
AC 2011-2361: EFFECTIVELY UTILIZING LOCAL AND REMOTE THERMO-FLUIDS LABORATORY EXPERIMENTS TO ENHANCE STUDENT LEARNING.

Ms. Meghan Marie Rock

Mr. Harry Marx, Rochester Institute of Technology

Harry Marx graduated from the Rochester Institute of Technology in March 2011 with a B.S. in Mechanical Engineering Technology. He is currently an employee of Micron Technology.

Mr. Seth M Kane, Rochester Institute of Technology

5th year Mechanical Engineering Technology Major. Actively pursuing Bachelors degree. Worked at Johnson and Johnson as a Project Management Co op. Also worked at Fisher-Price as a Product Development Intern.

Robert Garrick, Rochester Institute of Technology (COE)

Rochester Institute of Technology, College of Applied Science and Technology. Robert is an Associate Professor. He holds a BS in Electrical Engineering, MS in Mechanical Engineering, MBA Ph.D. in Mechanical Engineering, and a PE license in Mechanical Engineering. Prior to this academic position Robert worked 25 years in the automotive component industry. His primary research interests are in the domain of product realization, and energy efficient buildings. He can be reached at rdgmet@rit.edu or through LinkedIn.com

Larry A. VILLASMIL URDANETA, Rochester Institute of Technology (College of Applied Science and Technology)

Larry Villasmil is an Assistant Professor in the Department of Manufacturing and Mechanical Engineering Technology at the Rochester Institute of Technology. He received his BSME in 1988 from the "Universidad Nacional Experimental del Tchira" in Venezuela. After graduation, he joined "Petrleos de Venezuela" working in several positions as a rotating equipment specialist in the E&P division. He earned his MSME in 2002 and PhD ME in 2006 from Texas A&M University. His research interests include Computational Fluid Dynamics, Rotor dynamics & Turbo machinery, Industrial Power Generation & Refrigeration, Heat Transfer, and Fluid Power. He teaches courses in the area of thermal and fluid sciences such as fluid power, applied fluid mechanics and thermo-fluid laboratory. He holds memberships in ASME, AIAA and ASEE.

James H. Lee, Rochester Institute of Technology (CAST)

James H. Lee is an assistant professor at the Rochester Institute of Technology. His areas of research expertise include internal combustion engines, renewable fuels, the design and implementation of sustainable energy systems, and technical and economic analysis of system upgrades to improve energy efficiency. Dr. Lee is a professional engineer licensed in the state of New York.

Effectively utilizing local and remote Thermo-fluids laboratory experiments to enhance student learning.

Abstract

Technology advancements over the past two decades have expanded exponentially. In the education field, this has taken the form of remote laboratory experiments utilizing innovative and efficient tools to enhance the learning experience of students. This paper presents an economically feasible method for the utilization of a hybrid learning environment between face-to-face learning and computer technology. The approach is directed towards “hands-on” experiments of real time and remote laboratories to enhance the learning experience of students. Using computer technology software and remote testing procedures, the effectiveness of the students’ learning can be evaluated. The benefits and limitations of remote experiments are evaluated to provide better insight into this innovative learning experience.

Introduction

Although remote laboratory experiments have been studied for educational applications since the early 1990’s, they are still in their infancy, and are only recently becoming a reality.¹ Moore’s Law proposes that computer technology development doubles every year, and completed developmental stage can then be utilized the next year to continue these advancements.² Taking into account this exponential growth in computer technology, remote laboratories are now at a developmental stage where their potential to become an essential tool for science education is promising.

