INCLUSION OF TEACHER CONSTRUCTIVISM IN SYSTEMATIC PROFESSIONAL CONTINUOUS DEVELOPMENT

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Abstract
Teacher education and ways of improving it are key factors of educational innovations. To improve the quality of school education and lifelong learning, it is necessary to support teacher continuous professional development. The aim of the study is to present outcomes of research of innovative teacher professional continuous development courses. Design-based research was used as the main research method. A key result of the research is the finding that teacher education, including professional continuous development, has to be closely linked with practical experience through the use of a systematic and teacher constructivist approach. Constructivist principles and characteristics of teacher professional continuous development courses were studied within the PROFILES project. Building up teachers’ pedagogical competences, using their own experience from learning and teaching and thus connecting pedagogical theory and practice is the core of teacher constructivism.

Keywords: development, systematic teacher education, teacher constructivism.

1 INTRODUCTION
Many reports about innovations in education contain a number of findings and recommendations on how to solve this issue. The main aim, common to all reports, is preparing students to be a “21st century workforce”. On the basis of the contemporary situation, experts predict that teachers have to motivate and prepare students for lifelong learning and work within a situation of global economic competition [1]. There is agreement that society needs a workforce with generally high levels of STEM (Science, Technology, Engineering and Mathematics) literacy for all students, as well as a sufficient number of highly gifted individuals ([2], [3]). These reports identified core components of current education: teachers and teaching, contents and curricula, assessments, etc. Not surprisingly the emphasis in every report is highlighted in the direction of the quality teachers based on quality teacher education: pre-service, in-service and all continuous professional development (hereinafter CPD).

The quality of teachers is one of the most important factors influencing the quality and effectiveness of school education and student performance [4]. Since the mid twentieth century attention has been paid to these issues in international documents by organisations such as UNESCO and OECD. It was recommended that all teachers should have ample opportunities to improve and update their knowledge, skills and competences to be able to perform the tasks required in society [5].

But it is necessary to pay attention to the way in which teachers are trained as research findings show that teachers are reluctant to accept changes in teaching activities, practices and curricula which are forced on them by administrators and policy-makers. They persist in teaching in ways they believe in and which they have experienced as students, which is shown by the results of many studies ([6], [7], [8]). However, to replace the “old teachers’ beliefs” requires quality teacher education. The most common mistake is that teacher education (especially teacher CPD) does not respect the principles of adult learning (andragogy). It is necessary to know and remove barriers which, according to experts, teachers as adult learners have to participating in learning and continuing their education. Another important factor is that teachers build up their pedagogical knowledge, skills and competences similarly to students, using their own experience from teaching and thus connecting pedagogical theory and practice – which is known as “teacher constructivism” [9].

The above mentioned factors were respected in teacher CPD within the PROFILES project (Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science) in the European 7th Framework Programme [10]. The findings presented in this study were based on project activities aimed at teacher training in inquiry-based science education (hereinafter IBSE). One of the objectives of this project was to find an effective PROFILES CPD course in the implementation of IBSE. The authors of this study focused on research into the systematic and constructivist approach in this science teacher education. In this study the findings of their research are presented, in particular the principles and characteristics of systematic and constructivist science teacher education.
2 RATIONALES

Research findings and experience show that no educational innovation will be possible and sustained unless systematic and ongoing teacher education is provided to support the changes required in instruction [1]. But it is important to identify and to respect the factors that influence the effectiveness of this teacher education. When preparing the teacher CPD course it is necessary to take into consideration that even though the teachers are educated they are adults and it is necessary to respect the learning principles of andragogy. The Canadian Literacy and Learning Network [11] classified seven key principles of adult learning which distinguish adult learners from children and young people:

- Adults cannot be made to learn. They will only learn when they are internally motivated to do so.
- Adults will only learn what they feel they need to learn. In other words, they are practical.
- Adults learn by doing. Active participation is especially important to adult learners in comparison to children.
- Adult learning is problem-based and these problems must be realistic. Adult learners like finding solutions to problems.
- Adult learning is affected by the experience each adult brings.
- Adults learn best informally. Adults learn what they feel they need to know whereas children learn from a curriculum.
- Children want guidance. Adults want information that will help them improve their situation or that of their children.

