PHYSICS EDUCATION IN HISTORICAL PERSPECTIVE AND FUTURE TRENDS

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Abstract

This article deals with physics education form its emergence in 19th century to the present and outlines future trends. Physics had become part of general education and remains an important part of science literacy. Current breakthrough of information and communication technology (ICT) is based on physics achievements, on the contrary interest of students in science and technology studies has been falling. The traditional role of schools as the main source of information has been replaced by ICT's and teacher's role in a modern school has been changing too. ICT's provide an opportunity for innovation of education methods but they easily distract attention of students from physics content. We discuss physics educational content and teaching methods for different school levels, whether they are appropriate for 21st century education and societal needs. We researched the state and perspectives of physics education in the Czech Republic and identified the problem that number of pre-service teachers does not match the demand of schools for qualified physics teachers.

Keywords: Innovation, technology, Physics education, ICT, science literacy, educational goals, teaching methods research projects.

1 INTRODUCTION

The determination of the priorities of physics education and the subsequent creation of a curriculum is the first step towards effective education in physics.

First, we have to answer the question of what is "the curriculum" and to think about the approach to education. Reasoning should be based on concept pairs [1]:

- Individual X Society
- Past (tradition) X Future
- Abstraction (ideals) X Concreteness

Philosophical attitudes can then be expressed as:

- Personnel (progressive; based on student uniqueness; individualization)
- Polytechnic (given by the labor market; technology control)
- Essential (given by the information society; various literacy)
- Academic (given by the "culture of the West"; linking the civilization values and the student's interests)
- Activist (sociocritical, global; to acquire skills solving problems in society -social problems - environment, integration, ... connection with various ideologies)

The structure of the curriculum should include the following sections:

- Ideological (examples of ideas: humanity, globalization, anti-xenophobia, co-operation, harmonious personality, general goals)
- Content (more specific goals, traditionally: acquiring knowledge, then skills, attitudes (influence of ideologies), competencies) = “core-curriculum”, “Kernkurikulum”, “basic curriculum”, “standards”, ...
- Organizational (school system, types of schools, frame educational plan (FEP), specific school, school educational plan (SEP), methodical guides, textbooks)
- Methodical (forms and methods of teaching, choice is in the hands of the teacher)
The basic division of curriculum concepts can be characterized as:

- Student friendly (cognitive development of student) X Intermediating (fixed content)

When speaking about science literacy which is a part of general literacy, we mean physics, chemistry, and biology.

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2 HISTORY OF SCIENCE EDUCATION

An analysis of historical trends in science education can provide valuable insights into future reforms.

The requirement voiced by Jan Amos Komenský (1592–1670) to incorporate natural sciences into general education had been ignored for over a century [2]. A fundamental change occurred in middle of the 19th century when the countries of the “old continent” radically reformed their educational systems. Second half of the 19th century was in sign of rivalry between classical education based on classical languages and modern education largely incorporating natural sciences.

Finally, natural sciences have asserted themselves and nowadays they take a great part of curricula at all levels of education worldwide. We investigate this great transformation from the point of central European view focusing on the role of physics and chemistry school experiments in science education.

In the Czech territory compulsory school attendance for both boys and girls started by the imperial Education Act (i.e. Hasner’s Law) in 1869 [3]. The law established public schools called “obecná škola” (in German: Volksschule) and higher quality schools called “měšťanská škola” (Stadtschule) both having 8 grades (for 6 to 14 years old). At public schools there appeared a new subject “Přírodopis” consisting of “Silozpisy” (Physics) and “Lučba” (Chemistry). Another subjects were “Přírodověda” (Biology), “Zeměpis” (Geography), “Dějepis” (History), “Náboženství” (Religion) etc.

Even from today’s perspective the methodology presented in the book by J. Klika [4] is very advanced and modern. Experiment was identified as the key element of teaching physics. Emphasis was given on pupils learning laws of nature by observing and doing experiments, description and explanation of the phenomena by language (using physics terminology) should follow next. The described process of learning is actually very close to Piaget's constructivism.

