Laptops and Diesel Generators: Introducing PhET Simulations to Teachers in Uganda

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In early 2008 I had the opportunity to give workshops for high school physics teachers in Uganda on inquiry-based teaching and PhET simulations. I hope this description of the workshops will help increase awareness of the conditions teachers face in developing countries, and inspire others to conduct similar workshops. This work demonstrates what is possible with some concerted, but not extraordinary, effort.

The Physics Education Technology Project (PhET) develops research-based interactive computer simulations for teaching physics and makes these simulations available free online.[1,2] We have a simulations on a wide variety of topics, including virtual laboratories such as *Circuit Construction Kit* (Fig. 1) and *The Photoelectric Effect* (Fig. 2), which are designed to supplement laboratory experiments. Research has shown that these simulations can also be an effective substitute for lab equipment, sometimes producing greater learning than using real equipment.[3]

PhET simulations are used with great success in high school and college physics classes throughout the U.S. and other developed countries. They have the potential to be even more useful in developing countries such as Uganda, where laboratory equipment is scarce, but computers are becoming cheaper and more widely available.

While national exams in Uganda contain a major laboratory component, most schools cannot afford adequate lab equipment. Teachers often lecture about how circuits work to students who have never seen a real circuit, but who will be expected have a thorough understanding of circuits for their exams. The PhET simulations can fulfill a vital need by providing virtual laboratories to explore physical systems that students cannot access otherwise.

PhET simulations are ideal for students in developing countries for several reasons: They cover a wide range of physics topics, and therefore can substitute for a large number of laboratories, the equipment for which could cost thousands of dollars. PhET is free and open-source, and can easily be copied and distributed on CDs in areas without internet. PhET simulations are designed to incorporate real-world contexts to help students see the applicability of physics to their everyday lives. This is particularly important in developing countries where a focus on applications of science that can be used to improve people's lives, rather than abstract principles, is vital for economic development. Finally, the simulations are based on research and extensively tested to ensure that they are effective for learning and easy to use[4], an important feature in environments where both teachers and students have little experience with computers.

In early 2008, I ran two 2-day workshops on PhET simulations for high school teachers in Soroti, Uganda (Figs. 3-4).[5] The workshops were organized by Pilgrim, Inc.[6], an indigenous non-profit humanitarian organization that leads many development projects in

the Teso region of Uganda, including two education projects: a secondary school for refugee children called Beacon of Hope College, and the creation of a new regional university called Teso University. Pilgrim has many contacts with educators and is in a good position to oversee the ongoing implementation of the simulations within its school.

Pilgrim sent announcements of the workshops to teachers from all over the Teso region, an area approximately the size of Connecticut. Pilgrim bought 10 refurbished laptops and rented several desktops for the workshop, so there would be a computer for each pair of teachers to use.

The workshops were modeled on those that PhET runs regularly at AAPT meetings, but with a larger emphasis on inquiry-based teaching, since this concept is much less familiar to teachers in Africa. I chose activities that could both serve as models of inquiry-based teaching and also help the teachers learn physics. The types of inquiry-based teaching included interactive lectures with colored cards (a low-tech version of the personal response systems we use at the University of Colorado), simulation-centered labs and tutorials, and conceptual homework. After researching the requirements for national exams, I chose to use sample activities on one topic from the O-level exam, electric circuits, and one from the A-level exam, the photoelectric effect. I also (thankfully!) made the schedule flexible to accommodate laid-back timelines, power outages, and other unexpected events. (See Table 1 for workshop outline.)

Table 1: Workshop Outline:

- Intro to Inquiry-Based Teaching (interactive lecture with colored cards)
- Intro to PhET Simulations (interactive lecture with colored cards)
- Free exploration of simulations (small groups)
- Reviewing simulations for use in teaching (small groups)
- Circuits Tutorial (small groups) – O level
- Photoelectric Effect homework (small groups) – A level

I brought installation CDs to distribute to teachers containing the PhET installer, as well as all software needed to run PhET, including Firefox, Java, and Flash, for every possible operating system I might encounter, including different versions of Windows, Macintosh, and Linux operating systems. The day before the workshop, we installed the software on the rented computers. Most computers there did not have Java or Flash, and there was no internet, so much of the extra software was necessary, but every computer I encountered in Uganda was running Windows, so the software for different operating systems turned out to be unnecessary. Most ran Windows XP, although the computers themselves were often up to 10 years old.