According to the Canadian Literacy and Learning Network [11] when the principles of andragogy are followed, adult learners progress more quickly, and they are more successful in reaching the desired outcomes.

A very important factor is the motivation of the teacher engaging in the teacher CPD course [12]. 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 [13].

The results of many studies ([6], [7], [8]) substantiate the close relationship between teachers’ beliefs and their classroom practices. What is important to consider in teacher training is that teachers’ beliefs about the subject content are highly influenced by their own experiences as a student and their beliefs about the subject pedagogy are primarily influenced by their own teaching practice [7]. However, it is not easy to change teachers’ beliefs. According to [7], there is strong inertia in their beliefs. Teachers were monitored for four years after their teacher training to see whether they implemented innovative teaching methods which they had acquired into instruction. Most of them reduced the frequency of implementation of these new teaching methods with each passing year, and went back to those ones used before teacher training ([14], [15]).

Another important factor that can help change teachers’ beliefs is teamwork in education. According to Richardson [8], teachers change their attitudes towards their own beliefs more easily through discussions with colleagues.

A very important factor influencing the changes of teacher beliefs is the design and content of the teacher CPD courses. To accept changes in attitude to instruction, teachers need to be not only theoretically familiar with a method, but they also need to try it out in classroom practice. The gap between teacher education and teaching practice is a significant issue that limits the development of teacher professional competences. But teacher educational programmes are often relatively short, with only a few hours of workshops, and limited follow-up activities. Such educational programmes have a chance of succeeding with those teachers whose beliefs match the assumptions inherent in the innovation. It is estimated that such teacher education is successful in only 15 percent of cases [16].

The abovementioned and other factors may significantly affect the education of teachers, especially teacher CPD. Therefore, we established a research problem to find a teacher CPD strategy that would minimize the negative impact of these factors. We attempted to verify a premise that the appropriate strategy for teacher education (including CPD courses) is a systematic and constructivist approach. Constructivism is a well-known theory of “how people learn”. It is preferably applied to the education of
students [17]. In the context of their CPD, teachers also learn for the whole of their lives, thus acting in the role of teacher-learner. It is therefore possible to assume that constructivism can be applied to their education. Teachers also construct their knowledge and skills through experiencing the teaching/learning of students and reflecting on those experiences [18]. Teachers compare new ideas with their previous experience (teachers’ preconceptions), after which they either change their beliefs or they reject these views as irrelevant. They use their own experience from classroom practice and thus they connect pedagogical theory and practice [9]. In this active formation of knowledge, skills and beliefs teachers have to ask questions, inquire, and evaluate. It is reasonable to study if this way is appropriate for changing teachers’ attitudes to learning in CPD. But it will be a complex process, which is why it is necessary to start with this approach systematically from the pre-service to the in-service period as systematic teacher CPD is based on practical experience. The complexity and diversity of teacher education led us to the premise that it is necessary to implement systematic and constructivist teacher education, which we will look at in more detail.

3 METHODOLOGY

The research problem presented in this study was to determine and develop systematic and constructivist teacher education (including CPD) for science teachers. Many teacher education models are implemented, but often without a systematic and constructivist approach. The dynamics of teacher education are also important, as these will enable implementation of the latest research discoveries.

The study provides research outcomes which aimed to answer the research question regarding the creation of systematic and constructivist teacher education for science teachers, including school practice. The research question was: **Is it necessary to develop and to implement teacher CPD including teacher constructivism based on systematic and constructivist approach?**

Design-based research (hereinafter DBR) was used as a basic research method. DBR as a development research method is described as a cycle: (1) analysis of a practical problem, (2) development of solutions, (3) evaluation and testing of solutions in practice, and (4) reflection and production of new design principles [19]. The DBR method was applied here in these four steps:

1. Analysis of practical problems: factors and barriers in science teacher education (especially teacher CPD)
2. Development of solutions: construction of a systematic and constructivist teacher CPD course
3. Evaluation and testing of solutions in practice: testing, evaluation and modification of the systematic and constructivist teacher CPD course
4. Reflection on and production of new design principles: establishment of principles and rules of systematic and constructivist teacher education (including CPD)

Case study, structured observation, questionnaire, structured interview and analysis of teachers’ products were used as specific methods.