At the end of 4th chapter J. Klika summarised the method of teaching physics as follows (text was adapted for contemporary language, but the content of the message is authentic):

“I. Teaching is conducted via an inductive method in the form of a series of observations. This series begins with the experiment; the other elements are either other experiments or experiment-like insights of the pupils based on their own experience. Pupils compare the basic experiment with their own observations. Observation of each experiment is followed by its description and analysis, i.e. searching for essential points of the experiment and their links.

II. After stating the laws of nature deductive approach is applied to use the new law as an explanatory principle for weather phenomena as well as for tools and machines used in practice. Thus pupils find out: by understanding laws of nature they learned things important for life.”

According to J. Klika [4], this method of teaching physics was originally proposed by J. Crüger [5] and further developed by C. Baenitz [6]. Nowadays we can state that the discovery of this method was a milestone of school didactics and after one and a half century the method remains valid.

Although the theory of teaching and scholarly understanding of learning processes was advanced in the late 19th century, the practice was very different. Application of the theory into day to day practice at schools faced many problems including the lack of qualified teachers and lack of funds for teaching aids.

When we look at the situation at US high schools [7] total students enrollment in physics drastically dropped since 1890. Moreover physics became an elective subject.
3 PISA

Recently published results of the international survey TIMSS (Trends in International Mathematics and Science Study) [8] and PISA (Program for International Student Assessment) [9] of 2015 on the measurement of pupil learning outcomes are a source of reflection on the state of the natural sciences pupils' literacy. The results of pupils in primary and secondary schools in the Czech Republic and other European countries either continue to decline and they are below 20 years ago.

What is the reason for the presented inauspicious outcomes in a large number of European states? Is it the result of changes made in the curriculum in the past years, or is it in the preparation of teachers of science teachers or in changing the relationship of our society to education? In addition to lower value, the trend of change is also important, and there is little reason for optimism.

Because the results of education are closely related to economic performance, students' declining learning outcomes threaten not only the level of future university (mainly in technical study programs) students but also the prosperity of the corresponding country.

3.1 Science literacy

For the purposes of the PISA 2015 survey, the functional science literacy [9] was defined as follow:

Science literacy is the ability to think and act in all matters related to natural sciences and their principles as an active citizen.

A science literate person is able and willing to engage in substantive debate about natural sciences and technologies, for which he must have the following three skills:

1. **Explain phenomena scientifically**
   Recognize, offer and evaluate explanations of diverse natural phenomena and technologies.

2. **Evaluate and design scientific research**
   Describe and evaluate scientific research and propose scientific research questions.

3. **Scientifically interpret data and evidence**
   Analyse and evaluate the different forms of data, assertions and evidence and to draw appropriate scientific conclusions.

Other criteria for describing essential aspects of science education are knowledge in content, procedural and epistemic dimensions.

**Content knowledge** is understood as a knowledge of basic theories and principles of science and knowledge of the content of natural sciences.

**Procedural knowledge** includes knowledge of common procedures and strategies used in scientific research, methods of polling, the use of skills, algorithms, techniques and methods. It is used to
evaluate and design experiments, interpret data and produce scientific conclusions. Procedural knowledge is practical knowledge and can be used directly to solve the task.

**Epistemic knowledge** is a newly introduced knowledge dimension that has been defined precisely for the purpose of the PISA science literacy research. It has a role in verifying any claims in scientific discovery, and includes the pupil's ability to evaluate the results of scientific research and then decide whether appropriate procedures are used and justified conclusions are made. It also includes the ability to suggest, at least in rough terms, how the problem can be scientifically explored. Epistemic knowledge is the knowledge of the concepts and characteristics necessary for the process of creating and building a knowledge system in science and their roles in justifying the reliability of scientific knowledge, e.g. hypotheses, theories or observations and their roles in the cognition process.

Considering the previous required pupils' skills in terms of natural science literacy, the change of the Framework Educational Program (FEP), and in particular its science subjects' content, should correspond to the current perception of the world by contemporary young people.

We believe that the content of science (Physics) education at primary and secondary schools should be created by experts, physicists who know the current state of science and the development of knowledge, rather than educators. The composition and methodical processing should then be created by staff of universities preparing teachers of physics together with experienced teachers from schools. However, it should not be forgotten what is the aim of basic education, to prepare pupils for everyday life so that they are not lost in it and they are applicable to the labour market and to further lifelong education.

