Interactive e-learning content for physics

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Abstract

Nowadays, internet and multimedia are important sources of information. Teaching processes have to adapt to these, but information-communication technology (ICT) also offers the chance to develop new teaching methods that are specifically designed to exploit the advantages of ICT over traditional methods, rather than trying to convert traditional methods to an ICT form.

Within the frame of a national project we are developing e-learning material to be used by high-school students (age 15-19). In developing the material we were aiming for more interactivity and contextual richness, by including examples from the "real world" and measurements of actual experiments, and for dynamic adaptation of the task's difficulty and pace to the users’ achievements.

We developed interactive graphical tools and incorporated them into the problems. The feedback and the flow depend on answers, given on previous steps. After a failed attempt, the user is provided with hints to try again, or is led along a longer step-by-step route to the solution. Feedback on students’ performance is provided to teachers, who can choose the detail of this information.

The material is comprised of blocks (individual, independent short tasks). A teacher can build a worksheet from these blocks, or build a task from scratch. The design of the content is entirely separated from the technical aspects, so the teacher can focus entirely on the content. Our team is developing an online platform where materials can be created and the required interactivity added. The material can also be exported as a SCORM package.

Introduction

As part of a national project, funded by the Slovenian Ministry of education and sport and co-funded by the European social fund, we developed e-learning material that is freely available on the internet. Our main goal was to exploit the pedagogical value of the interactivity made possible by current internet technology, and to let the material be designed by experts in the field of physics education, which included active secondary school teachers and university staff working in teacher training programs.
We started off by identifying, common flaws of most of the existing material which we summarised as:

- lack of interactivity,
- problems are too unidirectional in the sense that answers do not affect the flow,
- poor feedback to the user.

Next we decided on guidelines to follow in developing the new materials:

- as much interactivity as reasonable and possible,
- nonlinearity (as opposed to unidirectional approach) in the sense that answers from the user should influence the following steps,
- rich feedback to the users, with explanations and hints,
- include phenomena from "real life",
- provide detailed feedback to the teachers.

In the end, all the materials developed that passed our internal quality inspection were published on the portal [www.nauk.si](http://www.nauk.si). The portal is developed so that it allows further development, modification and use of the materials, which are published under the Creative commons attribution, non-profit, share alike licence, which means that everybody is free to use, distribute, modify and make derivative works of the materials, provided the original author is attributed, the purpose is non-profitable, and the resulting material is published under the same licence.

**Method**

Our team consisted of two groups. One group consisted of the authors of the materials which were all experts in physics education. The other group consisted of information-communication technology (ICT) experts, who were responsible for the implementation of the ideas that came from the first group as well as for general structure of the ICT environment.

*Design of the tasks*

The tasks were designed according to the before mentioned guidelines.

To achieve interactivity, the ICT team developed different tools, starting with the commonly used single choice, multiple choices, and numeric answers. In addition to these, tools have been developed to draw lines and vectors, and measure distances and angles. These can be used on pictures and videos. Also, a matching tool was developed that allows the user to match entities from one column to those from another. Among other tools there is also a star-map tool that allows the user to interactively use the star-map of the local sky.

To achieve nonlinearity, the problems were designed as a nonlinear tree, where depending on the response to specific question different feedbacks and different routes are taken in the proceeding steps. In implementing this feedback loop, we adopted four guidelines:

- At the first failed attempt, the feedback provides hints depending on the user's responses.
• After two failed attempts, the program reveals the solution, briefly explaining the necessary reasoning to reach it. We found this two attempts guideline necessary to avoid frustration from getting stuck at one problem.

• In cases when the solution requires multiple steps, the user is guided through the necessary intermediate steps, applying the above guidelines at each step.

• In case of a correct answer, the program still provides a brief explanation, so that the user can double-check his reasoning.

The tasks are, where appropriate, derived from real life problems or real experiments.

