A $17 million engineering laboratory reveals its inner workings, becoming a lesson in itself for University of Colorado engineering students.

RICHARD G. WEINGARDT

Teachers giving courses at the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado are encouraging engineering students to look away from the blackboard and stare at the wall instead. Or the ceiling, depending on the day’s lesson plan. The laboratory building is designed as a teaching tool, a real-world model that students can study and manipulate for a hands-on demonstration of engineering principles.

The laboratory, at the base of the Flatirons Mountains in Boulder, Colo., was designed to reawaken enthusiasm for the University of Colorado’s engineering program and halt the rising dropout rate among freshmen and sophomores. Richard Seele, dean of the college, initiated the building design in an attempt to break away from traditional teaching methods, involving lectures and theory-dominated discussion, which inundated students with information without demonstrating real-world applications.

To make the ITLL a vehicle for learning, all of the mechanical, electrical and architectural systems in the building were left exposed or showcased behind Plexiglas panels wherever possible. In addition to observing real engineering applications, students can monitor and even manipulate portions to test first-hand how the architectural engineering theories taught in the classroom actually function.

BUILDING AS-LAB

The three-story, 34,000 sq ft ITLL houses two large laboratory plazas containing 34 workstations, each outfitted with computers. Quiet, windowed studios nearby give students and instructors places to gather and hold discussions away from activity on the plazas.

Several concrete and steel structures are visible in the laboratory. Over 200 monitoring devices incorporated into the building, including strain gauges attached to steel beams, columns and trusses, along with optical fibers embedded in concrete members, allow students to examine and compare structural performance. Students are able to measure the effects of temperature changes, wind and snow forces, and floor loadings.

The gauges are hooked to reading devices at each workstation, allowing students to evaluate and analyze data on a daily or even hourly basis. Students can monitor exterior wall deflection caused by temperature changes or high winds coming off the Flatirons at any time of day. Even the concrete drilled-pier foundations were constructed with monitoring gauges so stresses and underground movements could be followed.
The TII facility serves as a useful teaching tool not only because its "working parts" can be observed and monitored but also because, in some cases, these parts can actually be manipulated. Mechanical ductwork, for instance, can be altered to demonstrate the effect certain variables, such as duct size and shape, have on performance. To find out how quickly the temperature will rise when air flow is reduced, for example, students can experience the answer as well as calculate it.

Students can also manipulate the building’s electrical power and distribution systems, and they can alter the laboratory’s illumination, which comes primarily from natural light.

Meteorological instruments are located throughout the building, as are sensing devices to monitor mechanical and electrical equipment, together with energy flow and usage. Air circulation, heat transfer, solar energy effects and temperature stratification in the high ceiling bays can be measured to evaluate the efficiency of the building’s HVAC system. Electrical engineering students can study the TII’s electrical usage to learn power consumption characteristics.

Windows and cutaways show piping, ducts, dampers, conduits, various types of insulation, and electrical distribution lines inside the walls. Fan power boxes are open, exposing internal mechanisms, such as motors and electrical control panels. Electrical, mechanical and telecommunications rooms have viewing windows, as does the elevator shaft. Students do not have access to critical electrical and motor panel boards, but inactive duplicate panels are color coded and labeled for study purposes.

STRUCTURAL SKELETON

To acquaint students with as many types of structures as possible, Richard Weingardt Consultants Inc., Denver, structural
engineers, incorporated seven different framing systems within the building:
- Composite concrete and steel decks;
- Reinforced concrete flat slabs;
- Concrete waffle slabs;
- Concrete panel joist slabs;
- Steel bar joists and light-gauge metal decking;
- Prestressed concrete slabs;
- Precast concrete slabs (mid-reinforced).

The company also specified two types of lateral resistance systems: concrete shear walls and steel tube X-bracing. Precast and cast-in-place exterior elements serve both architectural and structural purposes.

Beams and columns are either structural steel or reinforced concrete, and steel spandrel girders consist of both standard rolled sections and custom-fabricated trusses. The structural steel frame members were left exposed, without sprayed-on fire protection insulation, because they are 20 ft or more above the floor or are protected by a state-approved sprinkler system.

Redundant structural assemblies, such as a second cage of steel reinforcing bars and ties mounted on the outside of a concrete column and beam in service, were installed to show students what is beneath the concrete surfaces. A steel beam cantilevered beyond the third-level balcony holds a section of light-gauge metal decking with studs to illustrate what lies below the concrete balcony floors.

Architecturally, the ITLL complements the Italian Renaissance architecture of the university’s main campus and blends in with the adjoining engineering center, a cluster of stark, shed-roofed buildings with exposed concrete surfaces.

The building’s exterior is glass, sandstone and cast-in-place and precast concrete. Terracotta clay tiles cover the roof. The building’s south side is almost entirely made up of exposed, precast beams and columns constructed between cast-in-place concrete foundation walls and existing landscaping that needed to be pre-

served. The north side includes an enclosed bridge connecting ITLL to the existing engineering center, built in the 1960s. The underside of the bridge structure, a concrete waffle slab, and the bridge roof, a one-way concrete flat slab, were left uncovered.

Acoustics were a major concern in the ITLL because of the building’s high bays, open interior spaces and hard surfaces. Carpet tiles, sprayed-on acoustical wall coatings and special surface-mounted acoustical panels, which students can manipulate, were installed to reduce noise and echoing.

Students need to be given the opportunity to learn in an environment that reflects “real life” conditions.

The ITLL construction process was captured on video and in time-lapse photographs taken every 30 minutes. The entire activity, recorded on CD-ROM, is now in use in the University of Colorado’s Construction Management Program as an on-site construction lesson.

INTEGRATED TEACHING
A system of integrated teaching and learning recognizes that students need to be given the opportunity to learn in an environment that reflects “real life” conditions.

Course work in the first year of the engineering program at the ITLL introduces undergraduate students to practical aspects of engineering. The novice engineers work in teams with a special focus on creative and group problem-solving processes designed to improve their presentation and communication skills. Second- and third-year courses are devoted to reinforcing experiential learning and exploration through lectures. The graduating class concentrates on interdisciplinary projects incorporating the previous three years’ studies into “real-world” design projects. Integrating actual work with requisite studies is expected to produce a stronger level of engineering knowledge and awareness, a benefit for students planning to enter the workforce.

Richard G. Weingart is CEO at Richard Weingart Consultants Inc., Denver.