It is not uncommon to see simulations of experiments used as supplementary educational tools. These virtual laboratories exist in high schools and colleges across the United States and Canada to promote a blended learning environment in which students are provided access to different forms of media to enhance the learning experience. The ability to use a simulated environment to further understanding of fundamental concepts is a powerful educational tool which can provide a highly detailed and realistic learning environment. Remote laboratories allow students to access and operate real equipment remotely. Remote laboratories provide the accessibility to complete the laboratory from any location. The remote laboratory provides the student the experience of adjusting real equipment and observing the actual response of real systems. These systems have losses, friction, and all of the many nuances that are difficult to model in virtual systems. Students are given remote control of the testing equipment, allowing them to vary the parameters of the experiment being run from any location. Results are then displayed back

through live streaming video. The actual data is recorded so the students can perform the analysis of the experiment being studied. The data recorded can then be compared to the theoretical performance (no losses, no friction, ...) of the system to allow the student to understand the similarities and differences between theoretical and real systems. These laboratories will enable all students, including high school students, access to specified testing equipment typically available only to students at major universities.

The experiment for this study was within the Thermo-Fluids Laboratory class. This class has the following intended learning objectives that are applicable to the execution of this experiment; determine appropriate data products for a particular apparatus, conduct experiment collecting sufficient and correct data products, complete analysis of data and compare to theoretical performance of system, prepare a written test report that includes analysis, data synthesis and conclusions. The intended learning objectives map to the program objectives of; the ability to formulate, conduct, analyze and interpret experiments and apply experimental results to improve designs and processes, the ability to identify, analyze and solve technical problem, and effective communication.

Student Perspective

Some studies have attempted to capture the experience of the students who have conducted remote experiments. This study is unique in that it is completed and written by students, and will include their direct opinions and suggestions. Rather than provide a statistical analysis of a student's understanding and appreciation of a new learning goal, this study presents a direct student evaluation and critique in addition to highlighting the benefits. It is also necessary to focus on perceived drawbacks of this learning technique so improvements can be made to foster a greater acceptance and appreciation among educators and students alike. The technology exists, and with the support of educators, it can flourish.

Utilization of Remote Laboratories

The most significant advantage of performing experiments remotely is that they are more economically feasible than local laboratories of the same scale and/or quality. "Traditional hands-on labs put a high demand on space, instructor time, expensive apparatus and experimental infrastructure, often in a number of identical lab stations, which can be of little use for other purposes".³ These remote laboratories allow all students to run tests at the same time, and the school does not have to purchase, store, set up or maintain the equipment when it's not in use. There are fees for using these online laboratories, but these fees are substantially less than the capital costs to acquire experiments of the same scale and quality. It may make better financial sense for colleges who use the equipment frequently to purchase the equipment, making

the investment upfront, rather than to rent out the remote laboratory time. However, for schools which do not utilize their laboratory equipment very frequently it may make sense to pay for it on an as-needed basis, or even try the laboratory experiment remotely before purchase to insure the desired learning outcomes are achieved.

There are some debates surrounding the effectiveness of these labs as “hands-on” experience, and various models are currently being developed to better measure how adequately the students are learning the material through these remote laboratories. According to the writers of MIRACLE (Model for Integration of Remote Laboratories in Courses that use Laboratory and E-learning systems) “remote laboratories offer students remote control over real experiments operating at a distant location... it can be the best possible alternative to the real hands-on laboratory”.⁴ A contributing factor is the actual data generated by doing the laboratory remotely, enables students to analyze the system utilizing their own gathered data, rather than an generic dataset. One argument is that remote laboratories only partially replace local laboratory work by familiarizing the students with the equipment prior to class, better preparing them to run labs and focus instead on theory based questioning. The authors suggest that some of the laboratories be conducted remotely and others locally to ensure that students do not lose touch with doing these experiments locally.⁵ From our experience this is a very reasonable approach.

Remote laboratories provide students with the ability to complete the labs independently without the presence of the instructor, thus allowing for flexibility in scheduling laboratory sessions. There is also the added benefit of being able to repeat more than once the laboratory to clarify concerns during the analysis of the results, or to gather additional information that may have been initially overlooked.⁵ Another advantage of performing remote experiments is the increased accessibility and opportunity for those students who are unable to attend laboratories locally.⁶ This provides online colleges the ability to offer these science oriented activities which may have previously been available.