Underlying technology
The ICT part was done by team NAUK (NApredne Učne Kocke – Advanced learning blocks). The name is derived from the ambition to develop the materials as blocks (independent tasks) that can be combined together to form a more complex task according to the author's specific needs. The word "nauk" in Slovenian also means "teachings", with a somewhat archaic connotation and "moral of a story".

The portal is based on Ajax methods. It uses Hypertext mark-up language (HTML) and Cascading style sheets (CSS) for page design, Flash to provide interactivity, Extended mark-up language (XML) and Comma-separated values (CSV) for data storage and settings and a Wiki-like mark-up called fwiki for writing content, all bound together by JavaScript. All of the technologies used are supported by all contemporary major browsers, and installed by default on many computers, therefore very little, or no additional installations are required by the user.

The reason for introducing the fwiki syntax was to separate the content part from the underlying technology. We assumed that good authors do not necessarily have programming knowledge required to implement their ideas. Therefore, authors used the relatively simple fwiki syntax to write the content, decide on branching, insert required tools, etc. while all the underlying technology, (links, jumps, Flash tools, JavaScript) was provided by the NAUK team. The portal has an input field for the fwiki content and a parse button to translate the fwiki into HTML, adding all the required functionality.

The material produced can be exported as an HTML page with accompanying files, or as a SCORM package.

Results
The portal www.nauk.si is open and accessible to the public. The materials are published under the before mentioned Creative commons licence. Currently they are mostly in the national language, but some of them, have been translated to English to encourage internationalization.

Results are best shown through examples.

Car in a curve
A car has been driven through a curve. The curve has been identified on satellite/aerial photos of the area. The scale of the image has also been found. A pendulum, hung from the rear-view mirror, has been photographed while driving through the curve. The task in
the material, developed using this data, is to determine the speed of the car. The calculated result is then compared to the picture of the speed indicator, which has been initially blacked out.

The material provides the user with the picture of the curve and the tool to measure distances, which has been adjusted to the scale of the picture. The tool therefore already displays distances in actual real-life meters. A picture of the pendulum is also provided with the tool to measure angles. Care has been taken to assure that the picture preserves the angles of the real-life objects.

Example

A car is driving on the curve shown on figure 1. A pendant is hanging from the rear-view mirror. The driver sees the view shown on figure 2. Determine the speed of the car.

\[ v = \frac{\text{distance}}{\text{time}} \]

I would like to solve this step by step

Figure 1

Figure 2

Figure 1: An example of a task.

The user is asked to determine the speed of the car. This task requires several steps and the data has to be measured from the pictures.

If the user's first attempt is unsuccessful, since there are so many possibilities where the process could have gone wrong, the user is provided just with some general tips on problem solving, such as:

- Consider that moving through a curve at uniform speed is an accelerated motion, more precisely circular.
- Consider how the speed of the circulating object is related to its acceleration.
- Consider the relation between the motion of the pendulum and the car.
- Consider the forces on the pendulum in a circular motion and how they relate to its acceleration and its displacement angle.

The user is offered two choices: 1) to return and try to solve the problem again, or 2) to solve the problem step by step. After a second unsuccessful attempt the program leads the user through the step-by-step path.

The first step is to determine the radius of the curve. The user is given an explanation of why this is necessary, such as:

"To determine any quantity in a circular motion it will be most likely necessary to know the radius of the motion. Therefore, determine the radius of the curve."
This task may appear easy, but the centre of the curve is not marked on the picture, therefore the user is required to determine it himself. Failing to do so might yield a wrong result. In such case, the user is given a tip such as:

"Unfortunately, the answer is incorrect. Bear in mind that the centre must be at equal distance from all points on the curve. Use this to determine where the centre is and what the correct radius is."

In case the answer is still incorrect, the user is given the result and an explanation, according to the two attempts guideline. The feedback in this case could be such as:

"Unfortunately, the answer is incorrect for the second time. The correct answer is \((46 \pm 1)\) m.
To measure the radius of the curve, you must determine its centre. Use the measuring tool to find such a point and then measure the radius of the curve."

The text may be accompanied by pictures for clarification.

