Using Technology to Provide an Interactive Learning Experience

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Abstract

Most pedagogical material found on the Internet today is still very passive; merely electronic versions of books, notes and other traditional learning material, little changed from before the Internet. In this paper we will describe two interactive, online text books one of us (Forinash) has written that use simulations to engage students in active learning. We will also briefly describe other work we have done involving real (as opposed to virtual) student laboratory experiences outside the classroom using mobile devices such as tablets and smart phones.

Keywords
Interactive media, ebooks, smart phones, tablets, mobile devices.

Interactive?

Gutenberg's invention of movable type around 1450 did not revolutionize the content or the format of the information being provided. It did have the important consequence of speeding up and broadening access to information. In a similar way, much of our modern technology, especially the Internet, has accelerated and expanded access to the world's knowledge base. Instructors today routinely provide a course syllabus, course information, instructor notes, assignments, sample tests, supplementary reading, and web links to other material, all online using a course management system or simple web pages. Many university students now receive access to a PDF version of the course textbook when they register for a course.

These uses, however, are _not_ interactive. Much like an enhanced printing press, this technology serves to accelerate the one way transfer of material from the instructor to the student. In this regard it is not much different from what was already being done 560 years ago by Gutenberg; the information flow is unidirectional, albeit much faster. While, in hindsight, Gutenberg's creation was seminal to mass education, the communications revolution of the past century has yet to produce comparable improvements in human learning. However, today's technology, the Internet in particular, has the capacity to function much more interactively in a bidirectional and even multidirectional way.

What do we mean by interactive? Email, group email, chat rooms, web feedback pages, clickers, QR codes, and interactive whiteboards are all two-way communication tools using technology adaptable to education. Some classes on our campus require students to create

collaborative knowledge bases such as wikis, class web sites and blogs which are multi-participatory. Contributions to a web site about environmental issues have been a requirement for an upper-level environmental physics class taught by one of us for eight years and the students always rate this as a valuable part of the course in end of semester student evaluations. One of us has taught a philosophy of science course where students could anonymously post an essay for other students to comment on before making final revisions for submission for a grade, thus taking advantage of peer review and a type of crowd sourcing (student response was very enthusiastic). Pre-lecture, online quizzes are a great way to make sure students at least look at some of the course material outside of the classroom and come to class prepared. They also provide valuable feedback to the instructor so that classroom presentations can be tailored to the level of the students. Post-lecture online quizzes and online homework allow the instructor to assess whether the students are keeping up with the material being presented. PodCasts and VodCasts of classroom presentations are ways for students to review material at their own pace.

What about the textbook?

In introductory physics (which one of the authors teaches), there are several alternatives for an online textbook, each with differing degrees of interactivity. The *Textbook Equity* site (http://textbookequity.org/category/physics/) allows users to download, modify and use several different versions of introductory physics books. The instructor can use as much or little of the book as they deem useful and can customize the text to the course they are teaching. *Openstaxs* (http://openstaxcollege.org/) and *Flatworld* knowledge (http://catalog.flatworldknowledge.com/) offer similar products that have been designed by professional development teams.

Another alterative is to do away with a textbook entirely and simply use video lectures found on YouTube, Khan Academy (https://www.khanacademy.org/) or other sites. This provides a more interactive presentation of the material and makes a flipped classroom possible where the students view the lecture outside of class and come to the classroom ready to solve problems and actually 'do' physics.

Going up the scale of interactivity we come to offerings such as *Hyperphysics* (http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html), an online textbook which allows the reader to jump around to different topics as they go through the material. The presentation is not linear in that the reader can follow their interests rather than being forced through the material in an order set by the author.

