Adding value to Physics Education Technology simulations

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Abstract: The Physics Education Technology (PhET) group at the University of Colorado, Boulder has created more than 60 open source, research based simulations that cover concepts in basic physics to state of the art research. We have added value to some of the PhET simulations by tinkering with the source code. The modified simulations are easily embedded into collaborative learning environments and online assessment systems. We believe this will lead to enhanced student interaction and learning outcomes. Examples of how we use these simulations in two open source environments will be presented. The first is a MediaWiki *(the software that runs* Wikipedia*) wiki installation and the second is an Online ASsessment and Integrated Study (OASIS) installation.*

Introduction

The Physics Education Technology (PhET) group at the University of Colorado at Boulder have developed a suite of realistic, open source simulations that cover the main topics in introductory physics courses at the university level (as well as some covering advanced topics). These simulations are a hit with all age groups who try them – from budding physicists to wily professors. In this paper, we explore two methods for adding value to the flash based PhET simulations. We will discuss embedding the simulations into an evaluative system and embedding them into a wiki. Using these simulations has allowed us to engage more effectively the students in learning and conceptualisations. This has been particularly true with our introductory stage one course in physics for which the students usually need extra motivation to engage in learning.

Methods

We chose to work on the PhET simulations because of the research that has been conducted on their effectiveness and user friendliness (Adams, Reid, LeMaster, McKagan, Perkins, Dubson and Wieman 2008a; Adams, Reid, LeMaster, McKagan, Perkins, Dubson and Wieman 2008b). As with most things, the PhET simulations can be improved. We have found that the lack of automated control over the *important* variables in the simulations as one area where they can be improved.

At this stage an example may help clarify our intentions. The Mass and Spring laboratory simulation is one of the most popular PhET simulations and is available for free download at http://phet.colorado.edu/. The figure below is a screenshot of the modified simulation. As you can see in Figure 1 there are three springs, four known masses, and three unknown masses. Based on this simple list of equipment several activities can be conceived.

In the original simulation, the user only has control (via sliders) over some of the properties in the equipment list. For example, the spring constant for the third spring (right most spring) and the friction can be varied. The spring constants for the other two springs and the values of the original masses (50g, 100g, 200g, and 100g) cannot be manipulated. This limits the activities that can be constructed around the simulation.
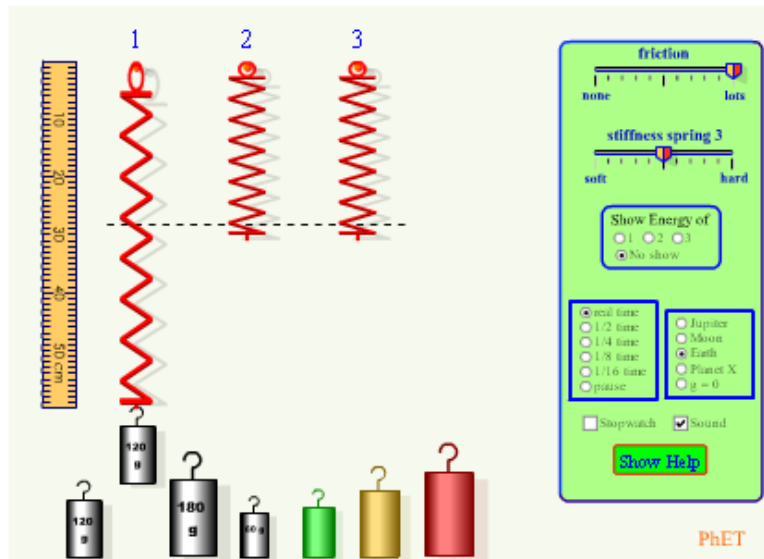
Figure 1. Screen Capture of modified PhET Mass and Spring Simulation

For many activities, like virtual laboratories and evaluative systems, it is preferable to set the values of the masses and spring constants at the time the simulation is loaded. The *Flash* application with which the simulations were written has a simple method of doing exactly this and it is documented in the user manual. Essentially, values for variables within the simulation can be passed to the simulation using the **FlashVars** parameter in a dynamic html environment. An example of some code that sends 60g for mass one and 120g for mass two to the mass and spring flash simulation is shown below:

