DEVELOPING E-LEARNING MATERIAL FOR PHYSICS LABORATORY EDUCATION

Patric Granholm

Turku University of Applied Sciences, Faculty of Engineering and Business

Hiromasa Ohnishi

National Institute of Technology (NIT), Tsuruoka College

ABSTRACT

An increasing demand for alternative ways completing studies require more supporting online material. We present here an attempt to generate online of material for physics education as a cooperation between National Institute of Technology, Tsuruoka College (NITTC) and Turku University of Applied Sciences (TUAS). The paper starts with a comparison between teaching traditions at NITTC and TUAS. There are difference in the balance between the focus on theory and experiments. Teaching at NITTC is traditionally more focused theory whereas is it, at TUAS, is focused on laboratory work. At both institutions, the process of increasing the online support is in an initial state. Supporting online material is available as is, but mainly for theory studies and problem solving. However, there are also some attempts to do online experiments. Both providing good support for physics education but as the material is built for a general usage they do not fill the lack of supporting material for a specific course or set of laboratory work. Our attempt is to create online experiments and support material closely coupled to both laboratory and theory classes. The physics simulators should have appealing animations combined with graphical representation of the change in the physical quantities studied. The visualization is important to enhance understanding the phenomenon. The aim is that our tools work as a glue between theory and experiment. One advantage with HTML5 is the simplicity to introduce it to students. There is no environment dependence, only a web browser is required to use HTML5 materials. The aim with the cooperation is that each partner design material to support their own education and at the same time share their material and good educational practices with the other partners. We use Blackboard as educational platform and to share the material. The choice of Blackboard was based on the fact that it is common for all 51 NIT colleges in Japan.

KEYWORDS

Physics education, Simulations, Physics laboratory, HTML, Standards 6, 7, 8.

INTRODUCTION

The basic conditions for science teaching at university level has changed during the last years. The gap between the expected basic knowledge that we expect that the incoming students possess and what they really have grows. The Finnish Education Evaluation Centre has studied the knowledge level in Mathematics that students leaving upper secondary school possess. The study compares the level during time period from 2003 to 2012 and shows a clear decrease in the level during these years (Metsämuuronen 2017). Similar concerns can be found elsewhere as well (Chew 2013). At the same time the expectations on what new students know are not changed leading to the increased gap.

Development of the physics education at TUAS and NITTC

Faculty Engineering and Business at TUAS

During the past years the curriculum ICT engineering programmes at the Faculty of Engineering and Business has changed. Changes have been made to introduce learning experiences inspired by the CDIO initiative (Crawley 2014) e.g. a conceive design project has been introduced for all first year students. The course has been successful as introduction to engineering and to motivate student to the field. However, introducing a new courses require that the credits give for other courses are reallocated. During this process the compulsory physics curriculum has been restructured. In the curriculum from 2009 in three courses are included; Basic Physics (3 ECTS credits), Electricity and Magnetism (4 cr) and a Physics Laboratory course (4 cr). In the next curriculum a CDIO inspired course Basics of Science (6 cr) was introduced to make a soft start to science. The content of this course covered the typical content of a Mechanics course as well as some aspects of environment studies. The last major structural change was made for the 2014 curriculum. The year before that the physics package consisted of four courses; Basics of Science (6 cr), Electrostatics and Magnetism (3 cr), Electronics (3 cr) and the Laboratory Course in Physics (6 cr). In the change for the 2014 curriculum all specializations were redefined and the compulsory science courses during the two first years became common for all specializations. In this change the physics curriculum was reduced to two courses; Engineering Physics (5 cr) covering topics from mechanics, electricity and magnetism to heat transfer and optics and Measurements in Physics (5 cr) as a laboratory course.

As can be seen from the development history of the physics curriculum the laboratory course has been of great importance. It has been implemented in such a way that the students work in groups, 3 – 5 students in each and about 10 groups in the laboratory at the time. During one session all groups are working on different topics, i.e. 10 different experiments run simultaneously with two teachers supervising the work. The Laboratory course run parallel to the theory course but the subjects within the courses are not synchronized i.e. some student's do the experiment for a topic before the theory in introduced in the theory class. It is obvious that this is not optimal and as the basic knowledge in physics, that our students possess, is not good it makes the situation more problematic.