One goal of our student experience was to gain a varied exposure to different technologies and systems. With this exposure to different applications we feel that we are better able to adapt to changes in our future careers. Utilizing remote laboratory experiments allows the University to expose students to different applications without the need to purchase extensive equipment. In addition, with the ever increasing growth of technology additional experiments are able to be adjusted, monitored, or changed remotely. Using this approach we are able to be exposed to a larger spectrum of experiments. In industry, remote experiments have been essential for many years, in various applications. For example, when a technician could be working in a dangerous situation they could run the test remotely from a safe location. This safe location could be in an adjacent room or outside of the state/country.

Students Perception Comparing Remote Laboratories to Local Laboratories

Our group consists of three members, one female and two males, all of whom are of senior status in the Mechanical Engineering Technology B.S program at Rochester Institute of Technology (RIT) We agreed as a group to evaluate the advantages and disadvantages of using remote experiments and noted no difference of opinion based on gender or age. We worked with Jack Gilbert from GDJ, Inc., whose testing facility is located in Ohio, to run the wind tunnel laboratory remotely from RIT. Our goal was to run and compare the “Lift and Introduction to Aerodynamics” thermo-fluids experiment, with the same software and the same equipment locally to allow a direct comparison of the student experience.

In both cases, the wind tunnel used was a Model 1440 Flotek Wind Tunnel, which has a 12” x 12” test section area and a 12:1 entrance cone contraction ratio. Both wind tunnels were upgraded to have an Airfoil Stepper Motor Controller and a Data Acquisition board to read 16 channels of pressure data in real time, also provided by GDJ, Inc.⁷ The experiment consisted of evaluating the performance of a NACA4415 cambered airfoil at different wind velocities and angles of attack. The motor controller was used to change the airfoil’s angle of attack from the LabVIEW (Laboratory Virtual Instrument Engineering Workbench) program. The same LabVIEW interfaces were used to operate both wind tunnels. (see Figures 1 and 2) this allowed us to focus on the remote laboratory experience and not be concerned with different LabVIEW interfaces.

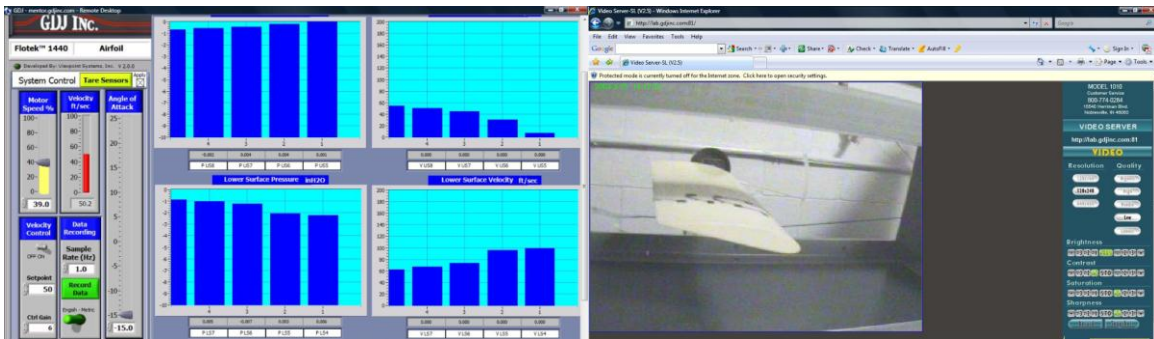


Figure 1: LabVIEW Interface

Figure 2: Live Streaming Video of Airfoil

To operate the wind tunnel remotely at GDJ Inc. a LabVIEW Runtime program needed to be installed on the local computer at RIT to access the wind tunnel. This was the main technical problem encountered. We will review this problem in detail as it appears typical of conflicts between the installation of executable programs and the university browser’s security settings. The problem encountered was accessing the LabVIEW controls and interface from the GDJ Inc. webpage, even though we had already changed our computer security active X controls settings