<embed src= "massandspring.swf" FlashVars="massOne=60&massTwo=120">

In addition to **FlashVars= "massOne=60&massTwo=120"** being included in the html <embed> tag, the simulation needs to be modified to handle the **FlashVars** parameter. This can be done quite easily because the source codes of the PhET simulations are available for download at the PhET website. Obviously, that would not be possible with closed proprietary simulations. To allow the simulation to use the value of 60 g for mass one, we can add the code below to the initialisation function of the simulation

if (level0.massOne!=null): mass1=level0.massOne

This line sets the value of the internal variable **mass1** to the **FlashVars** parameter **massOne**, if **massOne** has a value. If not then **mass1** would be left as the default value from the unmodified simulation. A similar line of code could be added for each mass and each spring constant allowing complete control over all of the important variables in the simulation.

We have done exactly this for several of the PhET simulations, including the Mass and Spring simulation and believe it is a significant improvement over the static values in the original simulations. With the modified simulations an educator can now ask the same question to any number of students but with different values to probe the learners' understanding of a concept or method or construct a group activity where all the students use different masses.

Using the improved simulations in various online environments

Examples of the value added simulations in use will be discussed below. Initially, we will describe how the modified simulation is used in the online assessment system called OASIS. Secondly, we will describe how the modified simulation is used on a wiki environment – specifically *MediaWiki*

wikis. We choose these examples because they are 'open source' environment and therefore allow us to share our resources with other physics educators.

Figure 2. An ample of formative assessment using OASIS in which we have embedded the added value mass and spring simulation from PHET

Online assessment environment

The evaluative system we chose for this example is the Online Assessment and Integrated Study (OASIS) software developed at the University of Auckland. We chose OASIS for several reasons. Firstly we have previous experience with the software (Kruhlak, Mullins, Coghill and Ng 2005) and secondly it has recently become 'open source' software that is available for free.

Using the value added simulation in OASIS takes advantage of the power in randomised data sets in that each student receives unique data with which to complete their assignment. For simplicity we choose a question that uses the Mass and Spring laboratory simulation. In this example the student is to determine the unknown spring constant for one of the springs by measuring the displacement for three different masses. Then plot the results and finally calculate the spring constant from the slope of the graph. A screenshot of the question (with the simulation omitted) is shown in Figure 2.

This question could be used as a pre-laboratory exercise or part of a formative assessment. The results table associated with Figure 2 is shown below in Figure 3.

Part	Your Answer	Correct Answer	Tolerance	Marks	Comment
1	4.0	4.41	2%	0.0	Incorrect (click here)
2	None	1.0	1%	0.0	Incorrect Units
3	9.0	8.82	2%	1.2	Almost correct, try zooming in on the ruler. (click here)
4	None	1.0	1%	0.0	Incorrect Units
5	20.0	20.05	2%	1.5	Correct
6	None	1.0	1%	0.0	Incorrect Units
7	0.16	0.098	2%	0.0	Incorrect (click here)
8	None	1.0	1%	0.0	Incorrect Units
9	0.0	0.0	25%	1.5	Correct
10	None	1.0	1%	0.0	Incorrect Units
11	None	10.0	4%	0.0	Incorrect (click here)
12	None	1.0	1%	0.0	Incorrect Units
				Total: 4.25	

Figure 3. Results table for Figure 2

Hyperlinks send the students back to an appropriate page on the web where they can find the resources to correct their mistake(s). These are coloured in the result table on the screen. When OASIS is used for formative assessment, the students can redo the same exercise over and over until they feel confident with their understanding of the concepts or methods. As you can see in the in Figure 3 (answer 3), the answers that the students submit are screened for appropriate feedback.

The Wiki environment
We know transition to the examples of the value added simulation embedded into MediaWiki wikis – the same software that powers Wikipedia, Wiktionary, Wikibooks, etc. Again for simplicity, we discuss the Mass and Spring simulation which has been embedded into a wiki webpage in a distance learning lesson at http://www.wikieducator.org/ and one that was developed for a conceptual physics course at the stage one level.

Wikieducator, a MediaWiki installation, is a community project working collaboratively with the Free Culture Movement (http://en.wikipedia.org/wiki/Free_Culture_movement) towards a free version of the education curriculum by 2015. The lesson is quite long as it must motivate the learner and be self-contained to meet the requirements of the distance learning environment and can not be included here. However, the entire lesson can be accessed at wikieducator.org/Masses_and_Springs/Hooke's_Law (http://www.wikieducator.org/Masses_and_Springs/Hooke%27s_Law).

