Adaptable virtual X-Ray laboratories for online teaching, learning, and authentic practice

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The presented Virtual X-ray Laboratories (v-XRLab) have been developed to address the lack of advanced and expensive research equipment for educational purposes, facilitate hands-on practice associated with online science or engineering courses, and enhance students' knowledge of equipment design and operational principles. Also, in contrast with fully computerized contemporary X-ray equipment, the v-XRLabs help students understand factors affecting data accuracy and method limitations first-hand, and, consequently, better estimate reliability of the experiment results.

During the COVID-19 pandemic, the virtual labs helped instructors minimize drawbacks of lost access to actual physical laboratories.

Integrated cloud-based virtual laboratories (ATeL's v-Labs) allowed learners to perform authentic research and laboratory experiments online, using highly accurate digital copy of a multifunctional X-Ray Powder Diffractometer (v-XRPD) and X-ray Fluorescence (v-XRF) spectrometer. The v-XRPD realistically imitates the design and operation of a typical flat plate geometry diffractometer, and it also includes educational analytical software.

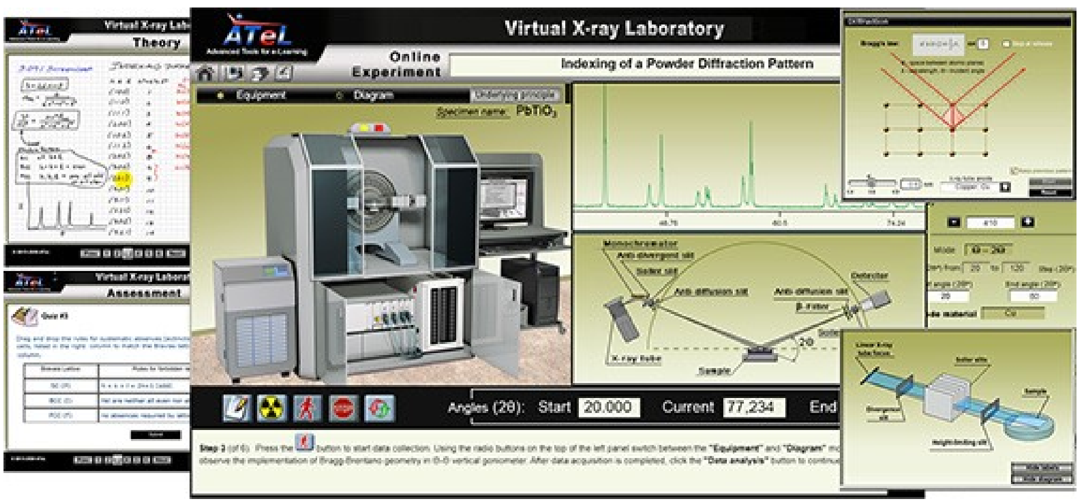

Figure1. Screenshots of an online experiment "Collecting Data and Indexing of a Powder Diffraction Pattern

The v-XRLab includes an open repository of samples available for experiments. The Diffractometer can work with CIF files obtained from the CCDC CSD, XY formats produced by a vendor's instrument, and some other plain text files as well. The open collection of virtual samples available for online experimentation includes alloys, ceramics, polymers, nanostructured materials, thin films, and even human kidney stones.

Experimental data can be collected and handled manually or automatically. Virtual data can be exported to popular software as well.

The v-XRLabs incorporate self-guided online experiments that couple hands-on practice with efficient contextual 'just-in-time learning" by integrating simulations with video and voice instructions, manuals, quizzes, references, and other multimedia learning resources. This combines skill development, knowledge acquisition and performance-based assessment into a single process.

A complimentary authoring tool enables instructors to modify existing online experiments and to create new ones, as well as to add new samples in the repository. New samples can be either based on actual XRD patterns or be calculated from known structural data.

The v-XRLabs incorporate an augmented reality (AR) X-Ray diffractometer (AR-XRPD) and its attachments running on a mobile device or smart glasses and synchronized in real time with the main simulated XRPD and the relevant processes. This dramatically enhances student engagement and provides them with unique opportunities for data analysis and deeper exploration of the equipment and processes in augmented reality.

The v-XRLlabs were incorporated into courses on chemistry, materials science, forensics, mineralogy, metallurgy, and materials characterization techniques, among others. They has been used as follows: (i) as the only tool for lab practice on the relevant subjects, by the students who have no access to real equipment including MOOC students; (ii) for hybrid experimentation in combination with equipment; (iii) for preparing students and tech personnel to effective and meaningful hands-on practice in actual X-ray labs; (iv) for performance-based assessment of students' and trainees understanding, and their ability to apply acquired knowledge and skills for performing experiments, and solving practical tasks; (v) and for lecture demonstrations.

The presenters will share their experience in using the v-XRLabs during the COVID-19 pandemic and beyond it. The v-XRLab can be accessed at the following link: https://atelearning.com/XRLab/index.php

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