But can such an adaptation of FEP fundamentally change their current negative attitude to the natural sciences? The document itself probably not, it is necessary to actively involve teachers. Here we can encounter the problem of natural (age) replacement of physics teachers [10], [11]

Based on the analysis of both reports, TIMSS and PISA, the current status of the teaching staff seems to be the most important element of the level of natural science literacy in addition to other factors. This is mainly about the age structure and specialization of teachers for the first grade of elementary school; for the 15-year-old pupils, the data from the survey show the low qualification of teachers for physics and chemistry.

### 4 ICT IN SCIENCE EDUCATION

How to adapt the form and content of teaching for the younger generation? In recent years there has been a tremendous upsurge in communications technology and this has resulted in the transfer of a significant part of human life into the virtual world. The primary source of information has become the Internet and being online is already a common part of life. Of course, this aspect is also taken into account in the classical learning process.

In the virtual world, one of the limitations is the current technology which is used. In science education, this can cause in some cases a distortion of reality and consequently erroneous judgment. However, if we are forced (urge) to take up current trends in ICT teaching today, we should pay close attention to keeping the educational content preserved and not distorted by the technologies used. Very often, ICT distract attention away from the content.

An example, how to implement elements of the real world into ICT education are remote laboratories. Compared to virtual laboratory, they partially replace classical laboratories in the way they get measured data. Although the control is via the virtual environment, the source is always a real experiment, which is the source of the current measurement data.

Such adjustment can be more comfortable for today's generation. The remote lab can work 24 hours a day online, so it is fully up to the user to make the most of the service and perform the assigned tasks.

There is no need for supervision compared to classical contact education, and no time constraints. On the other hand, such a form of education lacks specific skills associated with experimental work, such as circuit engagement, fine motor activity when parameter setting is made.

Remote laboratory are one of the marginal themes that seeking to promote in the field of education to create an alternative to acquiring basic experimental techniques in the virtual world. They have a peculiarity, they are a bridge between these two worlds - the virtual environment can convey real world responses to experiments. They have more potential to prepare for real life than full virtual simulation.
However, the disadvantage is the limitation of the design of the measuring device and the absence of some skills that can only be obtained in a real laboratory.

5 CONCLUSIONS

Available data show that the number of approved physics teachers, especially in elementary schools is significantly deficient, and with respect to the age structure of physics teachers will continue to decline.

Today's children generally have no opportunity to spend time in the countryside or anything produced in the workshop. The environment in which they grow up is not "real" from the point of view of natural sciences. The challenges posed by today's lifestyle do not require skills based on natural sciences. And so people's reluctance and comfort to deal with real things goes hand in hand with the decline of critical thinking, weakening imagination, and lack of continuity that is needed to complete any particular work. Additionally, children are learning the knowledge and adventure in a state completely finished. They lose imagination while they accept a view of a world as they see on screen. What they see on the screen is detailed, perfect and "comfortable" as it is not, moreover created by specialists.

The science literate person has to try on concrete examples how nature is explored, how the theories are created, tested, confirmed, and temporarily accepted. Mastering of such knowledge can be achieved in purely verbal terms, but this approach is not enough to acquire the ability that characterizes a natural literate person in the broader sense. The real understanding of theories and concepts will develop in most cases only on the basis of a specific activity through the own student's experience. This deficiency caused by using a "virtual world" can be eliminated by using remote laboratories with real experiments.

In physics, students are first exposed to unusual terms for which they do not have their own motivation or life experience. The tempo and the large scope of the lesson often prevents them to absorb the idea of the theory at all. The topics are very often served in finished or at least semi-finished form, but natural science is based on work with assumptions, with doubts and corrections. It is not, of course, necessary for every generation to discover the laws of the world from the beginning, but every generation has the right to at least inspect the process by which mankind has come to the present scientific knowledge.

School experiments used in the late 19th century were designed to be as simple as possible. They still clearly demonstrate basic laws of nature. We believe that basic school experiments used in the 19th century can be refurbished by ICT's; however students attention does not be diverge from pure laws of nature remaining valid and beautiful.

REFERENCES

[1] P. Kolář and V. Žák, “Proměny fyzikálního kurikula” – první postřehy z literatury In Moderní trendy v přípravě učitelů fyziky 8, to be published

5643