For the conceptual physics course the simulation was used as a virtual laboratory. The students were asked to record the period of the oscillation of Spring 1 for several masses. The results were entered into a data table on a separate wiki page. Figure 4 shows snapshots of the data table from the beginning of the assignment to the end in a clockwise direction. The figure was created from the page history in the wiki which keeps a complete record of all edits. It is clear to see that the students were

engaged in the learning process. In most cases they were able to determine an incorrect measurement from an incorrect one (see the tables in Figure 4). They also added an additional column in the data table to record the spring stiffness which was not part of the original task.
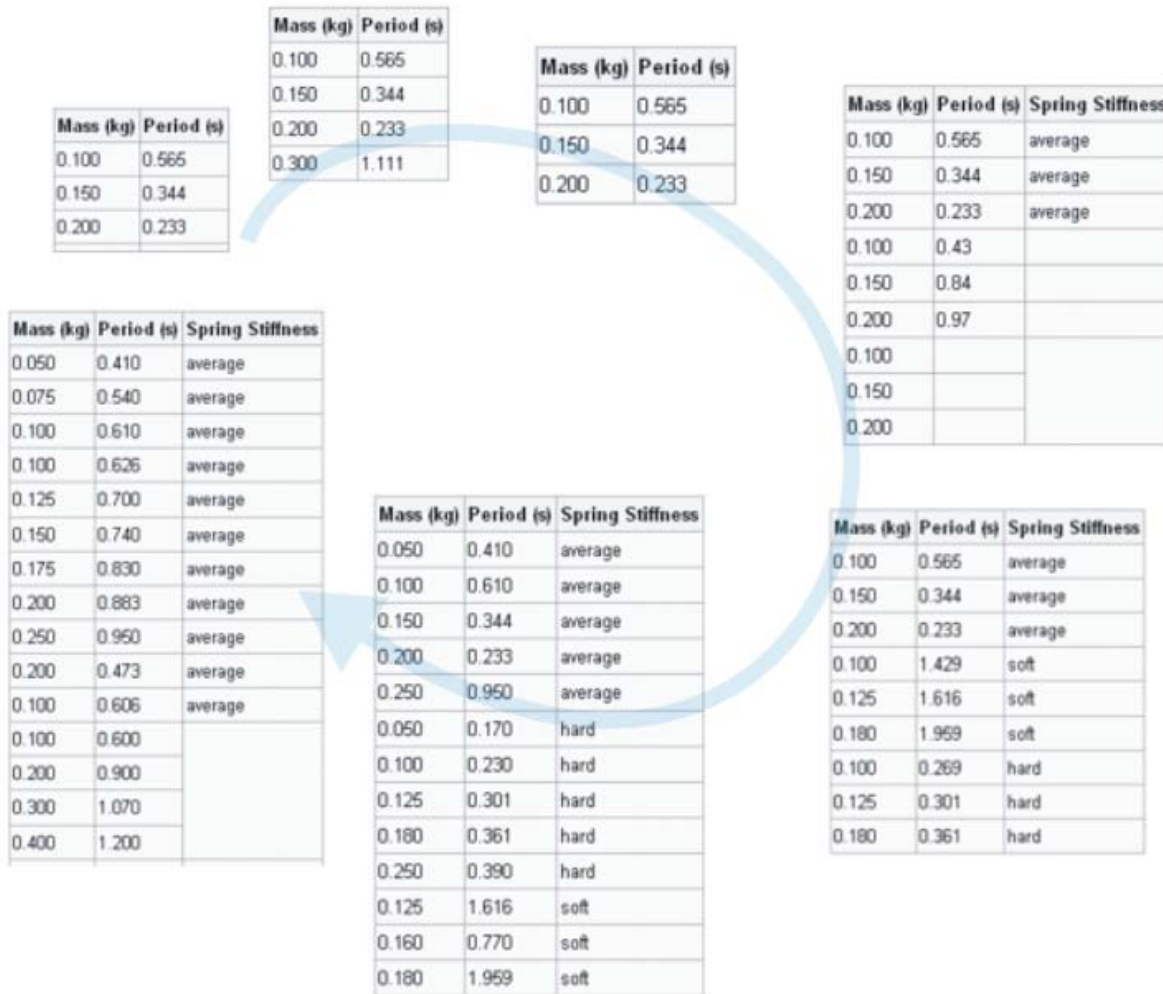
Mass (kg)	Period (s)
0.100	0.565
0.150	0.344
0.200	0.233
0.300	1.111