Although 30 teachers had signed up for each workshop, there were only 10 teachers in the first workshop and 8 in the second workshop. No one knew why there were so few, and the organizers speculated that perhaps they would be there in the afternoon, since they had to make a long journey from their distant rural homes. They never showed up, but I rearranged the order of the workshop to start with free exploration of the simulations, so that any late-comers would not miss the main presentation. I was thus

able to give each of the teachers a lot more personal attention, and starting with free exploration allowed them to discover how useful the simulations could be for themselves.

Most of the teachers had little or no experience with computers, and I spent much of the first morning teaching them how to open files and use a mouse. I was surprised how quickly they were able to pick up the needed computer skills, and within a couple hours, they were exploring and learning from the simulations with as much proficiency as our students at the University of Colorado. This was less true in the second workshop, where after the second day, many teachers were still struggling with how to double click a mouse and didn't know when to single-click and when to double-click. The difference seemed to be that the first workshop was mostly young teachers in their first few years of teaching and the second workshop was mostly older teachers with many years of experience.

All the teachers saw the value of the simulations, and said they would be extremely valuable in their classrooms for illustrating important concepts for which their students did not have good visual models, such as electric and magnetic fields. While the teachers were enthusiastic about the simulations, this enthusiasm was mixed with frustration, as most of the teachers in the first workshop did not have access to even a single computer at their schools, and thus would not be able to use these wonderful tools. I had requested that the workshops be limited to teachers who had access to a computer in their school, but this request turned out to be impossible to enforce. After the first workshop, the directors of Pilgrim recognized the difficulty of this situation, and decided to donate a desktop to the school of each teacher who had participated in the workshop.

Even when the teachers thought they would not be able to use the simulations with their students, they still recognized that the workshop was valuable for helping them learn things that they could take back to their students. Several teachers commented, after completing a tutorial on voltage using the *Circuit Construction Kit* simulation that we use with our college students, that they had never had a model in their heads of what is happening in a circuit, and now they did, so they would be able to answer their students' questions more effectively.

Another goal of the workshop was to introduce teachers to the idea of inquiry-based teaching. Everyone I spoke to in Uganda reported that without exception, classes there consisted of teachers lecturing and students taking notes. When I described inquiry-based teaching, Ugandans of all walks of life responded with enthusiasm and said it sounded like a great idea, but that they had never experienced it in their education. The teachers in the workshops were also enthusiastic, and many of the older teachers nodded in approval and recognition when I discussed the problems with traditional lecture-based teaching. However, it was unclear how well they would be able to use these methods themselves based on a two-day workshop and a very small sample of materials.

I did receive a powerful validation of the impact of the idea of inquiry-based teaching on at least one workshop participant during a visit from the District Education Officer (DEO). The DEO, the equivalent of a State Board of Education Director, came to

observe the workshops to evaluate whether the simulations should be used in schools throughout the region. When he asked whether one could demonstrate a concept with a simulation during a lecture, I started to explain how to use a projector to put the simulation on a screen. However, I was interrupted by a workshop participant who explained that you shouldn't just lecture to students, but should instead ask them to discover the concepts for themselves, and the simulations are ideally suited to help them do that.

The teachers were extremely uncomfortable when I asked them to answer multiple-choice questions with colored cards. It became clear that many of the teachers did not know the answers to some of the physics questions I asked, and were embarrassed by publicly displaying their ignorance. Their reactions were more extreme than I have observed from American teachers, probably because the Ugandan culture places a stronger emphasis on teachers as authority figures. I tried to alleviate their embarrassment by asking them to focus on how they could use this kind of activity with their students. In retrospect, however, I could have put more emphasis on the idea of role-playing as students, and answering the questions not as themselves but as their students would.

In the second workshop, the teachers asked to practice installing the software from the CDs I provided, so that they would know how to do it when they got home. I guided them through the installation process two at a time, with each teacher at his[7] own computer. Each pair took about an hour to work through it, after which I was not confident that some of them would be able to do it on their own. I asked those who had computers at their schools if there was someone there who knew how to use a computer. They all cited a systems administrator or computer science teacher, so I suggested they ask that person to install the software.

Power outages are another fact of life in Uganda that I encountered in my workshops. The entire country is powered by a single hydroelectric dam built in 1954. This dam doesn't supply nearly enough power for a rapidly developing country, so blackouts and brownouts are common. Power was relatively good during my visit due to recent floods, and there were only two power outages during my workshops, one lasting a few minutes and one lasting several hours. We were able to continue working by using the laptop batteries and a diesel generator that the Pilgrim staff got working just as the batteries started dying. While laptops may seem preferable to desktops in such an environment because they can run on batteries, locals recommended buying desktops for schools because laptops are likely to be stolen.