to those recommended by the manufacturer we still had issues. The system tested utilized Windows 7 64 bit with Internet Explorer 8. The problem with the remote test lab (page http://lab.gdjinc.com:87/GDJ_Flotek.html) was the attempted access of an executable file (.exe) via ftp in Internet Explorer. No current web browser or security software will allow this action as it is highly suspicious as virus/worm activity. To overcome this issue the group downloaded the executable file LVRTE861MIN.exe. This executable file installed the LabVIEW Runtime. After the installation the LabVIEW program was now accessible by Internet Explorer. A secondary issue was that running the experiment required two windows one for the LabVIEW settings and data screen (Figure 1), and a second window for the streaming video of the test section of the wind tunnel (Figure 2). We found this to be problematic because we were constantly switching screens, or minimizing windows to view both simultaneously. A possible solution would be either dual monitors, or inserting the streaming video and the LabVIEW screen into one window.

Advantages

The remote laboratory was significantly faster to complete than the local laboratory due to the setup time being eliminated. The laboratory experiment required testing both a cambered and non-cambered wing therefore the set-up and changeover time for the local experiment was a significant portion of our scheduled laboratory class time, approximately 50%. While setting up the experiment did expose us to the necessary steps to configure the experiment it did not directly add to our learning in the aerodynamics field. Utilizing the remote experiment allowed the group more time to discuss what was actually taking place and time to explore additional settings not included in the local procedure. As students we feel the drive of instructors to efficiently use class time and remote experiments may be part of the solution. We also appreciated sound being available during the remote test because it allowed a more realistic environment with an option of volume control; whereas, during the local laboratory we found that noise from the wind tunnel to be somewhat annoying, and interfering with our group communication. The audio portion of the remote experiment added to the feeling that you were actually controlling the wind tunnel. We found it extremely helpful to access the remote laboratory asynchronously from the class time. We had forgotten to write supportive observations during the experiment that would help us explain the air separation along the wing at different angles of attack. We were able to correct this mistake easily by repeating a portion of the remote laboratory outside of the class time.

Drawbacks

Most problems we noticed when running the remote laboratory seemed trivial when we discussed them. During the local experiment we were able to handle the two airfoils that were evaluated and while it may have seemed trivial at the time, with the remote lab we were not able to do this. Handling the key components of the laboratory experience added to our overall experience. As schools consider using remote laboratory experiments they may want to purchase the key components of the experiments to allow the students to handle these pieces as part of the pre-laboratory preparation and during the experiment. In our case, the key components were the

airfoils being tested. With the airfoils we could see the specific pressure tap locations and feel the non-cambered and cambered airfoil differences. Also, the local laboratory required us to change out the two airfoils and their pressure sensors, which could be seen by some as a waste of instructional time. Setting up the lab helped us to understand how the laboratory equipment was designed and how it was gathering the data. The laboratory setup was interesting to us; we enjoyed experiencing the setup of the equipment and being able to ask the Professor questions about the apparatus. With the remote laboratory the experiment was all set up which saved significant time, ensured the safety of the equipment, and guaranteed that the sensors were hooked up in the proper locations. This allowed for a more stable laboratory environment without requiring instructor direct support for the laboratory group. Conducting the experiment asynchronously from the class obviously did not allow interaction with the instructor to address questions, therefore class time would need to be allocated to review questions or issues with the team. We feel the optimum solution would have the instructor demonstrating the laboratory and then allocating review time once the students have completed the experiment. This additional access time should be budgeted for the class and remote access charges. Lastly, during the local laboratory there were additional flow visualization tools available. In our case this was accomplished locally with helium bubbles that were introduced into the inlet of the wind tunnel to allow the students to visualize the flow over the wing. With this we were able to observe the effect of the angle of attack on flow separation from the wing. This was a great visual learning aid. The remote lab had string attached to the wing to show the air separation from the wing. While this was helpful the flow visualization using helium bubbles was superior to allow the students to visual flow streaklines.