One of the most sophisticated online textbooks for introductory physics is from *Kinetic Books* (http://www.kineticbooks.com/). This book has questions and quizzes embedded in the text so that the reader is constantly testing whether they understood the material or not. If the quiz result is poor the book offers remedial material and re-tests. If the reader is successful they can continue on with new material. This is a very advanced approach to the concept of learning from written material. It is, unfortunately, relatively expensive and likely to remain so due to the extensive development efforts needed to build such a product. It also seems doubtful that these types of books will be available for higher level courses where enrolment is too low to support the development of such a complex resource.

What about writing your own electronic book? There are many programs in existence for creating texts with varying degrees of interactivity. Examples include eCub, Sigil, Jutoh, Calibre, KooBits, Scriviner, Inkling Habitat, MegaZine3, Soomo, BookType, Atlantis, Adobe, iBook Author and more. There are also many formats to choose from for the final product: PDF, epub, Amazon, etc. In the following we describe two interactive books created by one of the authors (Forinash).

Wave Tutorial

In 2005, one of the authors (Forinash) started writing an online interactive textbook on waves (http://homepages.ius.edu/kforinas/W/Waves.html) using OpenSource Physics tools (http://www.opensourcephysics.org/) provided by Wolfgang Christian and Francisco Esquembre. The site was completed in 2011 and awarded the MPTL (http://www.mptl.eu/) award in 2013 and the MERLOT (http://www.merlot.org/merlot/index.htm) award in 2014. This tutorial consists of 32 separate chapters, each covering a particular aspect of waves. Each chapter starts with a simple introduction and an interactive Java applet (Figure 1).
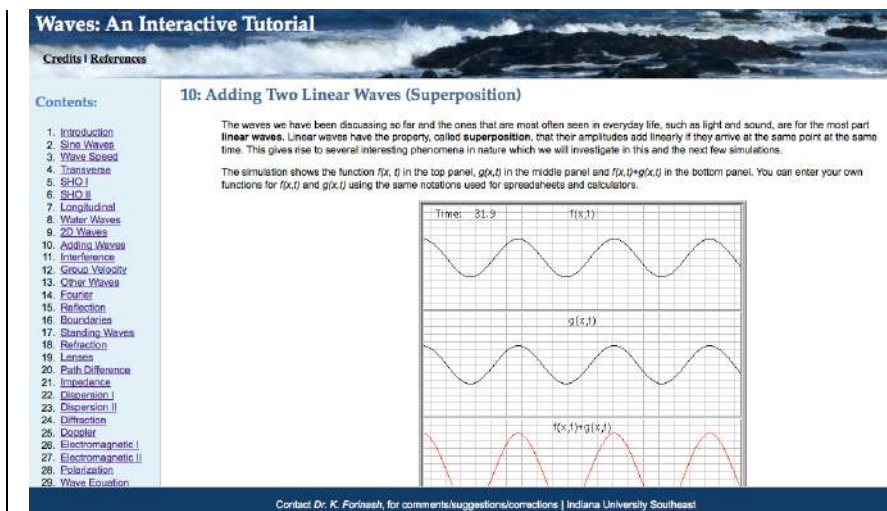

Figure 1. Top part of chapter 10; Adding Waves.

Each simulation is followed by a series of questions that ask the reader to change the parameters of the simulation to see what happens. The fact that the simulations allow the representation of a moving wave, rather than a static picture helps the student connect the mathematical description with a time dependent visualization. For example, the simulation in chapter 10 shows the superposition of two waves as they are moving. The student can modify the shape of two waves and see what happens when they are added, point-by-point (Figure 2). In a series of guided questions, the student is asked to experiment with the simulation by changing various parameters to learn about the behaviour of waves. Questions two, three and four of chapter 10, for example, ask the student to change the phase of one of the waves to see the effect of this parameter on the combined wave. In other questions they come to an experimental

understanding of standing waves, nodes, antinodes, interference and beats. The intent is for the reader to learn by experimentation rather than memorization.

Figure 2. The first few questions of chapter 10; Adding Waves.

Each of the 32 chapters is constructed in a similar fashion, each with a simulation and questions so that as the student works through the text they build an intuitive and visual connection between physical concepts and the mathematical descriptions which describe them.