In addition to the workshops in Soroti, I also visited King's College, Budo (Fig. 5), one of the most elite secondary schools in Kampala, the capital of Uganda (Fig. 4). This visit, like much that happens in Africa, was due to a chance meeting of someone who knew someone there, who saw an opportunity for collaboration. Teachers at King's College organize training for teachers from many surrounding schools, so this visit had the potential to introduce PhET simulations to a much wider audience. King's College was a sharp contrast to the stories I heard from the teachers in my workshop, who taught in

rural schools with no lab equipment and two physics textbooks to share among 70 students. At King's College, a sprawling and well-manicured campus, the teacher's lounge appeared well-stocked with galvanometers and other equipment. Teachers were proficient with computers and pulled out their laptops when the 10-year-old desktop failed to work, and boasted of a new computer lab with 20 laptops. I demonstrated the simulations to the nine physics teachers and met with the headmaster, who was eager to stay in contact and help spread PhET to schools throughout the area.

In the end, what were the outcomes of my visit? I made a strong impression on the teachers who participated in the workshop, opening their eyes to what can be done with technology and encouraging them to try it and to press their administrators for more computers.[8] I helped introduce the teachers to both physics and the principles of inquiry-based teaching, aspects of which they may be able to take back to their classrooms. I also made contacts within a relief organization and an elite school, both of which are in a good position to train others to use the simulations, and are committed to being test sites for the use of the simulations.

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Biographical Sketch:
Sam McKagan is a member of the PhET team at the University of Colorado. As a postdoc in quantum mechanics education research, she has designed, tested, and conducted classroom studies of many PhET quantum simulations. She has also designed curriculum and conducted research on student understanding of quantum mechanics.