Mass (kg)	Period (s)
0.100	0.565
0.150	0.344
0.200	0.233

Mass (kg)	Period (s)	Spring Stiffness
0.100	0.565	average
0.150	0.344	average
0.200	0.233	average
0.100	0.43	
0.150	0.84	
0.200	0.97	
0.100		
0.150		
0.200		

Mass (kg)	Period (s)
0.100	0.565
0.150	0.344
0.200	0.233

Mass (kg)	Period (s)	Spring Stiffness
0.050	0.410	average
0.075	0.540	average
0.100	0.610	average
0.100	0.626	average
0.125	0.700	average
0.150	0.740	average
0.175	0.830	average
0.200	0.883	average
0.250	0.950	average
0.200	0.473	average
0.100	0.606	average
0.100	0.600	
0.200	0.900	
0.300	1.070	
0.400	1.200	

Mass (kg)	Period (s)	Spring Stiffness
0.050	0.410	average
0.100	0.610	average
0.150	0.344	average
0.200	0.233	average
0.250	0.950	average
0.050	0.170	hard
0.100	0.230	hard
0.125	0.301	hard
0.180	0.361	hard
0.250	0.390	hard
0.125	1.616	soft
0.160	0.770	soft
0.180	1.959	soft

Mass (kg)	Period (s)	Spring Stiffness
0.100	0.565	average
0.150	0.344	average
0.200	0.233	average
0.100	1.429	soft
0.125	1.616	soft
0.180	1.959	soft
0.100	0.269	hard
0.125	0.301	hard
0.180	0.361	hard

Figure 4. History of the results as entered by the students in the wiki

A figure representing the final data table was added to the wiki. It is quite clear that the students were able to collect reasonable results except in the case of the one outlying point. This leads to a good discussion in the lecture which summarised the general trend and types of error. In addition, student evaluations were generally positive with regards to working within the wiki. This has led us to consider a more rigorous virtual laboratory in the future. For example, we could ask the students to take 4 measurements each and to fill a table of data. When each student has played with the simulations and taken the

Figure 5. Graph of the results for Figure 4

measurements, they can analyse all the data, i.e. calculate the different parameters as well as the mean and the variance. The discussion about the virtual experiment would then be conducted in class.
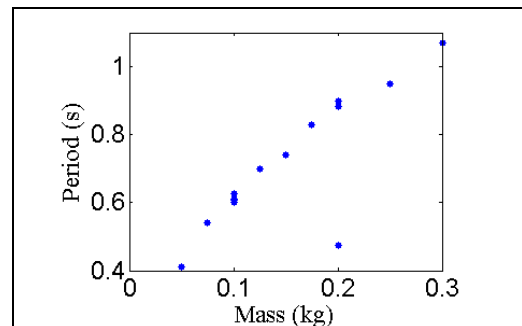
There are multiple advantages to this approach. First it reduces the cost for the space and the equipment necessary to develop such a laboratory in a laboratory. Secondly, it reduces the risk for

faulty apparatus which often deters students with a weaker background in physics. Thirdly, it saves considerable time for the students as they do not spend time fiddling with the equipment and a bigger data set can be taken as they share their results. Lastly, it gives the opportunity to the student to learn wiki edition rudiments.

Discussions and conclusion

In summary by modifying the PhET simulations and embedding them in different open source environments, we have created several useful resources for physics educators. These simulations are user friendly and they employ game features which are essential properties of educational software (Polonoli 2000). By using these simulations in the wiki environment, we have increased the student participation inside and outside the classroom. Also we have increased the student interaction. However, the role of the lecturer was pivotal in achieving a high level of participation (Yeo, Loss, Zadnik, Harrison and Treagust 2004). In order to develop these online embedded simulations into real education software or package, more refinement will be needed according to previous studies (Crosier, Cobb and Wilson 2002) and the study is only at its early stage. These simulations can be used at no cost and could potentially replace costly and time consuming assessment and laboratory. A virtual laboratory should encourage introductory level students to engage with the concepts and it could be used as preparation for the laboratory sessions in higher level physics courses. In the near future, we will develop these virtual laboratories further and measure the impact on the student conceptualisation and engagement.

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