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A Remote Radioactivity Experiment

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A Remote Radioactivity Experiment

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Imagine a high school with very few experimental resources and limited budgets that prevent the purchase of even basic laboratory equipment. For example, many high schools do not have the means of experimentally studying radioactivity because they lack Geiger counters and/or good radioactive sources. This was the case at the first high school one of us (MV) worked at, and after talking with numerous colleagues we know this is still the case at many schools. What options are there then for physics teachers to allow their students to *experimentally* investigate certain characteristics of radioactivity, such as how distance affects the intensity of radiation coming from a radioactive source? There are computer simulations that can be run, or perhaps the teacher has a light sensor and tries to make an analogy between the intensity of light from a light bulb and the intensity of radiation from a radioactive source based on geometric arguments to get an inverse-square law. But for many there is no direct experimental option if one does not possess a Geiger counter and good radioactive sample. It is for that teacher and class of students that an online, remote radioactivity experiment was created.

Remote experiments are not a new concept in education, as some undergraduate classes have used them for the past two decades. In science research, remote experimentation has been used in certain fields of science, such as particle physics and astrophysics, for many decades (e.g., the CERN particle collider). In fact, there are some clever, relatively simple and inexpensive ways to put experimental setups online using common electronic sensors, such as those from Vernier.[1,2] Remote labs that high school classes can access have been less common.

The iLab Network,[3-4] a project based at the Office for STEM Education Partnerships at Northwestern University that seeks to put remote labs and appropriate curricula online for high school science courses, features a remote radioactivity lab housed and run at the University of Queensland in Australia. What is remarkable, however, is that using the Internet, in a matter of about 10 minutes, a high school teacher or student can set experimental parameters for a number of different distances between a strontium-90 source and Geiger counter, the number of trials at each distance, and the time for collecting counts for each trial (see Fig. 1), submit the experiment, and then receive *real* data from thousands of miles away. A webcam allows the user to watch the experiment in real time. Figure 2 shows the live webcam view available to the user.

Students can use a graphing and fitting option while in the user interface (see Fig. 3), or they can export data to Microsoft Excel, make their own graphs, and obtain a best-fit function to extract their experimental results. By doing power law fits, students will find a nearly inverse-square relationship. If a teacher has a number of students perform the experiment, they will all get different results because, unlike a computer simulation with calculated, clean data, this is a real, physical experiment that produces real data, with statistical fluctuations from run to run. These differences can lead to fruitful discussions of the random nature of radioactive decay, sample size, experimental design and its effects on results, fitting data, reproducibility of experiments, experimental techniques, and so on.

High school curricula options for physics, chemistry, biology, and math classes have been developed.[3] The physics curriculum is designed as a five-day unit, and consists of 1) Introduction & Pre-Assessment; 2) Cellphone Radiation Podcast; 3) Radiation Discussion; 4) First Run of iLab; 5) Peer Review & Reflection; 6) Second Run of iLab; 7) Phenomenon Discovery; 8) Real-World Application; and 9) Wrap-Up & Post-Assessment. This experiment and the designed curriculum was pilot tested by 20 high school teachers, and has since been used by thousands of high school students in order to learn about the nature of the intensity of radiation as one varies the distance between a Geiger counter sensor and a strontium-90 source. Pre- and post-tests were taken by participants in the pilot before and after going through the curriculum developed for high school students for this lab. Data from the pilot test ($N = 594$ students) show significant

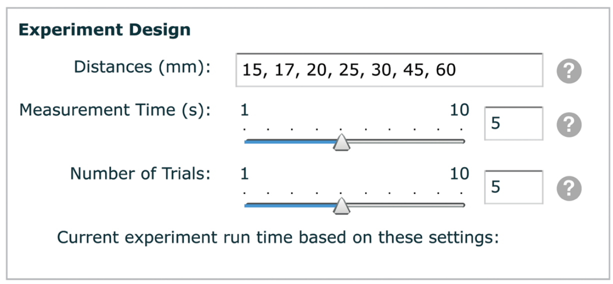

Fig. 1. Experimental design options in online experimental interface.