We do not have a course devoted entirely to waves at our institution. However, a significant number of the chapters have been used in introductory physics courses over the past few years. Although we have not done a formal evaluation of student learning, student reaction to the simulations, both as instructional material presented in class and as homework exercises has been very favourable.

Sound Book

A similar approach was used for a physics of sound textbook (https://soundphysics.ius.edu/). In this case, not only are simulations used but also embedded YouTube videos (Figures 3 and 4) are included. The site was designed by a group of computer science students using material assembled by the instructor.

SOUND
An Interactive eBook on the Physics of Sound
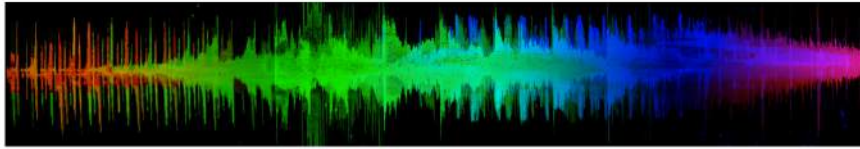
Search ...

4A: RESONANCE EXAMPLES

Resonance occurs in an oscillating system when the driving frequency happens to equal the natural frequency. For this special case the amplitude of the motion becomes a maximum. An example is trying to push someone on a swing so that the swing gets higher and higher. If the frequency of the push equals the natural frequency of the swing, the motion gets bigger and bigger.

For many systems we can make a graph of amplitude versus frequency and see where resonance occurs. Suppose we have a mass on a spring and attach a vibrator with a frequency we can choose. We start at low driving frequencies and measure the amplitude of the motion (how far it bounces) at each frequency. We might end up with a graph like the one below. Notice that the amplitude was a maximum at a driving frequency of 2.5 Hz. So the natural frequency of the system without the

Figure 3. The top of the chapter on resonance of the Sound book.

Air track resonance cart: Why is the amplitude of the cart larger at one particular frequency?

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Figure 4. Examples of resonance YouTube videos embedded in the *Sound Book*. The top video is an example of a driven pendulum. The bottom video shows a spring-mass system driven above, below and at resonance.

The *Sound Book* was used in a class this past spring semester (2014) and several complications were revealed. During the course meeting time students worked on group assignments which generally require access to the text. Some students elected to bring laptops, tablets or smartphones to class in order to have the *Sound Book* with them. Java applets do not run on most tablets or phones so only the text and videos were available in class, not the simulations. Two students printed out all the web pages of the online book and brought the pages to class. The site was also projected onto a screen during these exercises but this is not the most desirable way to access the material in class. The lesson learned is that online texts are not intrinsically portable. To make them so, the simulations need run on mobile devices and students must have access to a mobile device.

During the second week of class a new version of Java was released and all of the simulations stopped working for older versions of Java. Students had to update the Java engine on their home computers and the university's IT department had to update machines on campus so that homework assignments using the applets could be completed. This delayed homework assignments by about two weeks. Though it is well known that technology constantly changes, there is no way to anticipate this possibility.

Student evaluations, including student comments for two semesters of the sound course were collected (much of the material, including some of the simulations was tested in the course the prior year, spring of 2013). Based on these evaluations and informal comments given out of class, students liked the fact that they did not have to pay for a textbook but were not completely happy with the alternative. On the evaluations 75% of the students responded favourably (strongly agree or agree) with the statement "The course assignments [which included the simulation material] helped in learning the subject." However in comments they said they thought access to the book was problematic and the difficulties with Java applets very aggravating. The simulations have now mostly been converted into JavaScript to work on tablets and will not be affected by version updates as much so we expect student acceptance of the online material to improve in the course (which is presently being taught for a third time).

What about labs with real data?

Simulations are a great way to allow students to manipulate various parameters of an experiment in a controlled way. They allow students to slow things down and visualize complex processes. But science ultimately is built on real data. Can technology help us provide an interactive experience with data collection?