Tsuruoka College

National Institute of Technology (NIT) system in Japan is called KOSEN. It is a hybrid system of high school and college with the aim to foster practical engineers and researchers and to serv enrich vocational training (Kosen). After the graduation of junior high school, at the age 15 in the most of cases, the student can enter the NIT colleges. There are 51 colleges in Japan. The regular course consists of a 5 years curriculum and extended with a two year's advanced course for bachelor degree. All the NIT colleges commonly give fundamental physics lectures from high school level to introductory university level following the Model Core curriculum, describing the minimal standard for each subject. The format of the lecture and credits depend on each NIT college.

NIT, Tsuruoka College (NITTC) consists of four engineering courses in Mechanical, Electric and Electronic, Information Technology and Chemistry and Biology, with seven intensive research fields under the Department of Creative Engineering (NITTC 2017). This system was introduced 2015 by unifying the 4 departments to give the students multidisciplinary skills and skills in entrepreneurship. In the present stage, physics classes for all the courses are given from the second grade to the forth (total 9 cr). The education is based on theory classes, including laboratories work. Advanced contents in physics are given according to the specialization of the field of study.

The present teaching style is still mainly lecturing, but we need a change mainly for two reasons. One due to the structural reorganization at NITTC. After the system change, NITTC actively serves lots of opportunities for students to improve their skills, by planning collaboration with companies, a conference for young students, an exchange program with foreign universities, and so on. These activities are aiming to foster an active learner. One difficulty with this activity based education is an attitude problem to studies among the students. In the lecture-based studies the students tend to follow the teacher but in the activity-based model, the students are expected to take action by themselves. To improve this aspect, we need to introduce an environment, in which the students can face problems and carry the responsibility to solve them without teachers lecturing. This should be the case in the daily teaching not only in the special teaching activities.

Another problem is the lack of motivation to study physics. In a theory-based class, the students can learn the systematic aspect of physics effectively. However, this method requires enough mathematical skills, and it is very difficult to have a feeling for the physical phenomenon. Moreover, it is not always clear for the students in the engineering course, why they need to study physics prior to the major subjects. This makes it difficult for the students to keep their motivation to study physics. To improve the motivation and to have a feeling for the phenomenon we have, from 2015, introduced several laboratory works and demos in the class. This has increased the motivation in the physics class somewhat. Due to the limitation of the facility, equipment, and personnel for laboratory works, this activity is still very limited.

PRESENT USAGE OF WEB BASED SUPPORT MATERIAL AT TUAS AND NITTC

Supporting online material is available as is, but mainly for theory studies, e.g. at Khan Academy (Khanacademy 2005). There are also some attempts to do online experiments, e.g. Phet Interactive Simulations for Science and Math (Phet 2002). These sites provide good support for physics education. However, as they are built for a general usage they do not fill the lack of supporting material for a specific set of laboratory work.

Faculty Engineering and Business

Usage of web based supporting material could be a solution to the synchronization problem between theory and experiments. So far web based material has not been used to a larger extent in the physics education at the faculty of Engineering and Business. Two minor tests was performed during the autumn semester 2017. Both tests were small and not scientifically rigorous. The first test was to use an exciting web based experiment from the Phet initiative as a support material for a real experiment. This test was done with a small group of students from our international ICT-engineering class. The second test was to flip and synchronize theory to the lab instead of labs to the theory. The latter test was performed with chemical engineering students at the same faculty. One of the goals with this experiment was to mimic a course with less face-to-face contact with students and more distance learning.

In the first was to introduce the Phet Circuit Construction Kit (Phet 2002) to introduce circuits prior to the actual laboratory work where the students are supposed to first calculate theoretically currents and voltage drops in simple resistance circuits and then build the circuit on a breadboard and measure currents and voltage drops. A typical problem for our students is to realize that they need to break the circuit and connect the current meter inside the circuit to measure the current. This can easily be simulated with the Circuit Construction Kit. Another problem for the students is to translate the schematic drawing of the circuit in the instructions to a real circuit on the breadboard. We hoped that practicing with simulations would help the students to translate the schematic drawing to a real circuit. Feedback was collected as an open written feedback where the student was asked to comment on the simulation software and the benefits of the using the software. Their performance during the lab was monitored by the author. In most of the comments the students found the software easy to use and it was easy to build the circuit and measure the current and voltage drops. They did also find the beneficiary as supporting material. However, they didn't seem to perform significantly better during the actual lab than previous classes. One student also commented that the breadboard was still difficult to use and it was also physically difficult to build the circuit with the small components.

