Designing a Remotely Controlled Physics Laboratory to Demonstrate the Faraday Effect to Online Students

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A Project Proposal Submitted to my Graduate Committee

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Introduction

It seems that my academic interests have always hovered in the intersection between science and education. At an early age I was fascinated by the lessons of physics, biology and astronomy. It is also fair to say that much of my interest in science came from watching the Apollo missions successfully land men on the moon and being able to visit educational centers like the Boston Science Museum. Another influence that affected my outlook on education was my father, the college history professor. I had many chances to observe his teaching style that was mainly Socratic in nature. While he taught only face to face classes in history, he continually experimented with different methods to improve his teaching including the use of costumed persona, imaginative *what if* scenarios, and application of historical themes to current times. I never observed students sleeping in his classes.

My undergraduate degree is in Physics and Astronomy. It's been a long time since I have balanced quantum equations or determined force vectors, but I still retain enough information so that I might be qualified as an expert amateur. When I began my M.Ed. program I did not have a distinct outcome in mind, I only wanted to improve my professional skills as an Instructional Designer at the University of Alaska Fairbanks (UAF). About four weeks into my first course, Online Pedagogy, I came across an article describing the work of physics instructors at the Kaiserslautern University of Technology. While the article touched on three important aspects of online physics education, I was drawn to the section where (Eckert, Gröber, & Jodl, 2009) outline a set of design principles that comprise the effective remotely controlled laboratory (RCL). The experiments that the authors reference have been online since 2001 and are still available to anyone with a web browser in the world. These experiments are valid supplements to any first or second year Physics course. After seeing what the authors had done at Kaiserslautern, I knew that I wanted to design an RCL to supplement Physics education at UAF.

Rationale

My question then became *What Physics lab experiment should I create as an RCL?* I drew inspiration from the remake of a television show that had inspired me as a high school student. In 1983 PBS broadcasted Carl Sagan's *Cosmos*. It was an educational series that combined lessons from Astronomy, Physics, Biology, Geology, History, and Ethics. It was ground breaking in its scope, the content, and method of delivery. For 13 episodes viewers were enthralled each week as Sagan delivered rich lessons for about an hour. In 2014 Cosmos 2.0 was unveiled to the world with Neil Degrasse Tyson as the host.

In its second incarnation, Cosmos portrayed the pivotal work of various researchers through history. One of the scientists featured was Michael Faraday. Faraday's work is the mainstay of Electricity and Magnetism, but most people are not familiar with one of his most important discoveries. In 1845 he demonstrated that a magnetic field could rotate the plane of polarization of light. This was ground breaking because it showed for the first time the relation between light and electricity and magnetism.

Figure 1. Michael Faraday's laboratory at the Royal Institution. His original lab equipment used a silvered mirror to reflect lamp light across a magnetic induction coil and through a grated polarizing filter. (Druyan, Sagan, & Soter, 2014)

Unfortunately this lab exercise reproducing the work of Michael Faraday is not often given to students, even in face to face classes. Because it was so important to the development of modern physics, and the equipment list is relatively simple, I believe it is a perfect candidate for development into an RCL.

Review of Literature

While the laboratory experience is an essential part of science education, the creation and maintenance of labs as well as staffing is very costly (Gomes & Bogosyan, 2009, p. 4744). Gomes and Bogosyan (2009) also describe many of the engineering RCLs that are run from UAF's School of Engineering and Mines.

The first RCLs began to appear on the web around the year 2001. Now that educators have had a chance to study and refine the delivery of the lab experience via RCLs they have begun to develop guidelines and best practices for design. One guideline that seems to be gaining traction is the directive to make the RCL interesting enough that students will want to explore and play with it. While there should be contextual background information on the theory behind the experiment and the use of the equipment, users of the RCL should be able to access all the information they need to run experiments without having to read external materials. Cagiltay, Aydin, Aydin, Kara, and Alexandru (2011) make this case in Seven Principles of Instructional Content Design for a Remote Laboratory: A Case Study on ERRL (Cagiltay, Aydin, Aydin, Kara, & Alexandru, 2011). This corresponds with the directive from (Eckert et al., 2009, p. p133) that says that an RCL should be intuitive enough that the user should not be required to read extensive references.