The next task is to draw the forces on the displaced pendulum. For this purpose a "vector" tool is provided. It enables the user to draw vectors on the picture and move them around. Features also include drawing a vector parallel to the chosen one and
perpendicular to it. By moving the vectors around one can also visually construct a summation triangle or parallelogram.

Figure 4: An example of the use of the "vector" tool.

The next task is to determine the relation between the displacement angle of the pendulum and the resultant on it. The expression involves the tangent of the angle, so it becomes evident that for further calculation, it is necessary to measure the angle. This can be done by using the angle tool.

Figure 5: An example of the use of the "angle" tool.

The task continues through all necessary steps to arrive to the final answer: the speed of the car. Ideally, each step is explained so that the user is informed why it is necessary. Feedback is provided always by the same, before mentioned, guidelines.

A second example shows more tools.

Bounce of a tennis ball
A ball has been filmed running on a flat, horizontal surface, then bouncing off a force meter on one end and returning towards its original position. The ball's position is measured with an ultrasound sensor.

The task we will analyze here requires the user to determine the position-time dependence of the ball's motion.
The user is shown the movie and asked to predict the shape of the position-time dependence.

Figure 6: Movies or videos can also be included in the material and provide the source of data.

One way to do this is to use a multiple-choice question with different graphs as options. The choices should be such that they provide some insight into the possible misconceptions of the user. In Figure 7, for example, the bottom left graph is the correct answer, but the top right graph is the correct graph for velocity vs. time. Using such "meaningful" alternatives that address common difficulties, the statistics may provide valuable insight to the teacher on the level of knowledge of the users, but the feedback should include a warning to pay attention to the quantities on the axes, as being negligent is a very common source of errors.

Figure 7: An example of a single choice question. A "meaningful" set of choices can provide insight in the reasoning and difficulties users have with the material.

Instead of giving the right answer we use the graph obtained by actually measuring the experiment while filming it. The program allows us to import a CSV file as a source of
data for the graph, and provides a tool to read the data off the graph. Most programs dealing with tables can export data in CSV.

Figure 8: A graph of an actual measurement with the tool to read it.

This graph can then be used for subsequent tasks of determining the velocity before and after the collision, and from there the momentum. A similar graph of force vs. time is later used to estimate the impulse of the force and compare it to the change in momentum.

At the moment 49 materials are published for the secondary school level of physics and many more for primary school level and other subjects, namely mathematics and informatics.

**Conclusion**

**Plans for the future**
The project ended on 30.8.2010. However, the NAUK team has decided to keep working on it and add some functionality that was suggested, but there was no time to implement it.

A functionality that was intended from the beginning but has not been implemented yet is the analysis of all drawn lines. This would enable the analysis of vectors, and the addition of tasks such as drawing vector fields and forces.
This would also enable the analysis of polygonal lines, called "polylines" that can be used to draw graphs or sketches thereof, such as drawing the prediction of the position-time dependence of a movement. At the moment "polylines" can be drawn, but not analysed.

![Figure 8: A polygonal line ("polyline").](image)

In the future, the program should be able to log all the activities of a user during the problem solving procedure, and therefore provide as feedback to the teachers the exact steps the user performed while solving the problem. This should allow the teacher to identify similarities in the solving process of various students and determine what topics might need further discussion in class. A simple feedback in terms of achieved points, number of correct and incorrect answers is already available.

In terms of author input, a visual builder is planed, similar to popular programs for designing presentations, but it has not been implemented yet.

**Conclusion**

We started from a standpoint that ICT is an independent medium that can be used to present physics content. Therefore, we did not attempt to adapt types of tasks found in other media for ICT environment, but rather identified what we believe to be specific advantages of ICT and focused on developing content specifically designed to best exploit these advantages.

During the process we were also aware of the limitations and disadvantages of ICT and tried to avoid content that would be better presented in other media or other settings.

As a result, we produced materials that are now freely available for use and modification under the Creative commons attribution, non-profit, share alike licence on [www.nauk.si](http://www.nauk.si). Some of the material has also been translated to English to encourage internationalization.
References