To synchronize theory teaching to the lab schedule was tested on one group of students (n = 43) at the chemical engineering programme. The group was divided into 10 subgroups with 4 to 5 students in each group. The course was split in a theory part and a practical laboratory part. The fact that the subgroups do different laboratories from different fields during one laboratory session introduce a problem in synchronizing theory teaching to the laboratory teaching. It is not possible to teach all the theory at once and at the same time it is not possible to increase the number of theory lectures.

The content of the course was electricity, magnetism, optics and radiation physics. The obvious way to teach these subjects is to do it in the mentioned order. In this implementation we had to break the order. This was done so that the theory lecturing was drawn to a minimum and replaced with time for students to do pre-assignments. The pre-assignments where chosen so that the theory needed for the pre-assignments covered theory needed for the labs but was extended beyond that so that it covered the whole content defined in the study plan. All students were supposed to return their solutions to the pre-assignments before the end of the course. The returned material was a part of the assessment together with an individual exam at the end of the course. The minimum requirement to pass the course was that the student participated in all laboratories and did the laboratory reports as well as the pre-assignments. The result from the exam gave 30% of the final grade and laboratory work and the pre-assignments gave 70% of the grade.

An arrangement like this creates high demand on the self-study material given to the students. The tuition language for the chemical engineering group is Finnish which limits the available material. There are two physics book series written in Finnish especially for universities of

applied sciences, both consisting of two books; Momentti 1 and 2 (Inkinen 2017 and Inkinen 2012), and Insinöörin (AMK) Fysiikka part 1 and part 2 (Hautala 2016 and Peltonen 2012). Web based material in Finnish is provided by OpetusTV (https://opetus.tv/). The students were also encouraged to read books in English and to use English Web-based material but they were free to choose the supporting material to their own taste.
The physics web material at OpetusTV is divided into material for the University and Universities of Applied Science level and upper secondary school level. Even though the former is dedicated for the University of Applied Science level it was considered too demanding. This is not surprising as many of the students had not study physics during their upper secondary school. Thus the latter material, aimed for the upper secondary school, was more used.

Synchronizing theory to the laboratory work seems to work. However some improvements needs to be done. The deadline for the pre-assignments should be just before the corresponding laboratory session or at latest the same day. In the present test some students made their pre-assignments too late, at the end of the course, to give the benefit of connecting the theory to the practical laboratory work. Another mistake in this implementation was that the assessment was to strongly depending on laboratory work and the pre-assignments. The goal was to steer the students to work on the pre-assignments and in the laboratory. This worked, but as the students did this work in groups, and the weight of the exam grade was low they got easily good grades. It seems that they did not focus on learning just finding solutions to pass the course.

To develop this course towards a semi-online course with more distance learning would require more dedicated web material. Simulations of the laboratories to be done could be beneficiary. Also the online material for the theory part could be more dedicated to the course given. There could e.g. be online support for solving the pre-assignments.

Tsuruoka collage

In the view of the new situation, we have tried to introduce a simulation-based virtual laboratory environment since 2017, developed using HTML5. The created simulators are used in class. Although, needless to say, the real experiment is the most important aspect in physics, there are some advantages in the simulation especially for the educational purpose. One of them is that we can show the ideal situation in the simulation easily. Some of experiments are technically demanding. Furthermore, there may be some errors in the instructions. This makes it difficult for the students to catch the essential points of the phenomena, especially at the elementary levels. In simulations we can change the environment easily and repeat the simulations many times. Hence, the student can use the simulator in many stages of the study.

At the present stage, the created simulators are mainly used as a pre-assignment prior to the theory class, and for confirmation of a presented theory. For example, the simulator for falling motion is initially used to compare the horizontal throw motion with the free fall without any introduction of the theoretical aspect by the teacher. First he students analyze the phenomenon by themselves. After that, the teacher introduces the theory, and finally the students again examine the simulation for the confirmation of the theory. The created simulators are available on the course web page, and the students can use them any time. Introduction of the simulator, resulted in positive feedback from the students. Especially, the students' motivations are effectively improved, because what they need to learn is clear, and they can have some feeling for the phenomena they are studying. At the present stage, the simulators for free falling motion (Figure1), reflection of a sine wave (Figure 2), and the interference of waves, are available.