Instructor Perspective

The remote experiment as mentioned by the students provided appropriate data products and the ability to easily access the experiment to observe items that the students may have missed initially. This feature enhanced the course learning objective of determining appropriate data products by allowing students to iterate on the analysis by identifying questions, leading to additional data/observations, resulting in increased insight to improve the overall understanding of the material. This cycle of iterative learning also enhanced the course learning objective of completing the analysis of the data. Through the utilization of a remote experiment the understanding of losses, and measurement error was also enhanced as the students compared their measured results to the theoretical performance of a system. Overall, with the use of this remote experiment the intended course learning objective were achieved or enhanced as compared to the local laboratory experiment. Obviously, the ability to conduct remote experiments on equipment that is not available locally would have the potential to provide increased value to the course learning objectives and overall program outcomes.

Future Trends

Universities in China and Germany have been developing different remote laboratories that utilize Java applets to teach lessons such as resistor color band identification, “inverted pendulum, coupled tank and fan-plate systems”.⁸ There have been some problems with firewalls allowing the programs to run that require Java Runtime environment to be installed. The use of Flash is highly versatile and is being used to generate virtual microscopy laboratories as well as PLC controls and data display.⁸ However, “both Java and Flash require the user to install separate runtime browsers” they don’t simply work by going through a typical website. Developers using LabVIEW are able to generate remote laboratories of various kinds with the help of Remote Lab Generator (RLGen);⁸ however, as discussed earlier software compatibility issues may continue and would need solutions as increased remote laboratory experiments are used.

We were not able to find specific market analysis trends for remote educational laboratory experiments, but in looking into industrial applications this area is expanding. There are many examples of how industries all over the world are using remote technology to solve everyday problems. There are many diverse uses for remote applications within industry, one example of this can be found at Cisco Systems, Inc.⁹ They are attempting to promote the industry’s first non-intrusive tool for service providers, where they will be able to monitor and test the core optical networks. In order to test this access feature, the “ONS 15900 Wavelength Router” is an optical switching element which would allow these service providers to remotely monitor or troubleshoot client’s computers. Physical characteristics can be dissected as well as integrity of optical circuits without breaking the optical signals. All of this is done remotely, allowing the provider the ability to quickly assist their clientele if they are experiencing network issues.¹⁰ Another example of how remote applications are being used within industry is by monitoring existing highway tunnels while construction of a new tunnel or other construction activities occurs within close proximity. While these are just a few of many industrial applications it is apparent that there is a high level need for these remote applications. Therefore, the inclusion of a student remote laboratory experience may add to the student learning outcomes and prepare future engineers. With this in mind we feel that remote applications will greatly increase within educational sites following the growth within industry.

Conclusion

Remote laboratories are coming to a point in their development where we feel they will become essential to the education of future engineers. Future engineers will work in an increasingly technical and interconnected world. Engineering education programs will continue to balance the time for degree completion with the continued rapid increase of engineering knowledge and

applications. Remote laboratory experiments represent a partial solution to overcome some of these challenges. From an economics point of view these laboratories offer advantages that are too important to ignore. We believe the technical and delivery drawbacks we discussed will be resolved in time as the technology progresses. As technical and delivery issues are addressed the remote laboratories should become more acceptable to students and colleges. It is important to note that performing laboratory activities inspired us to further our education in the engineering field. For many students, engineering classes have concepts that can be taught in lecture, but aren't fully learned until lab. It is absolutely vital to maintain and offer some local laboratories. However, there are many colleges and high schools that do not need full access to all equipment but would thrive if given the option to offer remote laboratories. Next generation students have a lot to be excited about, and we can see that the students exposed to all these opportunities will turn to be better educated to address the challenges of an increasingly technological and interconnected world.

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