this constructivist approach in teacher education is appropriate and it is therefore possible to implement teacher constructivism. Teachers also construct their knowledge and skills through experiencing the teaching/learning of students and reflecting on those experiences [27]. Teachers compare new ideas with their previous experience (teachers' preconceptions), after which they either change their beliefs or reject these views as irrelevant. They use their own experience from classroom practice and thus they connect pedagogical theory and practice [22]. In this active formation of knowledge, skills and beliefs, teachers have to ask questions, inquire, and evaluate.

It is strongly recommended to apply these two core methods to teacher education (including training courses) in a systematic approach. The diagram shows the need to systematically link motivation and constructivism, which should operate in an integrated and simultaneous way.

5. DISCUSSION

The outcome of this DBR is the first stage of research into new limiting factors and how to overcome them in teacher CPD. The first group of these new factors was identified and a combination of methods for reducing them was then developed. It can be expected that other factors will be found, as can occur with the development of innovative educational technologies and the changing educational needs of students and teachers. Similarly, the development of other methods for reducing the influence of these factors can also be expected.

In the future, it is necessary to carry out this research on a larger number of respondents in various fields of education and also in various types of teacher CPD courses. This designed and partially verified systematic constructivist approach will require more detailed elaboration. The complexity and diversity of the systematic constructivist approach in teacher education led us to start with this approach systematically in the pre-service service

and to continue in the in-service period within systematic teacher CPD based on teachers' practical experience.

It is obvious that the diagnosis of factors limiting teacher education should become part of the planning and designing of teacher CPD courses and also the subsequent evaluation of results of these courses. Examining the issue of effectiveness of teacher CPD should be implemented not only in teacher CPD courses, but also in pre-graduate teacher education in general. It is likely that these research outcomes will find a place in adult education outside teacher education.

6. CONCLUSIONS AND IMPLICATIONS

This study tries to bridge the gap between educational theory and school teaching/learning practice in teacher education. New limiting factors in the effectiveness of teacher training in IBSE have been determined and some connected methods for overcoming these limiting factors have also been developed. It was suitable to perform this research in the context of training courses in the implementation of IBSE within the PROFILES project.

These new limiting factors have been identified: creativity styles of teachers, adult learning styles of teachers, and individual education of teachers. The developed method for overcoming the limiting factors is support of teacher motivation and teacher constructivism. It is necessary to do a more detailed analysis of these factors and the links between all elements of teacher CDP in future research. These outcomes of the research should be implemented into the education of science teachers.

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