We have chosen HTML5 for the simulation environment due to the following reasons:
(1) HTML5 programs is executed on the client computers. Hence, the load on the server is minimal.
(2) The update of the program is just to replace the program on the server.
(3) There is almost no environment dependence, only the web browser is required.
These aspects make the implementation and management in the lecture easier.

In our implementation, we have used Three.js (Three 2017) for the animation and jqPlot library (Leonello) for the graph. We have tried to couple the animation with the graph to enhance the connection between theory and experiment, as seen in Figure 1. Our activity is inspired by that in (Naturalscience). This simulator building is running as a student project in NITTC. Through this project, the students can learn physics more deeply, and adherently they can improve their programming skills. The feedback students give while developing simulators is a valuable resource for the teacher to understand the difficulties that the students face when they try to understand a phenomenon.

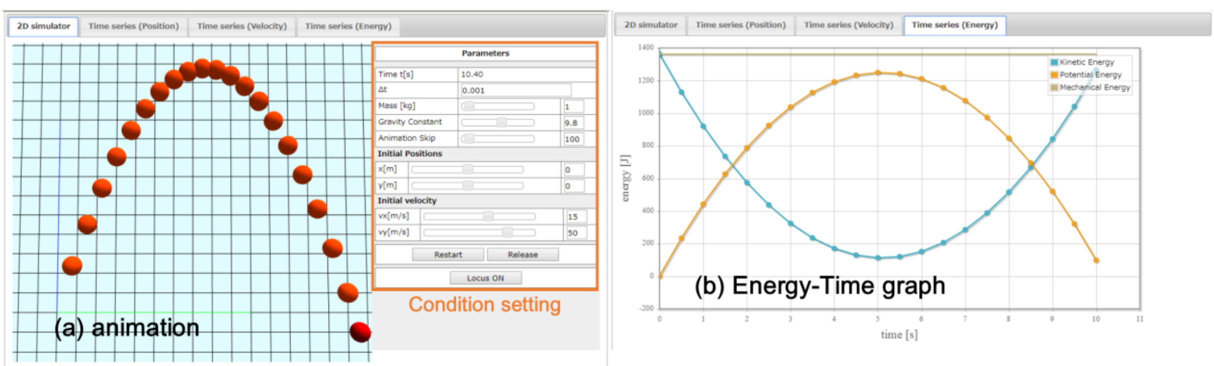

Figure 2. The simulator of the falling motion with animation (a) and Energy-Time Graph (b).

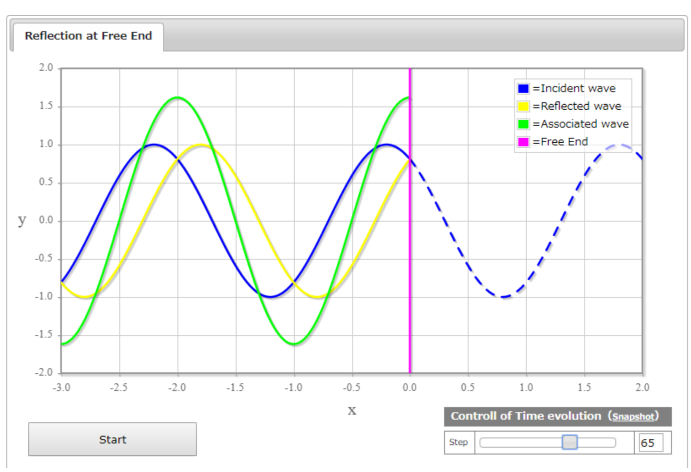

Figure 2. The simulator of free end reflection of a sine wave.

DEVELOPING COMMON SUPPORT MATERIAL AND FURTHER COOPERATION

The aim of this project is to develop online support material for physics education. The starting point is the cooperation between NITTC and TUAS. The aim is that it should be an open cooperation where lecturers from different institutions can get support to develop dedicated material for their own courses and share the material with their colleagues at other institutions.

Within the cooperation between NITTC and TUAS we have started to build HTML5 simulations to visualize physics. At TUAS the focus is on simulations of laboratory experiments. During the autumn semester 2017 two Japanese exchange students worked on these simulations. One simulated a heat transfer laboratory work and the other one worked on simulating a laboratory where the permittivity of air is determined with a current balance.

At NITTC, HTML5 simulations are built with the assistance of students. To increase the cooperation and to build more simulations, we are planning to extend the cooperation not only on teacher levels, but also using the international exchange program running between TUAS and NIT.

