

7 things you should know about...

Remote Instrumentation

Scenario

With a grant from a private foundation, a consortium of three universities and two oceanographic institutes has installed a bank of sensors and testing equipment on the ocean floor, as well as atmospheric instruments at the water's surface. The project includes underwater cameras, water sampling and analytical tools, and other devices to monitor and measure a wide range of oceanographic and meteorological activity. The equipment is linked to the institutions in the consortium, where researchers and faculty can control the devices.

Jennifer is an undergraduate in a marine biology class at one of the participating universities. During lab sessions, her professor, Dr. Morgan, frequently turns to the undersea lab to demonstrate experiments and show students the results. He can control video cameras on the sea floor, collect water samples and feed them into a tool that analyses pH and other parameters, and even position the water sample under a microscope, all through a simple browser interface. Over the semester, Dr. Morgan uses data from the instruments to show the class correlations between atmospheric conditions and the conditions of the water and marine life. Dr. Morgan knows that exposing students—particularly undergraduates—to authentic research such as this contributes significantly to their engagement with the material, their understanding of it, and their motivation to pursue further study. Outside class, Jennifer can perform most of the same manipulations from her dorm room, using a modified version of the interface. She can repeat experiments to see how the results change over time, and she especially enjoys watching the instruments that measure the movements of the tides and that monitor local sea life.

Meanwhile, students at numerous other universities can also access the instruments from their campuses. The foundation that funded the system stipulated that access be as wide as possible. Because it is open to universities and researchers around the world, the undersea lab is in use most hours of the day, transmitting data and observations over the Internet. Policies worked out by the founding members of the consortium establish who has priority for the instruments at certain times.

What is it?

Remote instrumentation is the practice of providing control of scientific instruments from remote locations. Devices for which a college or university might arrange remote access include astronomical instruments, spectrometers, or electronics equipment. Because of their expense and complexity, many specialized scientific instruments are out of the reach of some institutions, and for institutions that have such instrumentation, scheduling and other logistical issues prevent full utilization of those tools. Initiatives that offer remote access strive to address issues of access and efficiency, ultimately improving educational quality and student opportunities.

Who is doing it?

A number of institutions have remote instrumentation projects in place, including MIT, which began its iLab program several years ago. The iLab program allows users to conduct experiments with specialized equipment on the MIT campus—such as a shaker table that simulates earthquakes, and a flagpole equipped with a wide range of sensors measuring meteorological parameters—through a browser interface. Initially for MIT students, the program now makes its instruments available to researchers and students around the world.

The W. M. Keck Observatory, located at the summit of the Mauna Kea volcano in Hawaii, houses the world's largest optical and infrared telescopes. Due to its location and elevation—it sits at nearly 14,000 feet—many researchers cannot go to the facility, but researchers share access to the observatory through remote instrumentation. In addition, fields such as health care are using remote instrumentation for telemedicine and similar programs.

How does it work?

Remote instrumentation requires an interface, typically browser-based, that allows users to control the relevant functions of the instrument. As scientific devices become increasingly complex, knobs and levers are giving way to entirely computer-based control panels, which makes the development of a remote interface relatively simple. More complicated are software agents that oversee usage of the instrument, assigning priorities to individual experiments, maintaining the security of the data, and ensuring that the device is not misused.

With a typical remote instrumentation project, users log in to the system. The interface can be virtually identical to the primary set

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of controls for the device, or it might include controls for a limited set of the instrument's functions. Some instruments, such as chromatographs or spectrometers, analyze samples. A sample might be sent to the facility that hosts the device, where a technician loads the sample and prepares the instrument. Users from remote locations could then conduct desired experiments through a computer screen. If real-time interaction with someone at the facility is necessary or beneficial for the experiments, two-way communication can be set up, such as a videoconference.

Why is it significant?

For a host institution, providing remote access can improve scheduling for on-campus users, who can conduct experiments outside class or lab times, and promotes more efficient use of specialized equipment that might otherwise sit idle for long stretches, only to be swamped during peak times. Remote users benefit by having access to extremely rare or unique scientific instruments. Some instruments are so expensive and specialized that there might only be a handful—or even just one—in existence. Exposing students to such equipment, allowing them to engage in authentic learning experiences rather than just simulations or canned exercises using archival data, creates more compelling learning opportunities. Working with the actual tools of a field deepens students' understanding of the concepts at work and prepares them for careers using those devices. In at least one case, a remote instrumentation project exposed university students to sensitive hardware maintained by a commercial entity. The company controlled access to the equipment, protecting its interest while allowing students the opportunity to experiment with it.

Remote instrumentation can save time and the expense of travel, preserving or even expanding access to scientific facilities in times of stalled or shrinking budgets. Faculty can expose students to discipline-specific instrumentation without having to take field trips, and in some cases students can interact remotely with practitioners in the field. Moreover, by providing access to the general public or students, researchers may fulfill a requirement to disseminate publicly funded research as broadly as possible.

What are the downsides?

Remote instrumentation for scientific equipment carries several risks and challenges, among them security, access, and cost. Whenever sensitive assets are connected to a network, security concerns must be identified and addressed. Proper authentication of users is vital to prevent inappropriate access to instruments, data, or other network assets. The question of access inevitably arises when determining not only who is permitted to use an instrument but also who has priority. Negotiating an appropriate compromise for the use of remote instruments by all interested parties is necessary. A corollary to the issue of access is the level of expertise required to properly and safely control an instrument. The operation of some equipment must be overseen by technicians, which can complicate scheduling for users who cannot operate the instruments without supervision. Moreover, interfaces must be designed with these issues in mind, restricting access to functions that could inadvertently damage the

instrument. Finally, underlying all of these factors is the issue of cost. Specialized equipment is expensive to implement and operate, and the degree to which an instrument requires oversight by on-site technicians adds to these costs. Any organization that makes its instruments available must understand and account for the increased costs that such access entails.

Where is it going?

As network infrastructure matures—offering greater speeds, improved security, and increased access—opportunities grow for bringing experiences of genuine scientific instrumentation and work to a wider range of students. As institutions reap synergistic benefits of remote instrumentation, higher education will likely undertake more partnerships in which colleges and universities maintain different pieces of scientific equipment and share access to those resources, maximizing their usage while eliminating multiple purchases of similar hardware.

As scientific instrumentation is increasingly controlled solely through computer interfaces, and as security measures and software to manage resources become more sophisticated, the number and kind of instruments available through remote channels will increase. In addition, as the means of connecting scientific devices to the Internet become simpler and less expensive, institutions will be more willing to give remote access to older instruments that have been replaced with new equipment but remain valuable for teaching purposes.

What are the implications for teaching and learning?

Remote instrumentation has the potential to bring authentic learning experiences to a wide range of students, resulting in richer learning and a deeper understanding of the material at hand. It's the difference between simply reading about a principle in a textbook and being able to perform experiments that apply those principles. For some students, remote instrumentation opens the door to hands-on experiences they could not have otherwise. For other students, remote instruments can add considerably to the amount of time they can work with scientific equipment, broadening the range of experiments they are able to conduct and the opportunities for learning. Remote instrumentation can allow courses to be taught online that otherwise would have to be taught face-to-face because of their reliance on specific equipment, and faculty can include real-time demonstrations in lectures, bringing authentic examples of experimentation or problem-solving to students. Undergraduate learning in particular can benefit from linking course content to the tools and experiments of the discipline.