PROGRAMME

FY2MP_AKT Actual Physics Teaching

Course objectives

At the end of the course student has a knowledge of learning technology (on the example of Physlet simulations), practical skills, all what is necessary for science teaching.
Contents of the course will actually respond to innovative trends in science education (changing educational standards, the development of educational technology, etc.).
Students will widely determine the actual content of the course.

Syllabus

1. Questionnaire survey of interest
2. Workshops
   - 2.1 Theoretical and pedagogical background of using interactive simulations in teaching and learning science, particularly physics
   - 2.2 Practical aspects of running Physlets (online, offline, HTM5, tablets). Physlet simulations as free educational resource. Downloading and installing physlets and associated software
   - 2.3 Physlets and their application in various phases of teaching/learning process
     - 2.3.1 Physlets for lectures
     - 2.3.2 Physlets for virtual demonstrations and lab works
     - 2.3.3 Physlets for homework activities
   - 2.4. Tools for translation of Physlets' interface
   - 2.5 Assignments. Developing User Guides for application of specific physlets in teaching practice targeted to semi-guided exploration of natural phenomenon by elementary and high school pupils and/or translating sims interface from English to Czech language.

Notes for Workshops

Inroduction

Information and Communication Technologies (ICT) are at the very core of the knowledge-based society and its impact creates a significantly distinctive environment for education. Technology-enhanced learning including knowledge and content development tools and applications help us preserve, develop and disseminate knowledge, improve learning and education systems and strengthen the creativity of society.

ICT instigate enormous technological enhancement in information support of education. ICT make technology-based education and training easier to design, develop and deliver. Integration of new technologies in education obtains more and more innovative forms and play growingly decisive role in contemporary systems of education from secondary to tertiary level. ICT enable individualization of learning process according to learner needs considering their current knowledge, experience, preferences, customs and learning styles. Introduction and development of ICT-mediated teaching tools in *teacher training* environment obtain even greater importance as the future teachers would be prepared in advance to the application of ICT in their forthcoming teaching practice.

Computer Simulations

Nowadays teaching environment includes variety forms of computer-aided instructional tools (CAIT). The main advantages of CAIT in comparison with traditional instructional tools could be classified in terms of both *functional* and *technical* viewpoints

The functional advantages are, but not limited to, the following

- CAIT provide opportunities for learners to plan individually the time, place and pace of learning and accordingly gain more efficiency in instruction;
- Ability of objective automatic and on-demand control of knowledge and skills gained at any certain period of learning;
- Possibilities to take advantage of unique teaching materials and artifacts such as manuscripts, pictures, museum exhibits, etc;
- Ability for providing more individualized education by means of adaptive systems that are adjustable to learners' personal abilities and behavioral manners.
- Ability to work with digital models and simulations of objects and processes that are hard to or even impossible to demonstrate in reality;

With regard to the technical point of view, the following advantages are evident:

- Increasing ease of design and implementation;
- More simple updating and development;
- More effective dissemination (especially via Internet)

With a broad range of computer-aided instructional tools a special attention should be paid to *computer simulations*. Computer simulations are implementation of a physical model by means of a computer program. The starting point of a simulation is development of idealized model of a physical system. In general the development of models of natural phenomena is the essential role of science. Even more, it can even be argued that development of most general and most accurate models of natural phenomena is the core of scientific investigation.

Simulation emphasizes the *research mode of learning.* The results of simulation (visual and numerical data) serve as a bridge between laboratory experiments and theoretical calculations. Training in the context of computer simulation helps learners to understand easier the science of invisible, conceptual, abstract ideas. The results of an idealized computer model can serve as an impetus for the development of the theory. We can argue that computer simulations develop into the *third way (mode)* of scientific research together with the theory and experiment.

An important element of educationally effective simulations is that students view these simulations much as scientists view their research experiments. The scientist approaches research as an enjoyable opportunity to explore basic concepts, as well as to challenge, correct, and add to his or her understanding of how the world works. Similarly, the student usually finds exploring the simulations fun and, through this exploration, discovers new ideas about the science. A well-designed simulation focuses the student's attention on the basic scientific concepts. When something unexpected happens, the student questions her understanding and changes parameters in the simulation to explore and improve her understanding—approaches similar to those taken by a scientist working with an experiment. This behavior is in contrast to the way students approach hands-on experiments typically used in classes. Students often think that their goal with such experiments is to reproduce a preordained result as fast as possible, without making a mistake.

PhET project and Physlets

There are numerous simulations of natural phenomena available online that could in principle be used in science teaching process. But there appear to be many difficulties due to incompatibility with the curricula, lack of methodological guidelines and licensing and language issues. There is also another important problem that is very hard to overcome. In fact most of commercial educational simulations are embedded in more or less comprehensive software packages. Mostly there is no way to take apart specific simulation from the package and use it separately and it is necessary to buy and install a complete software package, no matter if only few simulations match certain curriculum requirements.