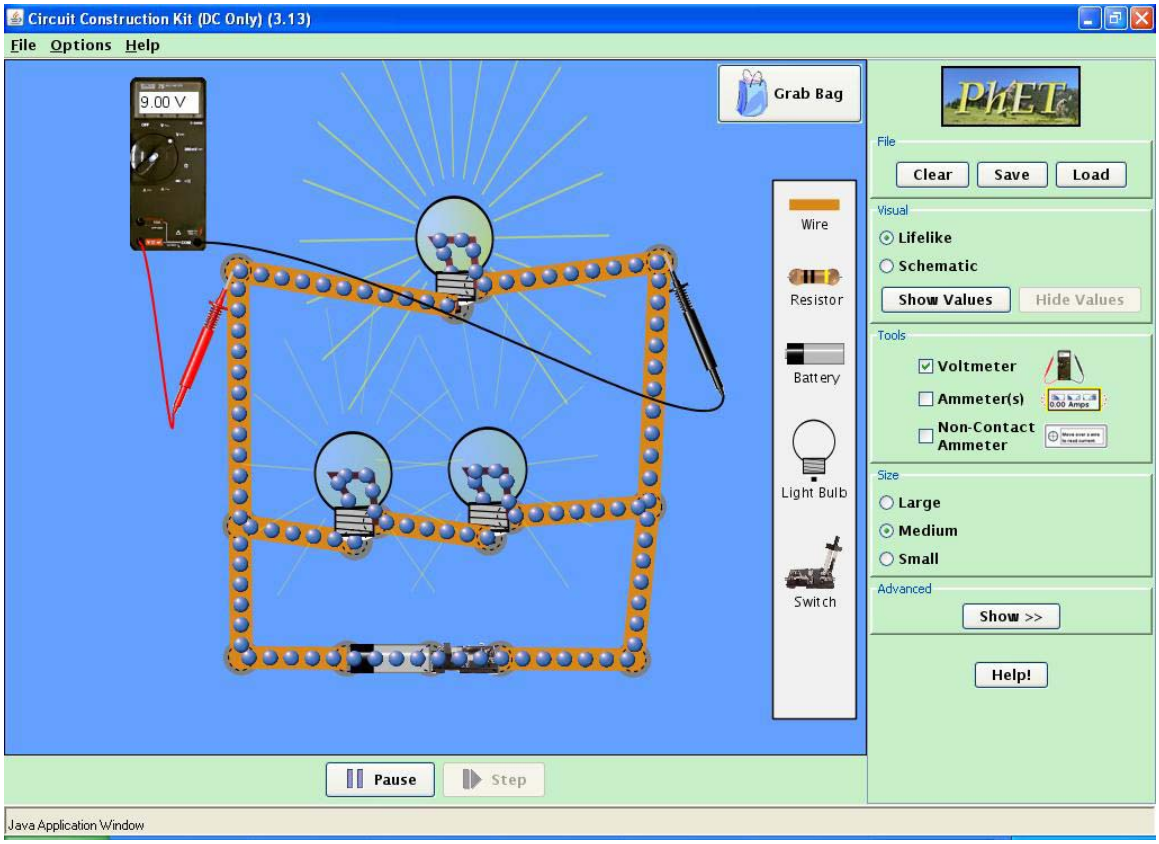

Fig. 1: *Circuit Construction Kit* simulation

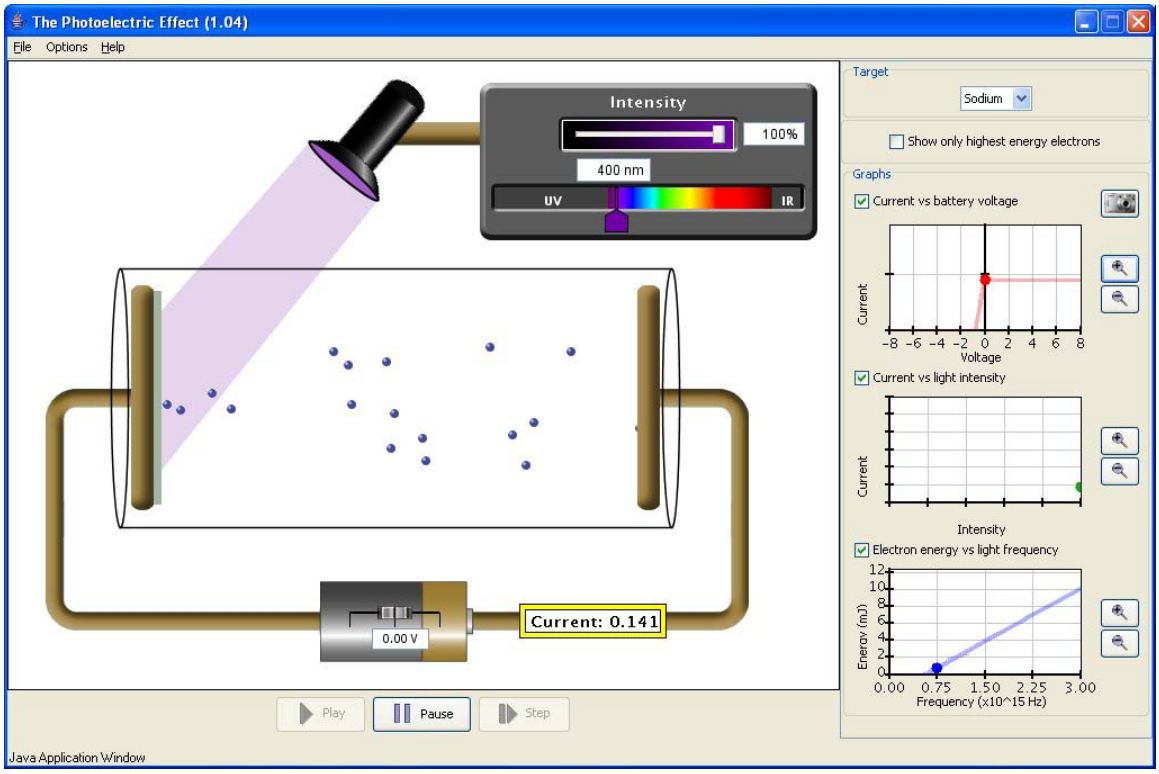

Fig. 2: *The Photoelectric Effect* simulation

Fig. 3: PhET Workshops for high school teachers in Soroti, Uganda

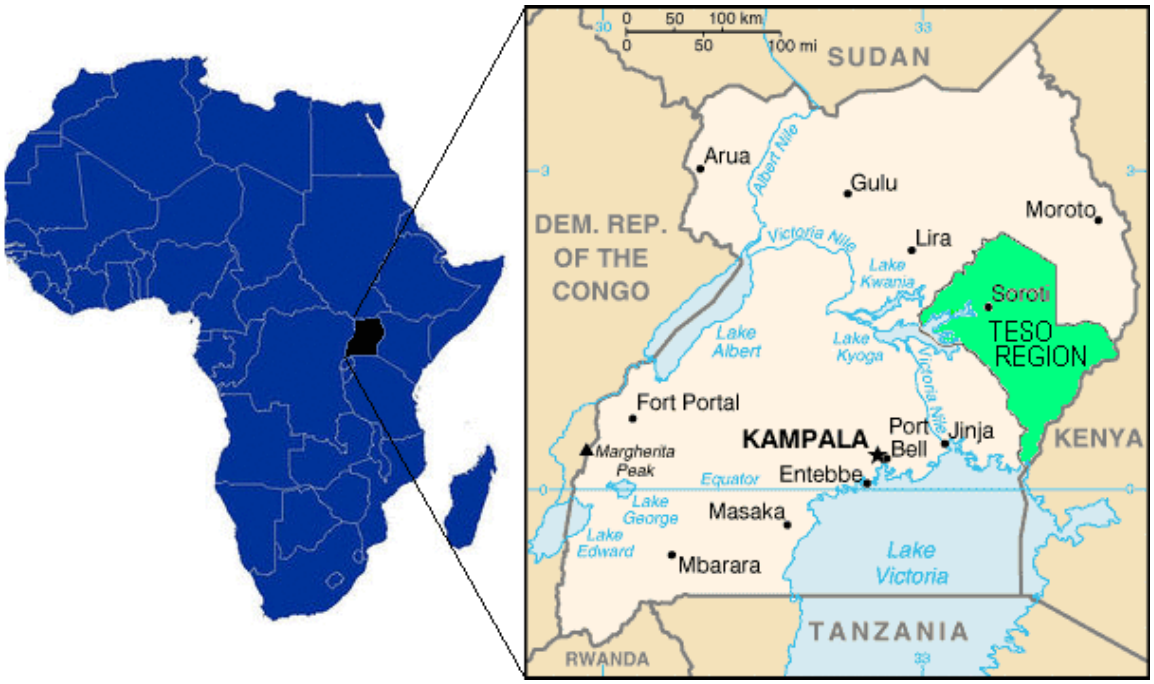

Fig. 4: Workshops took place in Soroti, Uganda, and teachers came from all over the Teso Region, shown in green.

Fig. 5: Introducing PhET simulations to physics teachers at King's College, Budo, an elite secondary school near Kampala, the capital of Uganda.

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[1] http://phet.colorado.edu

[2] Katherine Perkins, Wendy Adams, Michael Dubson, Noah Finkelstein, Sam Reid, Carl Wieman, and Ron LeMaster, "PhET: Interactive Simulations for Teaching and Learning Physics," *Phys. Teach*. 44, 18-23 (January 2006).

[3] N.D. Finkelstein, W. K. Adams, C. J. Keller, P. B. Kohl, K. K Perkins, N. S. Podolefsky, S. Reid, R. LeMaster, "When learning about the real world is better done virtually: a study of substituting computer simulations for laboratory equipment," *Phys. Rev. ST Phys. Educ. Res.* **1**, 010103 (2005).