Fig. 2. Live webcam view of the remote lab equipment at the University of Queensland.

gains between pre- and post-test overall scores, as well as for radiation content and experimental process scores, suggesting that remote experiment is a viable tool for teachers to use. For example, there was an overall gain of 21% between pre- and post-test content scores, which is a 1.03 size effect (size effect values over 0.5 are considered large gains in learning). There was also an 8% gain in inquiry skills (0.37 effect size), such as the use of multiple trials, larger time intervals for data collection, and multiple runs, as well as improvements in the critique of experimental designs. Both sets of pre-/post-test score improvements were statistically significant at $p \leq 0.0001$.

The iLab was also used with 123 undergraduates in a comparison between content learning using the iLab versus using a computer simulation. Students scored better using the iLab,[5,6] and reported gains in perceptions of ownership and control, feelings of reality, and curiosity about radioactivity. A majority of those students using a computer simulation stated they would prefer to use a real experiment, while almost no one who used the remote experiment reported he/she would prefer a computer simulation. Student responses commonly included statements similar to, "It meant more that something real was being measured, rather than a computer showing some numbers coming from equations."

Besides having students run the radioactivity experiment at school during class, remote labs present new and intriguing options for teachers. If time is limited in class, to the point where doing an experiment is not possible, the teacher can assign this experiment as homework. Or, a teacher can plan on doing additional activities in class using the time saved by having the experiment done outside of class. For example, the teacher could have more time to spend with students on actual data analysis rather than spending so much time simply collecting data. If students have access to the Internet at home, in a school computer lab, at a local library, or on a smart phone, they can do the experiment at their convenience. The experiment is set up to save the data and online experimental journal to a student's account. If students are absent from school when the experiment is done, they will be able to do the same experiment as the rest of the class, as long as they can get online. This lab option also allows students to do individual lab experiments, rather than most experiments that require lab partners due to limited equipment and time in class. In addition, teachers and students have the option to run multiple experiments with different experimental designs and compare results, which is normally not an option in a class with limited time and access to lab equipment. One observation from the pilot test was that those students who ran their experiments outside of class tended to do more runs overall, which is encouraged in order to show students the scientific importance and practice of doing reproducible experiments and verifying previous results. The fact that students did more runs is likely due to the lack of time constraints one often has in a class lab setting.

This particular remote lab is accessed asynchronously.

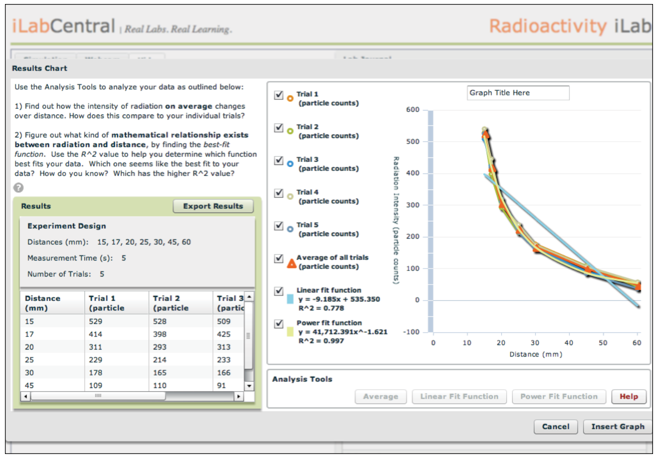

Fig. 3. Data analysis option from the online experiment interface.

When users submit their experiment and another one is already in progress, the request goes into a queue in the order received, and once the equipment is available the next experiment is accepted and run. Data from each experimental run are automatically saved in the users' online account and can be accessed at any time they next log in. This permits users to log off the site and retrieve their experimental results at a later time when it is convenient for them.

