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IMPLEMENTATION OF DESIGN-BASED RESEARCH METHODOLOGY INTO SCIENCE TEACHERS' TRAINING

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ABSTRACT

Teachers need research-based innovative educational methods for the upgrading of their teaching. The motivation of students and teachers in science education is the core of up to date teaching/learning. A very urgent task for educational research is to find appropriate educational methods and tools which have to be implemented into teachers' training and then in teaching/learning science. Design-based research is a new trend in educational research. The used methodology can be described as a cycle: analysis of a practical problem, development of solutions, iterative testing of solutions, reflection and implementation. This methodology was implemented into pre-service and in-service science teachers' training. An action research, which is close to the design-based research methodology, was presented to teachers for their development of teaching. We present the research outcomes of the implementation of the design-based research methodology into pre-service primary science teachers' training. Used teaching content is a hands-on experimentation with everyday objects.

Keywords: Design-based research, hands-on experimentation, motivation, science teachers' training.

INTRODUCTION

For the past decades, educational systems of many countries have been undergoing permanent reforms. The prerequisite for a successful reform of the educational system is its high-quality professional preparation and implementation. This, though, is not enough. If teachers themselves do not understand the reform and do not identify with it, the reform cannot succeed. The level of education, good awareness and namely strong motivation of teachers are the essential factors influencing the development of education.

In education, though, it is not only apparent reforms that have been happening but a whole range of significant factors have been taking place in a less observable way. These factors belong to changes in the relation of students and their families to education as a life value, post-modernist diversion of society from science and technology education, tendency to perceive education narrowly as goods in the economic sense, information revolution in the form of the Internet and ICT applications etc.

Teachers thus get into pressure from many directions and he or she needs to be equipped with other competences and innovated professional skills. They have to be able to defend themselves against i.e. cyber bully aimed at them, implement new contents and namely to gain new elements of the educational technologies. The teacher's education necessarily becomes a lifelong exercise. Teachers just turn to the educational professional institutes headed by the pedagogical faculties of the universities where they seek help and assistance. Teachers are not satisfied with only ready instructions on how to innovate their teaching but they want to know the scientific reasoning of these innovated methods and instruments. We may talk about the increased interest of teachers in the research-based teacher training. We may even talk about another dimension of the professional preparation of teachers, which is research competence.

MOTIVATION IN SCIENCE EDUCATION

Motivation in science education has been in the centre of attention of the professionals for many years. It is so namely since the time when the interest of students in science has been significantly decreasing. Motivation methods and techniques have been developed that are based on the innovated experiments and tasks etc. (Trna, 2005). We may not forget the fact that if a teacher is to motivate students efficiently, he or she has to be sufficiently motivated himself/ herself. Apart from external motivation, which takes namely the form of sufficient salary and social prestige, the inner motivation to teaching is there.
Inner motivation of a teacher when his or her work becomes their interest or even a hobby should be developed in the maximum scope. Among motivational factors we may count a thorough understanding of the substance of pedagogic-psychological processes which take place during teaching. Here again the teacher research competence may have its significant place which currently has most often the form of action research. This action research of the teacher may be conscious but also unconscious – intuitional. We anticipate that if a research-based teacher training is implemented into the lifelong education of the teacher, his or her inner motivation to science education will be strengthened.

DESIGN-BASED RESEARCH

Subject didactics (didactics of physics etc.) carry out research and development focused namely on the sphere of application including innovation. It is, therefore, useful to find out how other disciplines solve a similar methodological issue of the research and development relation. An analogous example is the situation in technical disciplines where the design approach has a significant position. Its core is orientation to the creation of a new product which brings about problems solving that so far have been only solved partially and the relevant tools and methods are only in their infantry. Design approach has been applied in a whole range of areas during the processes of creation and practical application.
Design approach to solve problems is interdisciplinary and integrative. With the use of this approach we may successfully describe and research the design process, which has been graphically described with the help of the Järvinnen (2004) model (Fig. 1).

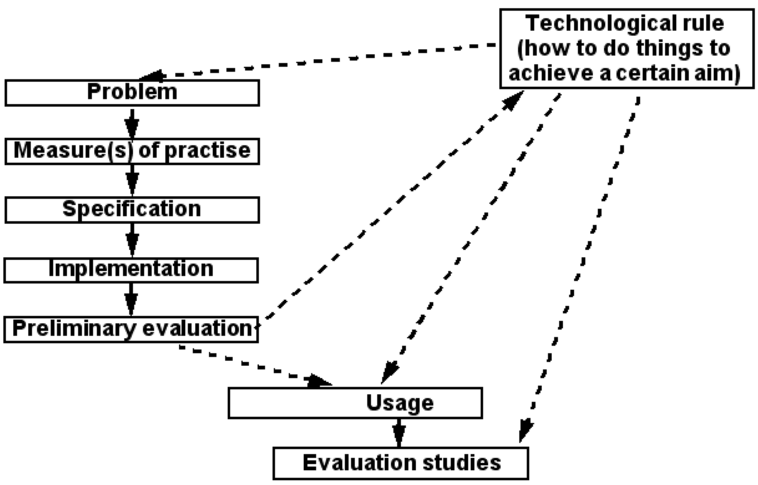

Figure 1: Järvinnen model of design process (Järvinnen, 2004).