[4] W. K. Adams, S. Reid, R. LeMaster, S. B. McKagan, K. K. Perkins, and C. E. Wieman, "A Study of Educational Simulations Part I - Engagement and Learning," *Journal of Interactive Learning and Research* **19**, 391 (2008); W. K. Adams, S. Reid, R. LeMaster, S. B. McKagan, K. K. Perkins, and C. E. Wieman, "A Study of Educational Simulations Part II - Interface Design," *Journal of Interactive Learning and Research* **19**, 557 (2008).
http://phet.colorado.edu/web-pages/publications/PhET%20interview%20Paper%20Part%20I.pdf
http://phet.colorado.edu/web-pages/publications/PhET%20interview%20Paper%20Part%20II.pdf

[5] For more information, including workshop materials, pictures and videos, and suggestions for others who would like to give PhET workshops in developing countries, see:
http://phet.colorado.edu/teacher_ideas/workshop_uganda.php

[6] http://www.pilgrim-uganda.org/

[7] All the workshop participants were male.

[8] In the feedback forms given at the end of the workshop, teachers were asked to rank the following statements on a scale of 1-5, with 1 as "not likely" and 5 as "very likely":

"I will *personally* use ideas I heard here in courses I teach."

"I will *pass on* ideas I heard about here to other teachers."

100% of the workshop participants ranked both statements with 4 or 5.