There are more benefits to the use of RCLs than just cost savings alone. Once the laboratory activity shifts from the in-person lab presence to the online realm, time spent engaging in lab activity goes from what is typically a few hours per week to a situation with access to equipment and experiments that can be granted at all hours of the day. Sttudents thus begin to spend more time with the lab curriculum. Furthermore, distance collaboration becomes possible when lab partners need not be in the same proximity (Ku, Ahfock, & Yusaf, 2011, p. 254).

An investment in RCL architecture relieves some of the scheduling constraints from science and engineering courses that contain lab components. The numbers of students that schools are expected to educate in science and engineering majors are putting more and more load on traditional lab infrastructure (Lindsay, Long, & Imbrie, 2007). Networking with other academic content providers and sharing developed resources is a trend that the authors of *Remote Laboratories - Approaches for the Future* call for.

The role of RCLs in online education is critically important. While there have been various efforts of recreating the laboratory experience with simulations and augmented reality, these efforts lack the perception of acting on something real. When students fail to get a sense of real interaction, their engagement and hence learning of the material suffers. RCL users felt more present in their labs than students who interacted with a simulation. More importantly, students of the remote labs expected more variability in their measured data than those that ran simulations (Sauter, Uttal, Rapp, Downing, & Jona, 2013, p. 42). This extends to the perception of the value of the data being measured. In a study conducted at Northwestern University students worked with RCLs and computer simulations of a classic radioactivity experiment. “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’(Jona & Vondracek, 2013, p. 26)”.

When asked to compare their experiences between RCLs and simulations of laboratory experiences, student RCL experiences have positive feedback loops that allow students to immediately see the results of their manipulations on real physical objects which are often hundreds if not thousands of miles away. Students that work with RCLs also generate higher quality reflective work and interact with the lab more than users of simulations (Sauter et al., 2013).

Statement of Bias

One major choice I am bringing to the design of this RCL based project is the philosophy of open standards and vendor agnostic requirements on the student side of the RCL experience. As it pertains to the machine and software requirements for a student’s computer or mobile device, the RCL should not require specific operating systems or browser applications. This is in line with the approach taken by (Eckert et al., 2009, p. 133) where the authors conclude that what makes part of a good RCL experience for students is not being burdened by specific software requirements on their end. On the experiment side of the RCL experience I believe that wherever feasible, open source software and readily available hardware solutions should be used, rather than specific use hardware/software combinations. This is reflected in an earlier publication from Kaiserslautern where (Gröber, Vetter, Eckert, & Jodl, 2007, p. 8) indicate their preference for open source systems so that the designs can be shared with and built by other instructors around the world, with materials that they have access to.

This is not the approach taken by some RCL initiatives. The North American Network of Science Labs Online (NANSLO), an initiative of the Western Interstate Commission for Higher Education (WICHE), has several online activities and more planned for review. NANSLO's labs deviate from the design philosophy of the Kaiserslautern University labs in several ways. Notably, users of the labs must first install various bits of software on their computers in order to be able to run the experiments. Mobile devices are not supported at this time. In addition to this initial barrier, a student must belong to a registered class of a participating and funding institution in the NANSLO program. The instructor of a class must first provide NANSLO a roster of students and schedule blocks of time where expected student activity is to occur. Subsequently students must visit a separate website, login there, and schedule lab time ("NANSLO Lab Tutorials," n.d.)

The NANSLO experience is different and inferior even without these considerations. One of the most fundamental activities of any lab exercise is measuring data. Rather than provide students with a webcam view of their remote lab instruments, key data values are merely displayed in text panels in a computer UI dialog box. This removes the student from truly understanding the physical limitations and parameters of the measuring device and eliminates the skills associated with calibration and interpolation.

The advantage of using proprietary software, scheduling and remote lab assistants like NANSLO employs is that certain experiments are easier to set up. The disadvantage of using proprietary and generic lab software that is fitted to a given exercise is that the student must spend time sifting through a foreign interface that has nothing to do with the scientific principles demonstrated. As Eckert, Gröber and Jodl point out, "the use of an RCL via the Internet must be intuitively clear and the user should not be forced to read a detailed manual" (Eckert et al., 2009, p. 133).