Design process consists of elements and links among them. According to Järvinnen (2004), the technological rule or design rule is the input or output of the research. Sequence from the problem to evaluation studies corresponds to the design method that is the development from design to product. This sequence includes the product creation. It is, therefore, a development stage. The proper design process research may be focused namely on the links marked with broken lines (Fig. 1).

If we use the design process in the subject didactics, it is obvious that the objectives of the relevant research will be developmental. Many research methods correspond to these objectives; usually they are combined with quantitative and qualitative methods. Introduction of the design approach into the subject didactics leads to the establishment of a new type of research, which we call the design-based research.

Based on the classification of the research objectives the design-based research has developmental and action objectives. These objectives have a dualistic character:
1. Research solution of the issue of development in education
2. Research creation of specific processes and tools that might lead to the development in education

The essence of the dualism of these two objectives is their inseparability and mutual interdependence. Design-based research thus fully complies with the topical requirement of implementation by "use-inspired basic research" in so called Pasteur's Quadrant (Stokes, 1997).

A question occurs: who may be an active implementer of the design-based research? If this is an individual, he or she must have research competences with rich experience from educational practice. He or she may not be a novice researcher. The complexity of the growing findings as well as practical issues in education requires team cooperation in the design-based research. In this team, professionals with the above mentioned competences have to be represented. In reality this may be a couple of researchers consisting of a researcher in the subject didactics and an experienced teacher from practice. Demands on the research methods require strengthening the team with an expert in research methods (designer, statistician).

Design-based research as a development research differs from other types of research. For illustration a graphical comparison is suitable between the design-based research as a development research and empirical research, which was compiled by Reeves (2006) (Fig. 2).