This research was inspired by research activities in the PROFILES project [10]. This project was based on development and implications of a teacher CPD course in IBSE. A PROFILES CPD course was developed as an appropriate specific instrument of teacher education.

The research sample consisted of 50 science teachers from secondary schools in the Czech Republic - participants in the PROFILES CPD course in 2011-2015. The subject, gender and experience composition of the sample is presented in tab. 1:

**Table 1. Sample selection of teachers.**

<table>
<thead>
<tr>
<th>Subject of teaching</th>
<th>N</th>
<th>Gender of teachers</th>
<th>N</th>
<th>Teaching experience of teachers</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>50</td>
<td></td>
<td>50</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Physics</td>
<td>16</td>
<td>F</td>
<td>41</td>
<td>0-5 y</td>
<td>6</td>
</tr>
<tr>
<td>Chemistry</td>
<td>16</td>
<td>M</td>
<td>9</td>
<td>5-15 y</td>
<td>19</td>
</tr>
<tr>
<td>Biology</td>
<td>18</td>
<td></td>
<td></td>
<td>More than 15 y</td>
<td>25</td>
</tr>
</tbody>
</table>
These teachers were not chosen randomly, but on the basis of their interest in being involved in the project. These teachers work in schools with different numbers of students and classes. Their schools were located in a large city, small towns and villages. A detailed description of the outcomes of the PROFILES project can be obtained from [10].

4 RESULTS

The research results presented in this study were developed within the PROFILES project; however, they were discovered and developed by the authors of the study. The main outcome of the research is the finding that it is necessary to develop and implement teacher education in a systematic and constructivist way. This education should be systemically linked with practical experience to support a constructivist approach and also to deconstruct teachers' beliefs connected with their prior educational experiences based on transmitting traditional teacher-centred teaching. The DBR used in this study have brought many findings of which selected parts are presented. These findings are divided according to the steps of the DBR.

4.1 Analysis of practical problems

The presented segment of the DBR outcomes is an analysis of the problems and barriers which can appear during adult teacher education. When the principles of andragogy are followed in designing teacher CPD courses, learners are more successful in attaining the objectives of these courses. The Canadian Literacy and Learning Network [11] established the set of rules for adult learning, which distinguish teacher-learners from student-learners. The analysis of the problems in teacher education in the PROFILES CPD course is structured according to these rules:

**Adults cannot be made to learn. They will only learn when they are internally motivated to do so.** Education of teachers in-service is even more difficult because of the nature of the teaching profession. The teacher whose aim is teaching others accepts being educated by someone else with difficulty. The teacher is often emotionally set negatively against the lecturers with a high degree of subjective criticality. If a teacher enters a CPD course it is often accompanied by external social motivation (e.g. to improve qualifications), which may be positive but also negative. The optimal situation is when the teacher is motivated by internal cognitive motivation, i.e. by interest in an increase in his/her competencies.

Preventing this problem in the PROFILES CPD course: The teacher-participants were selected on the basis of interest (intrinsic motivation). Their external social motivation was minimal.

**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 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 new paradigms of school education; they are interested in innovative teaching methods and tools. Thus the reasons for their entry into a CPD course are very practical.

Preventing this problem in the PROFILES CPD course: The content of the PROFILES CPD course was very pragmatic. The teachers-participants used action research and created their own teaching tools - PROFILES modules.

**Adults learn by doing. Active participation is especially important to adult learners in comparison with children.** In teacher CPD courses teachers were spontaneously interested in being actively engaged in the presented activities and testing them using their own experiences in practice. They were also willing to participate in the modification of these methods and tools.

Preventing this problem in the PROFILES CPD course: The activity of teacher-participants was an essential pre-condition for their participation in the project. This activity was entirely spontaneous and it was a major factor in the success of the project outcomes.

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

Preventing this problem in the PROFILES CPD course: The creativity of teachers was significantly expressed [20]. The solution findings were very common for teacher-innovators.
Adult learning is affected by the experience each adult brings. To achieve the desired outcomes the experience of teachers was the basic source, but in the form "bad beliefs" it caused complications. Many interesting ideas as a part of their PCK [21] were presented by teachers. The experiences of teachers were the source of many alternative solutions and ideas.