Fortunately there is a collection of educationally effective simulations that are developed under PhET Interactive Simulations project (http://phet.colorado.edu/). PhET stands for **Ph**ysics **E**ducational **T**echnology and provides fun, free, interactive, research-based science and mathematics simulations (sims). The PhET project has developed more nearly hundred interactive sims all of which are free, for students and teachers to use within classrooms to help students understand a variety of science concepts. These simulations are called Physlets (**Phys**ical App**let**) despite the fact that they cover various topics not only in in physics, but also chemistry, math, biology, and Earth Science. PhET simulations run through standard Web browsers and they can be integrated into a lecture, used with laboratories or as homework assignments, or used as informal teaching and learning resources. Physlets are used worldwide and at all levels—from grade school through upper-level university courses.

PhET Interactive Simulations can be used in many different educational settings, including lecture, individual or small group inquiry activities, homework, and lab. Sims can be highly effective learning tools; however, even the best sims are not automatically successful. They are tools that can enhance a well-designed curriculum and the efforts of a good teacher, but they cannot replace them. They must still be part of an overall instructional design and rely on the timely guidance of a teacher.

The basic strategies for using sims effectively include:

1. Define specific learning goals;
2. Encourage students to use sense-making and reasoning;
3. Connect with and build on students' prior knowledge & understanding (including addressing possible misconceptions);
4. Connect to and make sense of real-world experiences;

5. Encourage productive collaborative activities;
6. Require reasoning/sense-making in words and diagrams (i.e. multiple representations);
7. Help students monitor their understanding.

PhET sims can help: introduce a new topic, build concepts or skills, reinforce ideas, and provide final review and reflection. Sims are unique in the way they can blur the boundaries between lecture, homework, in-class activities, and laboratory, because one sim can be used in similar ways in all of these.

Lecture

Sims can be used as simple animated illustrations or in the form of interactive classroom demonstrations. As an animated illustration, the sim shows the process and can be slowed or sped up depending on the concept being shown. The invisible (photons, electrons, fields, …) can be made visible; and multiple representations (pictures, diagrams, graphs) can be clearly linked. Perhaps the most effective way to use sims in lecture is to begin with the teacher posing a scenario and asking students to write down their predictions. After students have written down individual predictions, they talk with their neighbors to come up with a final prediction for their group. The teacher then asks to hear predictions from the class and then runs the sim. After students see what the sim does, they write down what did happen and how it was different from their predictions. Finally, there is a whole class discussion about what they saw, and why it makes sense based on physics ideas.

The use of simulations in lecture in almost any form leads to a large number of spontaneous student questions. Students will often pose “what if” questions, essentially new experiments they would like the teacher to perform with the sim so that they can see the results.

Group Activities
When possible, it is even more effective to have the students work in pairs with their own computer and manipulate the sim themselves. The sims are carefully designed and tested to be easy to use and engaging for students. Classroom activities with sims can include a wide range of activity types. The goal of all of these types is to ask questions that will encourage students to explore the behavior of the sim, reason through their ideas, and develop corresponding mental models. One format is to give the students a sequence of challenging questions (often using a “predict-test-confirm or adjust thinking” approach) related to the sim, often with some real world connection component.

Homework Activities
The simulations are unique because their design allows homework assignments to successfully use a guided inquiry approach without the presence of a teacher. This built-in support also allows teachers to include homework questions that ask the students to extend their learning beyond what is possible in a standard homework problem by having them explain phenomena related to, but different from, what they have seen in class or in the textbook.

It is advantageous to assign sim-based homework *after* using the sims in lecture or with an in-class activity. However, sim-based homework questions can also provide introductory exploration of a topic *before* students have seen it in class.

Laboratory Activities
Sim “labs” enable exploration that would not be practical with real equipment. Students can quickly repeat experiments and rapidly explore the effect of many different parameters. Sims can also be used as a supplement to hands-on equipment laboratories, as prelab assignments, part of the lab itself or as a follow up assignment. Finally, the sims allow teachers to assign lab-type activities as homework.

While sims offer many of the same benefits as doing demonstrations using real equipment, the sims also have several additional advantages:

1) they can be used in classrooms where the real equipment is either not available or impractical to set up;
2) they can be used to do “experiments” that are impossible to do otherwise (e.g. sim shows immediate response to adjusting the amount of greenhouse gas in the atmosphere or the resistance of a bulb in a circuit);
3) it is easy to change variables in response to student questions that would be difficult or impossible to change with real apparatus;
4) they can show the invisible and explicitly connect multiple representations; and finally,
5) the students can run the sim on their own computer at home to repeat or extend the experiments from class to clarify and strengthen their understanding.