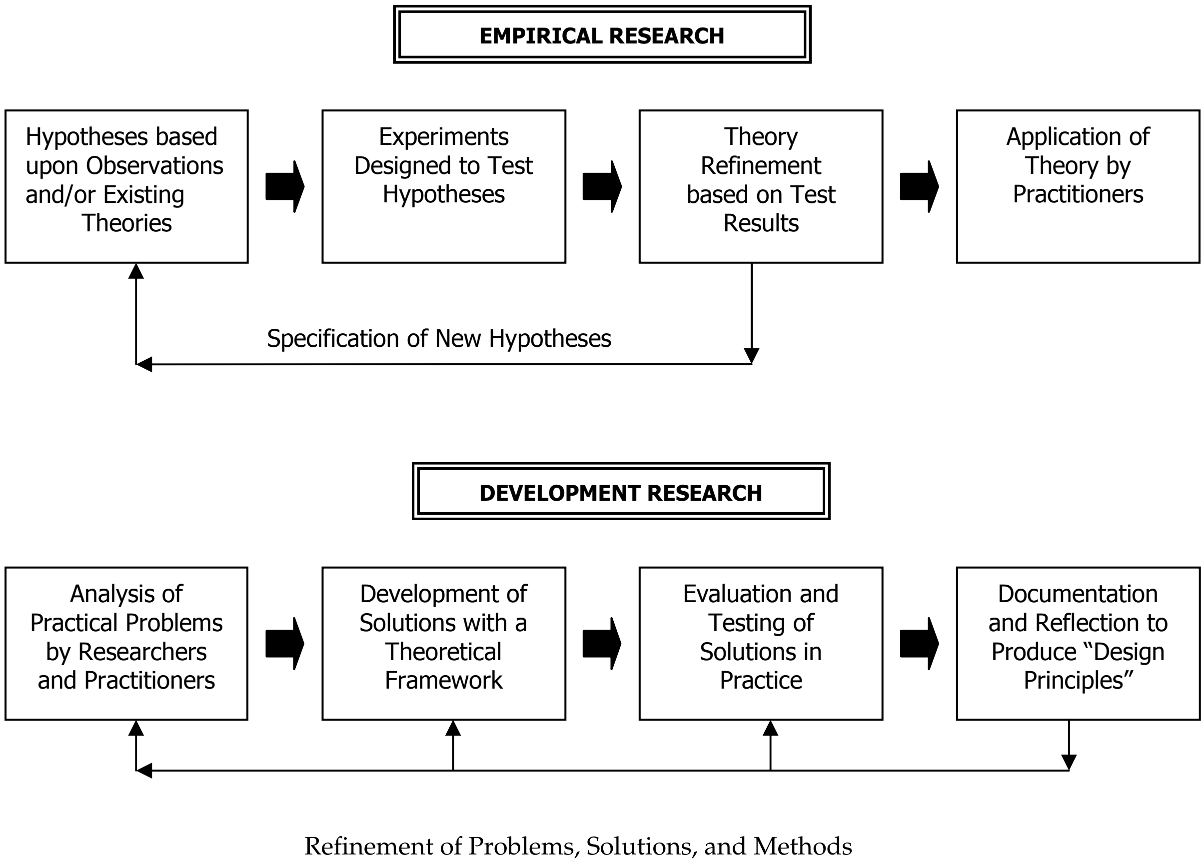

Figure 2: Empirical and development approaches to IT research (Reeves, 2006).

The advantage of the design-based research is its systematic interconnection with practical use. Often it occurs that the results of the empiric research that is carried out separately from practice are not understood or used by teachers. The basic principle of the design-based research on the contrary is the close cooperation between experts and teachers, which is a prerequisite of a suitable selection of examined issues and consequent use of the outputs of the research in practice.

IMPLEMENTATION OF A DESIGN-BASED RESEARCH INTO SCIENCE TEACHERS' TRAINING

Should we acknowledge the rightfulness of the design-based research implementation into science teachers' training, it is then necessary to find methods and techniques on how to carry out this implementation. According to our research and experience so far, we have discovered the basic methods of implementation of the design-based research into the science teachers' training:

1. Analysis of practical problems
2. Development of solutions with a theoretical framework
3. Evaluation and testing of solutions in practice
4. Action research
5. Design-based research

The first three methods correspond to the first three stages of the design-based research. These stages may exist relatively independently and also they work so in practice. After comes the comprehensive action research and design-based research.

Analysis of practical problems

Science teachers identify the existing educational problems while using methods of observation, analyses of students´ works, interviews, etc. In this way, the first signals of problems occur which the researchers consequently begin to study. Lately, i.e. de-motivation of students in science education, reduced systematic nature and conscientiousness of the students, reduced manual skill in experimenting belong among these problems.

Development of solutions with a theoretical framework

Many science teachers dedicate immense energy and working time to the development of various teaching techniques and namely tools. In this way they demonstrate externally the form of pedagogical content knowledge in different shapes. Most often these are school experiments and their varieties, complexes of school aids, working sheets, power point presentations, video recordings of experiments (loaded to you tube etc.), web presentations, didactic tests, etc. A frequent weakness of these creations is the failure to clarify the theoretical framework of their products. Huge potential is hidden here, which requires work organization and professional management of science teachers.

Evaluation and testing of solutions in practice

Science teachers are the authorities and true implementers and evaluators of the innovated teaching methods and procedures created by experts, namely researchers of subject didactics (Trna & Trnova, 2010). These teachers may work as participants in research teams, as co-authors of text books, teaching aids, etc.

Action research

The action research may be perceived as a simpler, initial stage of the design-based research. In the last years, action research has been implemented into the daily practice more often. Science teachers thus use the action research cycle for verification of their innovative ideas. Thus, there occurs a significant development of PCK of each teacher who uses action research on the basis of the research-based teacher self-training.

Design-based research

Science teachers may naturally be direct participants in the research teams that implement the design-based research. These teachers may in time become research professionals in the subject didactics and thus reinforce their numbers.

Examples of the implementation of a design-based research into science teachers' training

As an example of design-based research implementation, we may state the application of the method 4.2 Development of solutions with a theoretical framework. A theoretical framework was the theory of hands-on and minds-on experiments. The implementation process consisted in the assignment of a task to a twenty member group of in-service primary science teachers in the year 2009, when their task was to put together a series of simple experiments with the use of the human body (hands, sense of sight, sense of touch, sense of touch, sense of hearing) and simple aids that were coins. We give several experiments from the completed series as an example:

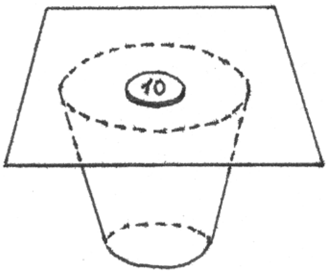

Figure 3: Inertia of a coin.

Cover a glass with a suitably big stiff glossy sheet of paper and place a heavier coin on it. By abrupt pulling (taking) out of the sheet the coin will fall into the bottle. We will receive the same result if we push the paper away:
Explanation: Inertia of the coin and little friction will cause the fall of the coin into the glass.

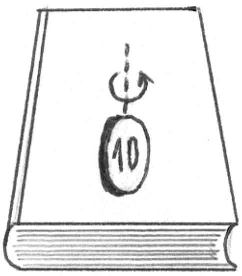

Figure 4: Coin as a balance wheel.