Preventing this problem in the PROFILES CPD course: The teachers-participants 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 CPD courses have their own formal part; however, they should incorporate the informal part, which is especially collaboration between teachers and between teachers and lecturers.

Preventing this problem in the PROFILES CPD course: The informal part of education was an integral part of the PROFILES CPD course. Teachers shared their experiences through cooperation between teachers; they also exchanged ideas, teaching materials, and tools.

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

Preventing this problem in the PROFILES CPD course: The course leaders in the PROFILES CPD course were chosen very carefully with respect to the abovementioned. The best teacher-participants became leaders in another PROFILES CPD course. Teachers-participants closely collaborated in the research project team.

4.2 Development of solutions

When creating the PROFILES CPD course basic systematic and constructivist principles, which were gradually strengthened, were used. At the centre of the PROFILES CPD course was the implementation and action research of PROFILES teaching/learning modules. The PROFILES module has been developed as a teaching/learning unit on a 3-stage model [22]:

- Initiation of the learning happens in a familiar and student-relevant situation where students identify with this socio-scientific situation and feel that it is within their sphere of interest and action. Teachers stimulate students through a scenario. This is a narrative (story) based on everyday problems. It is designed to evoke interest and to raise questions in order to find answers.
- In the second stage the students' triggered self-motivation encourages them to be involved in the IBSE learning process. Students create their own inquiry-based learning cognitive activities.
- In the third stage, the students transfer their inquiry-based learning to the relevant socio-scientific situation encountered in the scenario and develop reasoned justification for decisions.

The following parts of the PROFILES module: "Safety of the human body: swimming and diving" may serve as an example of the PROFILES modules. This PROFILES module was developed by the authors of the study:

Scenario: Death when diving

News from a TV broadcast: Yesterday the famous singer D. N. tragically died when scuba-diving at the seaside resort of H. A local police spokesman said that the exact cause of death would be clarified by means of autopsy ordered by the court. Senior instructor in diving L. T. answered our query as to what can cause a tragedy when diving - it may be a small injury, e.g. a ruptured eardrum. Details will be included in subsequent news.

In this case, students usually ask the following questions:

What properties of water can cause health risks or even the death of a person?

Which organs of the human body can be damaged when swimming and diving and why?

What kinds of swimming and diving in the water are risky?

Which rules of safe swimming and diving do we follow?

The next step is students' activities where students research, seek information leading to a solution, discuss with peers in groups and perform experiments. An example of an experiment:
Experiment: Dissolving of air in blood

Instructions for students' experimenting: The basic experiment aid is a plastic bottle with a wide neck. The bottle cap is drilled and the valve of a tire is screwed into it. Overpressure in the plastic bottles in all experiments is achieved by pressing with hands or with a small bicycle tyre-pump.

Water in a pressurized bottle more air dissolves than under the normal atmospheric pressure (see fig.1).

![Figure 1. Plastic bottle with water.](image)

After opening a bottle air bubbles from water will begin to release. After the moment it is released large amounts of bubbles (see fig.2).

![Figure 2. Bubbles in water.](image)

The third and the final phase was student decision-making. In this case, students, using inquiry, came to the following decisions and recommendations:

**Student decision-making:** Air is dissolved into the water in the over pressured plastics bottle. The air (nitrogen) is dissolved into blood during diving. Air embolism is the frequent reason of death after fast emergence. During diving the greatest danger is barotrauma which can cause varying degrees of damage of organs or even death. Barotrauma is caused by a pressure change within body which has been exposed to a certain period of overpressure and fast emergence on the surface leads to a sudden reduction in pressure. Due to the blood vessels dilate, pressure is changing and blood gases are released and blood starts to froth.

Formally, the PROFILES module consisted of materials for student activities and teacher guidance. These PROFILES modules were used as the core of teacher education in the PROFILES CPD course. The teacher-trainees in the project were familiarized with the PROFILES modules and their roles, and they implemented these PROFILES modules into their teaching. In doing so, the teachers modified these modules and at the end of the training session they made their own PROFILES modules, which teachers verified in practice through their action research. During the development,
implementation and verification of the PROFILES modules were applied through the principles of teacher constructivism, an overview of which will be presented in the next section.