Virtual laboratory experiments by means of computer simulations have much in common with the real laboratory experiments. Some analogies are shown in table below.

Real lab experience	**Virtual laboratory experience**
Sample	Model
Physical apparatus	Software
Adjusting the experimental setup	Testing debugging the program
Data Analysis	Data Analysis

The virtual experimental activities are designed to promote the development of skills and abilities normally associated with experimental work performed in a laboratory, for example when one is not available, when the experiment represents danger to the experimentalist or when it cannot be repeated because of time limitations. They are, preferably, a complement to real laboratory activities.

Although virtual experiments do not replace “real” experiments and *do not develop* certain procedure skills (like instrument reading, equipment manipulation and experimental setup building), they can be repeated over and over again, promoting different kinds of didactic exploration. These types of activities can also be available online, allowing students to review or explore them at any time, in any place.

Teacher Guidance

Physlets are designed in a way that considerable guidance and feedback is built into the sim (only specific parameters can be adjusted and students see an immediate response to changes). This implicit guidance can reduce the time students spend “getting stuck” trying to figure things out. Also, it means the students can go much deeper into the material without explicit guidance or feedback *from the teacher*. However, the amount of guidance on the science provided by the sim and the amount the teacher needs to provide depends on the particular sim and the background of the students.

It is important to not “over-guide” sim use. With guidance that is too explicit and structured, students actually explore and learn less. Students will explore sims more productively on their own than they would textbooks or most lab experiments. Because the amount of guidance needed with a PhET sim is less than with traditional materials, it is advisable first trying to use the sim with students with less guidance than you normally would. Then add some guidance if necessary. The key is to engage the students in productive self-driven exploration.

A particularly important aspect of learning science is to develop mental models of the science. A sim can represent expert models more explicitly than other materials, by showing things like explicit representations of electrons, vectors, or electric fields. However, there is still a great deal of thinking required for the students to make sense of the sim and to develop their own correct mental model. In fact, one way to use sims in class is to use them as an example of a scientific model. After a sim is used, the instructor can talk about how it is a model of the natural phenomena but not an exact replica and what it means to have a model.

As with any learning tool, PhET sims need to be carefully integrated into the curriculum with appropriate activities created around them. With this approach, PhET sims provide a unique tool that makes learning more fun and more effective.

As a summary we can characterize the following advantageous features of Physlets.

- Physlets are platform-independent, they can successfully ran on any operating system without prior installation, given that Java Virtual Machine is installed. The new generation Physlets are even more flexible, physlets pushed the boundaries of HTML5 to enable new sims to run in any modern web browser, including on tablets such as the iPad.
- New sim designs work well with either mouse or touch interactions, and sim performance is optimized for most current browsers
- All sims are independent and can be used together or separately from others on discretion of teacher or student
- Physlets collection is an Open Educational Resource and can be used freely for educational purposes without any limitation
- PhET team provides free translation tools that can be used for translating interface of sims to local languages without disrupting their original code. No programming skills are necessary for translation
- Colorado State University team supports free social network for teachers and students where participants can share their personal experience on sim use, provide methodical guidelines and localized versions of sims.

References

1. Wieman C.E., Adams W.K, Perkins K.K. PhET: Simulations that Enhance Learning. Science, vol. 322, p. 682-683, 2008
2. C. Wieman, W. Adams, P. Loeblein, and K. Perkins. Teaching physics using PhET simulations.
3. R. Dieter. Learning and Teaching Mathematics Using Simulations. Proceeding book of the joint international conference MPTL '16 - HSCI 2011, 15th-17th September 2011, University of Ljubljana Slovenia p.35-44. 2012
1. Christian, W. & Belloni, M. Physlet Physics: Interactive Illustrations, Explorations, and Problems for introductory physics. Pearson Education, Inc. 2004
2. http://phet.colorado.edu (last accessed on February 2015)
3. Gould H., Tobochnik J. and Christian W. An Introduction to Computer Simulation Methods: Applications to Physical System, 3rd edition, Pearson. Addison-Wesley, 2007
4. Bransford, J.D., Brown, A. L. and Cocking R. R. How People Learn, Brain, Mind, Experience, and School. Washington, D.C.: National Academy Press. 2000
5. Krusberg Z. A. C. Emerging Technologies in Physics Education. Journal of Science Education and Technology, Vol. 16, Number 5, p. 401-411, 2007
6. G.Demirjian. “Information Support of Modern Education: Rethinking Armenian Experience”. Proceedings of the Red-Conference: Rethinking Education in the Knowledge Society (Ascona, Switzerland), pp. 136-147, 2011