We think mobile devices (smartphones and tablets) can serve as a vehicle to engage students in science by moving students out of the rigid two hour student laboratory to collect real data in real life situations. For example, the internal accelerometer (used to orient the screen on tablets and smartphones) can be used to measure acceleration in a number of different situations (Wisman, 2010). We have analyzed the acceleration of a commercial jet (Forinash, 2014) using an app that we wrote which records acceleration in a spread sheet format so that it can then be emailed and analyzed on a computer. With mobile devices, students can investigate the motion

of their bicycles, amusement park rides, cars, skydiving or bungee jumping. Accelerometer apps have been used in many other contexts, for example, the acceleration during collisions (Vogt, 2014) and the acceleration of free fall (Vogt, 2012).

Most mobile devices have many other sensors, for example, magnetic field sensors. In Figure 5, we show an experiment where the magnetic sensor in a tablet is used to find the dependency of field strength as a function of distance along the axis of a bar magnet. Figure 6 shows the spread sheet data from a trial run.
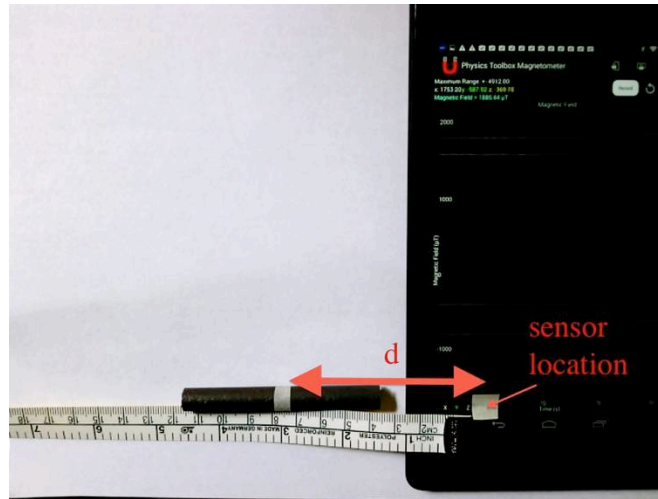

Figure 5. A tablet with a magnetic sensor used to measure the magnetic field of a bar magnet at different distances.
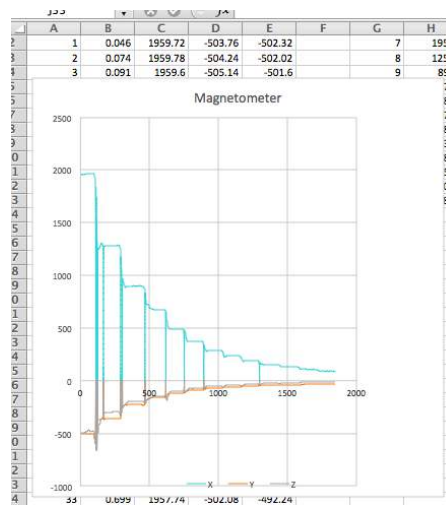
Using a mobile device for data collection often requires creative use of the technology. For instance, sound can be used for timing experiments if the beginning and ending of the experiment produce a sound. In Figure 7, a screenshot of the sound amplitude graph of a bouncing ball is shown. There are three bounces and the app allows a very precise measurement of the time between bounces which can be used to measure the coefficient of restitution of the ball. Similarly, the sound of a pair of scissors cutting a string holding an object and the sound of the object striking the floor can be used to determine the time of a falling object (Forinash, 2014) and to verify the gravitational constant.
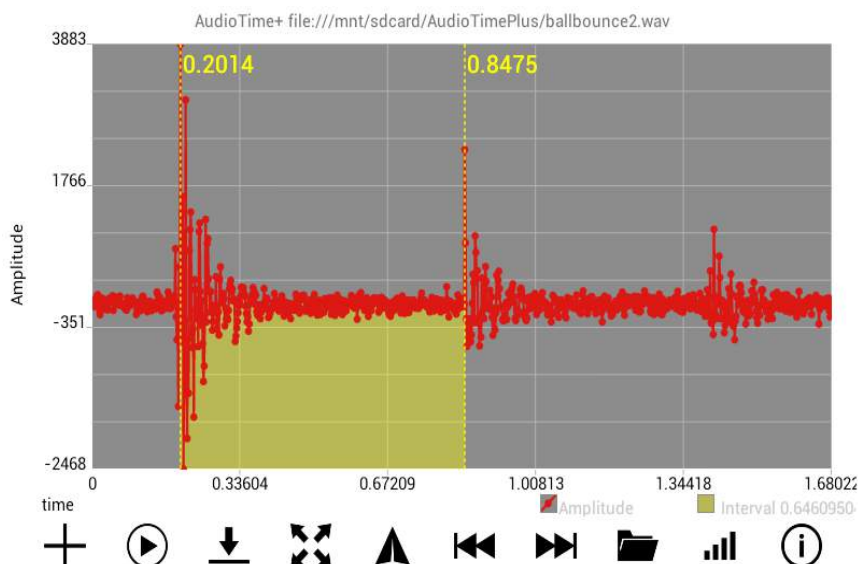