Methods: Design of the Project

My project will provide:

- An equipment list for the components associated with the makings of Faraday's experiment
- A software design of the web pages that the remote student would interface with the lab equipment.
- Two sets of lab procedures that develop sound laboratory processes and move students along to rich understandings of the physical principles involved in Faraday's discovery. The first lab procedure would be targeted as either a high school level exercise, not requiring extensive use of formulae but only elementary algebra, the other would be a more extensive investigation meant for college level physics geared up with the ability to use calculus.
- Notes of the experiences of people testing the design, including problems associated with RCL interactions, insights gained from the experience and possible recommendations.

Description of the Final Application Project

The purpose of all this is to demonstrate that this particular experiment could be a successful RCL. It will also provide a blue print for those wishing to actually construct the lab. The final project will incorporate the design elements listed above and record the experiences of people investigating the phenomena associated with the rotation of polarized light both at the levels of calculus and pre-calculus physics.

Anticipated Problems and Outcomes of the Project

I expect to spend quite some time finding appropriate materials available at the university which will prove useable in reproducing Faraday's experiment. My goal is to be as true to the work that was done almost two centuries ago, but do so in a cost effective manner. There will be some difficulty in not actually employing the RCL server interface with any robotic equipment that would physically interact with the materials. This will be a challenge in two areas. I will have to first make an educated guess as to the capabilities of high end consumer grade robotics and computer interfaces likely to be on the market in the short term. The other more difficult challenge will be trying to capture the RCL experience without actual robotic equipment. My plan is to use the features of Google Video Chat as a prototype for the RCL interface. The people acting as students will open a web page with the RCL interface and share that screen with me. I will be in the room with the equipment and be able to see which values they enter, which buttons they press, and which choices they select. I will then be able to direct a web camera at appropriate equipment parts and make proper adjustments. While the differences between such a lab set up and a planned one with actual robotics are significant, it is my hope that the actual RCL experience would not be that much different.

There is always the possibility that I will have difficulty arranging the use of lab space and equipment, but I have been given initial approval by the Physics Department Chair pending available time and space.

References

Cagiltay, N. E., Aydin, E., Aydin, C. C., Kara, A., & Alexandru, M. (2011). Seven principles of instructional content design for a remote laboratory: A case study on ERRL. *IEEE Transactions on Education*, *54*(2), 320-327. doi:10.1109/TE.2010.2058115

Druyan, A., Sagan, C., & Soter, S. (2014). The electric boy. In *Cosmos: A spacetime odyssey.*

Eckert, B., Gröber, S., & Jodl, H. -J. (2009). Distance education in physics via the internet. *American Journal of Distance Education*, *23*(3), 125-138. doi:10.1080/08923640903076735

Gomes, L., & Bogosyan, S. (2009). Current trends in remote laboratories. *IEEE Transactions on Industrial Electronics*, *56*(12), 4744-4756. doi:10.1109/TIE.2009.2033293

Gröber, S., Vetter, M., Eckert, B., & Jodl, H. J. (2007). Experimenting from a distanceremotely controlled laboratory (RCL). *European Journal of Physics*, *28*(3), S127. Retrieved from Google Scholar.

Jona, K., & Vondracek, M. (2013). A remote radioactivity experiment. *The Physics Teacher*, *51*(1), 25. Retrieved from Google Scholar.

Ku, H., Ahfock, T., & Yusaf, T. (2011). Remote access laboratories in australia and europe. *European Journal of Engineering Education*, *36*(3), 253-268. doi:10.1080/03043797.2011.578244

Lindsay, E., Long, P., & Imbrie, P. K. (2007). Remote laboratories - approaches for the future. In *37th ASEE/IEEE Frontiers in Education conference: FIE_milwaukee_07_remote.Pdf.* Milwaukee, WI, USA: ASEE/IEEE Frontiers in Education Conference.

NANSLO Lab Tutorials. (n.d.). NANSLO lab tutorials. [Web page]. Retrieved from http://www.wiche.edu/nanslo/lab-tutorials

Sauter, M., Uttal, D. H., Rapp, D. N., Downing, M., & Jona, K. (2013). Getting real: The authenticity of remote labs and simulations for science learning. *Distance Education*, *34*(1), 37-47. Retrieved from Google Scholar.