Common lectures using HTML5 simulations at both TUAS and NITTC may be possible. Within the cooperation we can analyze the differences originating from different learning cultures. HTML5 simulations and an online assignment of the theory (on balckboard) may become a package of online physics and as a tool for independent work for an active learner.

While the physics laboratories in TUAS and NITTC are cooperating and sharing their knowledge and skills to improve their lectures, they have their own problems, requirements and purposes with the lectures. An important thing in this collaboration would not only share the HTML programs but also share the skill to build them. An open platform allows change of the programs to develop them to fit the partners own purpose. At this point, we do not limit the number of partners and would like to invite other physics lecturers to join our project.

CONCLUSIONS

This paper presents an attempt to jointly create online teaching material for physics courses. The material should both support theory lectures and laboratories. Writing simulations in HTML5 makes the simulation easy to use it is also easy for the students to participating in the programming of the simulators.

Simulators have been built for a current balance, a projectile motion experiments and for visualizing reflection of a sign wave. Furthermore, teaching experiences have been tested both at Tsuruoka College and the faculty of Engineering and Business. These tests have not been scientifically solid but the results indicate that web based online material can help the students to learn physics. Designing and building new online experiments can be done as student projects and thus generate integrate learning experiences in both programming and physics.

The project is at an early stage but the aim is to deepen the cooperation within the project and to design common learning experiences. We are also interested in increasing the number of partners in the cooperation.

REFERENCES

Chew, C. M., Noraini, I. & Leong, K. E. (2013). *Secondary Students' Perception of Assessments in Science, Technology Engineering and Mathematics (STEM)*. Eurasia Journal of Mathematics, Science & Technology Education, 10(3), 219-227

Crawley E.F., Malmqvist, J., Östlund, S., Brodeur, D.R., Edström, K. (2014). *Rethinking Engineering Education - The CDIO Approach*. New York, Springer

Hautala M., & Peltonen P. (2016). *Insinöörin (AMK) Fysiikka osa 1*. Lahti: Lahden Teho-Opetus

Inkinen, P., & Tuohi J. (2017). *Momentti 1*. Helsinki: Otava

Inkinen, P., & Tuohi J. (2012). *Momentti 2*. Helsinki: Otava

Khanacademy, (2005). [Online]. Available: https://www.khanacademy.org. [Accessed 9 November 2017].

Kosen (2009). http://www.kosen-k.go.jp/english/

Leonello C., and Prichard P., http://www.jqplot.com/

Metsämuuronen, J. (2017). *Oppia ikä kaikki – matemaattinen osaaminen toisen asteen koulutuksen lopussa*. Finnish Education Evaluation Centre (in Finnish)

Naturalscience, http://www.natural-science.or.jp/laboratory/physicsjs.php (in Japanese)

NITTC (2017). *National Institute of Technology, Tsuruoka College College Catalogue*. http://www.tsuruoka-nct.ac.jp/wp-content/uploads/2017/07/souran2017.pdf

Peltonen P., & Hautala M. (2012). *Insinöörin (AMK) Fysiikka osa 2*. Lahti: Lahden Teho-Opetus

Phet (2002). *Phet Interactive Simulations for Science and Math*. University of Colorado Boulder. [Online]. Available: https://phet.colorado.edu/. [Accessed 9 November 2017]. https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab

Three (2017). https://threejs.org/

BIOGRAPHICAL INFORMATION

Patric Granholm, is a Principal lecturer at the Faculty of Engineering and Business at Turku University of Applied Sciences. His current teaching focuses on the introductory physics, sensor technology and statistical data analysis. He is actively developing teaching methods in these subjects. His current research activities focuses on nuclear structure physics and gamma ray spectroscopy as well as Monte-Carlo simulations of neutron radiation.

Hiromasa Ohnishi, is an Associated Professor at the Department of Creative Engineering at National Institute of Technology, Tsuruoka College. His current teaching focuses on the introductory physics, and the solid state physics. He is actively developing teaching methods in these subjects. His current research activities focuses on theoretical and computational study of photo-excited dynamics of electrons and phonons.

Corresponding author

Patric Granholm
Turku University of Applied Sciences
Joukahaisenkatu 3C
20520 Turku, Finland
+358 50 5985760
patric.granholm@turkuamk.fi