Figure 7. The sound of a ball bouncing three times as recorded by our sound app. A very accurate measurement of the time between bounces can be made from the recorded sound.

A mobile device can take additional data measurements with a simple external circuit containing other types of sensors. We have previously described a circuit containing a thermistor that can be used to measure local temperatures (Forinash, 2012a). In Figure 8, a similar circuit with two photo resistors is being used in a photo-gate timing measurement. As the Plexiglas with two tape stripes falls it blocks the photo resistors and the decrease in signal is recorded on the mobile device (a tablet in this case). Other measurements are possible with the same circuit using any sensor that acts as a variable resistor.

There are many other potential and existing uses of mobile devices as data collection devices. The camera can be used to measure spectra, an external probe can turn the device into a simple oscilloscope, the microphone can be used with an app to do a Fast Fourier Transform (Forinash, 2012b and Forinash, 2013). The speed of an object can be measured using the Doppler sound frequency shift (Forinash, 2014).

We have not done a formal evaluation of student reaction to using cell phones to collect data. However we have given an invited workshop to 50 high school physics teachers in Argentina at the International Conference on Physics Education (ICPE) 2014, Cordoba, Argentina, August 18-21. The reaction among the teachers was very enthusiastic; many participants left with ideas and plans for incorporating cell phone data collection in their classrooms. We think this indicates the utility of applying these ideas in the classroom, particularly in localities where lab equipment may be scarce. Our collection of ideas, articles, list of mobile device apps and laboratory exercises in English and Spanish can be found at http://mobilescience.wikispaces.com/.
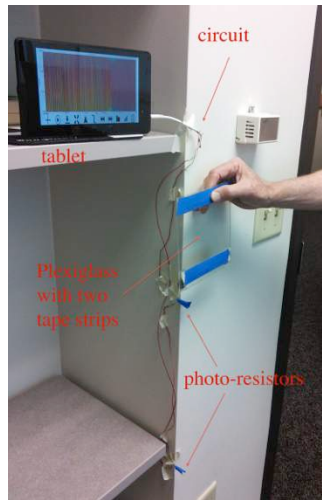

Figure 8. A tablet connected to an external circuit containing two photo resistors is being used to measure the acceleration of a falling piece of Plexiglas.

Conclusion

Science education has yet to fully appreciate or master the new communication technologies. It is always difficult to predict where technology will lead but we think electronic books will become much more interactive with simulations, video and quizzes for self testing. Books of the future will require an active participation with the knowledge presented rather than a passive reading. We also think mobile devices, such as tablets and smartphones, will become important tools for moving students out of the classroom and into the real world to take real data about the things they find interesting.

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