Spin (by a flip of a finger) a heavier and larger coin round its vertical axis on a large book (with smooth surface). During tilting of the book the rotating coin will keep the direction of the rotation axis in space and after the book is again balanced it rotates in the same way as at the beginning of the move. Explanation: According to the conservation of angular momentum direction of the coin rotation axis remains.

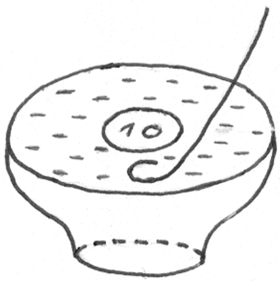

Figure 5: Surface tension.

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Put a light coin into a bowl with water with the help of a wire holder so that the coin remains on the surface. Explanation: Surface tension of water will keep the coin on the surface.

Figure 6: Thermal conductivity.

Take a smaller coin with two fingers and start carefully to heat it above a match flame. You will not be able to hold the coin for the whole time of the match's burning.

Explanation: the coin has very good thermal conductivity and low thermal capacity and, therefore, its temperature will fast increase.

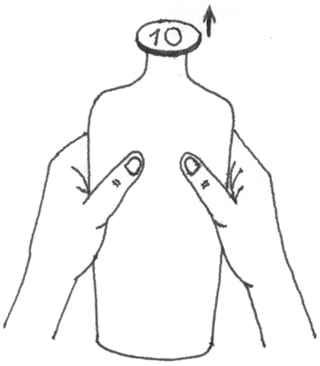

Figure 7: Thermal expansivity of air.

Place a coin on a moist neck of an empty glass bottle. Take the bottle into your hands – thus you will warm the air in the bottle (we recommend to cool the air in the bottle beforehand by a flow of cold water). After a moment the coin will start to jump up and down almost periodically.

Explanation: heated air in the bottle increases its volume and pressure. Such strength of the heated air will lift up the coin.

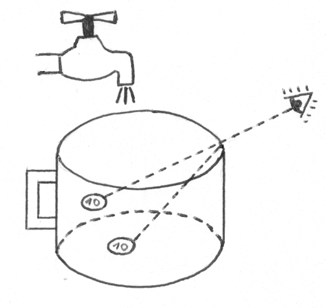

Figure 8: Refraction of light.

Place a coin on the bottom of a non-transparent mug so that you cannot see it from the side. After you pour water into the mug the coin will appear without you changing the angle of view.
Explanation: Surface of water in the mug will become a boundary of two different optical environments in which there will occur a refraction of light beams coming out of the coin – refraction from perpendicular – and in this way these beams get into the eye and we can see the coin.

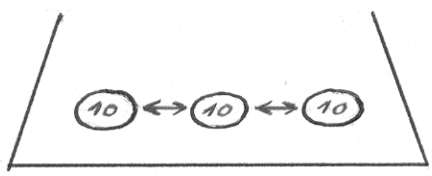

Figure 9: Blind spot.

Place three smaller coins next to each other in the distance of 8-10 cm. Narrow the left eye and look with your right eye to the coin placed on the very right. At the same time, bring your head closer to the coins. In the distance of 25-30 cm the middle coin will disappear. When you pull your head away, the coins situated on the very right will disappear.

Explanation: Light reflected from the disappearing coins falls on the blind spot on the retina where the eye cannot see.

The above mentioned series of simple physical experiments evidences the universality of use of a simple available aid – a coin and the scope of options to use human body in measurements and experimenting. Feedback verification of efficiency of implementation of the design-based research into in-service primary science teachers' training was carried out by a questionnaire. This questionnaire was applied to teachers who participated in the creation of experiments with coins. Frequency of their selected answers is stated in the table:

	Questions from questionnaire	Frequency of answers: YES
1	Were you interested in the creation of experiments with coins?	84%
2	Will you use some of the created experiments in your teaching?	61%
3	Have you understood the substance of the hands-on and minds-on experiments well?	47%
4	Will you create your own science experiments in the future?	25%
5	Do you feel a shift in your positive motivation to teach science after you completed the course?	28%

CONCLUSIONS AND IMPLICATIONS

All the above mentioned methods of implementation of the design-based research into the science teachers' training anticipate a daily practice of teachers and their experience. These methods, therefore, are intended namely for the in-service science teachers' training. It is obvious that all the mentioned implementation methods may be used in an adjusted form also for pre-service science teachers' training. Here it is worthy to inform students of the substance and function of the design-based research in science education. The teachers' training students may get the basics of the required skills in research necessary to create their theses.
A specific target group for implementation of the design-based research is doctoral students in the science education. Their doctoral thesis may contain implementation of the design-based research.
Subject didactics (didactics of physics etc.) as scientific disciplines may consider the design-based research as one of its fundamental specific research methods. This may solve one of the significant methodological problems of the subject didactics that is the defining of specific research methods. The design-based research may play a decisive role here.

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