Does a teacher want to ultimately have every experiment be a remote experiment? We think the consensus among physics teachers, and in fact all science teachers, would be a resounding no. Students still need to get their hands on physical equipment, tinker and use their creativity to develop their own designs of experiments, set up and calibrate equipment, troubleshoot when things do not work correctly, and learn about measurement and standard experimental techniques. Computer-simulated experiments are useful to look at phenomena that are inaccessible in a lab, and to do numerous, quick observations that would, in a physical lab, take too much time. However, we see many advantages in adding remote online labs to the toolbox of learning tools available to science teachers.[7] Experience with a remote experiment will introduce students to technologies and access to real experimental data in a new way. High school students will also be exposed to the concept of remote experimental work that many professional scientists now use. For instance, particle physicists can remotely access data from detector experiments all over the world, just by using their office computers. Biologists use remote sensors to measure biological characteristics of plants in numerous ecosystems. In medicine, surgeons are trying to perfect remote surgical procedures and technologies. NASA scientists and astronomers do amazing scientific research by remotely operating probes on the surface of Mars or advanced instruments such as the Hubble Space Telescope. And engineers from British Petroleum (BP) used remote robotic systems to stop the 2011 burst oil well in the Gulf of Mexico. Remote experimentation is already a significant part of the scientific and engineering landscape, and it will continue to expand its reach to more scientists as the interconnectivity of experimental groups continues to grow and evolve. It makes sense for high schools to be part of this once-restricted sector of the science research world because of widespread accessibility to the Internet and reliable interface technologies that allow remote access.

One might imagine that as technology that interfaces physical experiments with the Internet continues to improve and becomes faster and more reliable, more remote experiments could become accessible to high school, community college, and undergraduate students. Imagine a "warehouse" of remote experiments that could be used by students from anywhere in the world. Colleges and universities might consider taking certain remote experiments they currently use for existing undergraduate courses and making them available for high school science classes, in a way similar to what the University of Queensland has generously done with their radioactivity experiment (and a second setup is supposed to be online sometime in 2013 to handle higher volumes of submitted experiments). Because remote experiments would be online, and would be accessible by any school, new possibilities for broadening access to high-quality experiences and a leveling of the academic playing field could begin to emerge. Rural districts and inner-city schools, for example, would be able to do the same experiments, using the same equipment, as wealthier private and suburban school districts. In the longer term, improving educational equity and exposure to more advanced laboratory equipment through the use of remote experimentation are exciting possibilities that should be pursued and realized.

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References

1. Kyle Forinash and R. Wisman, "Simple Internet data collection for physics laboratories," *Am. J. Phys.* **70** (4), 458–461 (April 2002). Information for Refs. 4 and 5 of this paper may now be found through homepages.ius.edu/kforinas/Forinash2.html.
2. Kyle Forinash and R. Wisman, "Building real laboratories on the Internet," *Int. J. Cont. Engineering Education and Lifelong Learning* **15**(1/2), 56–66 (2005).
3. The homepage for the iLab Network is ilabcentral.org.
4. K. Jona, R. Roque, J. Skolnik, D. Uttal, and D. Rapp, "Are remote labs worth the cost? Insights from a study of student perceptions of remote labs," *Int. J. Online Eng.* **7** (2), 48–53 (2011).
5. M. Sauter, M. Downing, K. Jona, D. H. Uttal, and D. N. Rapp, "Get real: The authenticity of computer-based science labs," paper presented at the annual meeting of the American Educational Research Association, Vancouver, BC (2012).
6. M. Sauter, D. Rapp, D.Uttal, K. Jona, J. Skolnik, and R. Roque, "Grounding students' understandings of 'doing science' in actual lab experiences," paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA (2011).
7. J. Ma and J. Nickerson, "Hands-on, simulated, and remote laboratories: A comparative literature review," *ACM Comput. Surv.* **38** (3), Article 7 (2006).

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