4.3 Evaluation and testing of solutions in practice

The teachers in the third phase of the DBR tested and evaluated the PROFILES modules in their teaching and carried out self-reflections, which we studied through interviews, questionnaires, portfolio analysis, and case studies. Thus we obtained relevant data proving the effectiveness of the PROFILES CPD course. A sample of a teacher self-assessment questionnaire is given in tab. 2:

<table>
<thead>
<tr>
<th>Questions from the teacher questionnaire</th>
<th>Frequency of answers: YES (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you feel a shift in your competency to teach after the PROFILES CPD course?</td>
<td>96</td>
</tr>
<tr>
<td>Will you implement some of the PROFILES modules in your future teaching?</td>
<td>90</td>
</tr>
<tr>
<td>Were you interested in the testing and evaluation of PROFILES modules?</td>
<td>82</td>
</tr>
<tr>
<td>Have you developed your own PROFILES module?</td>
<td>72</td>
</tr>
</tbody>
</table>

In their evaluations teachers cited as positive features of the teacher CPD course elements of constructivist and systematic teaching.

4.4 Reflection on and production of new design principles

The final stage of DBR is to define new design principles and rules. Table 3 summarizes the main principles and specific characteristics of teacher constructivism developed in this research.

<table>
<thead>
<tr>
<th>Principles of the teacher CPD courses for fostering teacher constructivism</th>
<th>Characteristics of the teacher CPD courses for fostering teacher constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encouraging use of active learning approach</td>
<td>• Increasing the intrinsic motivation for learning</td>
</tr>
<tr>
<td></td>
<td>• Fostering openness to change in education</td>
</tr>
<tr>
<td></td>
<td>• Use of active learning methods and tools (e.g. workshops)</td>
</tr>
<tr>
<td>Active construction of knowledge and skills</td>
<td>• Search for relationships between different phenomena</td>
</tr>
<tr>
<td></td>
<td>• Identifying the links between knowledge already acquired and new knowledge (learning by building on preconceptions and experiences)</td>
</tr>
<tr>
<td></td>
<td>• Learning by doing (e.g. problem solving, action research)</td>
</tr>
<tr>
<td></td>
<td>• Implementation of different teaching/learning methods (different types of teachers’ personalities - intelligence, creativity, etc.)</td>
</tr>
<tr>
<td></td>
<td>• Learning from mistakes</td>
</tr>
<tr>
<td></td>
<td>• Involvement of surroundings in collaboration (social nature of learning - schools, staff)</td>
</tr>
<tr>
<td>Self-reflecting and assessment of learning by doing and understanding</td>
<td>• Implementation of different diagnostic methods</td>
</tr>
<tr>
<td></td>
<td>• Implementation of different self-reflecting methods</td>
</tr>
</tbody>
</table>

The ideal situation in the constructivist approach to teacher education is a spiral structure in the form of one spiral thread: motivation of teachers - teachers’ learning activities - new experience - teachers’ reflection - ownership and ability to integrate new knowledge and/or skill. The teacher-trainers’ role is to motivate and control this teacher learning process.
5 DISCUSSION AND CONCLUSIONS

Proposed solution of the research problem is closing the gap between teacher education and practice by the creation of systematic constructivist teacher education. It is necessary to improve all elements of teacher education. Systematic and constructivist teacher CPD is possible to develop and to implement using the discovered principles: encouraging the use of the active learning approach, active construction of knowledge and skills, and self-reflection and assessment of learning by doing and understanding.

Teacher education, and particularly teacher CPD courses, is one of the most difficult parts of education because it is influenced by numerous factors. Our research findings brought confirmation of already known information (e.g. issue of teachers’ motivation being necessary), but also new findings (e.g. principles of adult learning in teacher CPD courses). More research needs to be done on a larger sample of teachers who have more expertise, different experiences, different teacher education, are from different school levels and from different countries, for generalization of these research results. A comparison of the Czech results with some foreign partners in the PROFILES project confirmed that these results have a wider dimension, at least in Europe.

Another issue for future research is the research method of forming teacher CPD courses for teachers who are less intrinsically motivated. Interesting findings may be brought about through research into the impact of ICT on teacher CPD. We must also not forget that the upcoming generation of teachers is a part of the NET-generation, with special educational needs, similarly to the NET-generation of their students. The implementation of these findings to the practice of creating and implementing teacher CPD courses is clear.

REFERENCES


