

WHAT IS THE LAB OF THE FUTURE?

What is the lab of the future? Will it feature increased quantities of electrical outlets, wireless data and communications, interaction spaces, modular furniture, open labs and dance floors? These are current trends in laboratory design, but what about the future...

The laboratories needed for research and learning will be shaped and defined by many forces. It will be inextricably forged from the integration of computer technology, communications technology, emerging technology and most importantly the culture of the future generation of science students.

The Laboratory of the Future is Digital....

Computer technology is continuing to develop at a rate established by “Moore’s Law”, effectively doubling every six months. At its current state, the largest computer at Oak Ridge National Labs will operate at a 40-teraflop capacity. The processing power is used to collect, analyze, and graphically display data so that relationships and patterns can easily be understood and communicated. Computing power has been the single largest contributor to the growth and advancements in science. Its influence will continue to revolutionize the investigation, exploration, and teaching of science.

The Laboratory of the Future is Small....

In laboratories it has become commonplace to have computers connected to lab instrumentation. There are obvious advantages to this relationship as the computer can compile results with greater accuracy than can be achieved manually and avoid issues of human error. As the instrumentation benefits from advances in nanotechnology, it will become increasingly sensitive and shall require smaller quantities of materials for experimentation. This not only improves the level of safety in the lab but also results in a greater dependency upon the computer for experimentation, analysis, and results.

The Laboratory of the Future is Virtual....

Computer technology will also lead to a greater utilization of virtual laboratories. The development of software in combination with the computing power and visualization devices allows for the theoretical study of complex and dynamic systems. These studies can be based upon either real or simulated data. A student can investigate topics as diverse as the characteristics and composition of a compound, discover new molecules, as well as view chemical reactions, DNA structure, phases and progression of fire, formation of storm clouds, nanostructures and machines, the collision of two galaxies, or an atomic blast. This is similar to the collaborative research activities currently being conducted at the Beckman Institute at the University of Illinois at Urbana-Champaign. The wonder of this technology is the ability to “see” and interact with the atomicworld, the astroworld, and everything in between. Scale and time are no longer an issue. An event that happens in a few milliseconds can be experienced as a singular moment, in

slow motion, or fast-forward a few million years - all from the comfort of an office chair. This technology offers new ways to view the natural world in action that would otherwise be impossible to witness or study in such detail.

The Laboratory of the Future is Open....

Likewise, concurrent advancements in communications have occurred. This has dramatically impacted our ability to access information whether it is by videoconference, cell phone, instant messaging, e-mail, the web, or institutional databases. Information and data can be shared and provide the basis for independent analysis and discovery. This is not unlike current practices in the medical community. Information is collected from clinical trials such as those conducted by the Clinical Pharmacology Department at DMC Children's Hospital. Information from clinical studies is made available to pharmaceutical companies as well as other physicians and researchers. Opening up scientific databases to the web or by other electronic means could facilitate collaborative work between institutions as well as independent study without duplicating research activities that require a standard lab.

The Laboratory of the Future is Remote....

Increasing use of wireless nodes, high bandwidth and cable capacity like the Internet2, which is currently planned to link universities with national labs, will facilitate the ability to for scientists and researchers to work cooperatively between remote locations. This will make it possible to inexpensively share resources such as unique equipment or labs. Furthermore, these resources can be located at another institution, another country, or even outer space. For example students will be able to mail an insect collected locally to the "Bugscope" lab at the National Center for Supercomputing Applications. The sample is then prepped by a lab technician and placed in a Scanning Electron Microscope where students around the world can control the settings, resolution, and view the images remotely over the web. These images can be sent as still images or real time clips. Other laboratories such as the Amundsen-Scott Station, Hopkins Marine Station, and the NASA lab module at the International Space Station are also equipped and promote remote experimentation for research and educational purposes. These facilities provide the means for students to observe and even conduct experiments requiring extreme environments like the Antarctic, the ocean, or space, which would otherwise be improbable.

The Laboratory of the Future will be Augmented....

Emerging technologies such as augmented reality will greatly impact how science will be taught. Augmented reality will simultaneously combine real world experiences and perception with supplemental data. It can overlay visible objects with text and graphics that can reveal systems and structures that would otherwise be hidden. Wireless handheld PDA's and tablet computers can present information, assignments and procedures to students directly. These devices will be utilized to both support and direct lab activities. New technology such as the "Sonic Flashlight" developed by researchers at the

University of Pittsburgh and Carnegie Mellon University functions like an instant non-hazardous x-ray. Utilizing ultrasound technology, the flashlight can project images of bones and blood vessels over any region of the body. Lab activities can be enhanced by having students wear special glasses that allow them to simultaneously view an organism either in whole or dissected form that with supplemental digital information such as graphics and text, which highlight and identify specific organs or systems. This provides students with direct hands on learning experience that is specific to their project further enhancing the learning experience, which will ultimately lead to greater understanding.

The Laboratory of the Future is Synthetic....

There are some interesting projects currently under development like the “Living Anatomy Program” at the University of Buffalo. This project seeks to promote learning about the human body by developing a synthetic human body, which is a life-like body with organs that look, feel and smell like the real thing. This will provide students with a learning tool to gain deeper understanding of anatomy. Medical students will be able to practice surgical procedures without harming patients. This synthetic approach to science will provide students with a realistic experience that may not otherwise be practical or affordable.

The Laboratory of the Future is Cultural....

The needs and expectations of the students of the future will be dramatically different from those of past generations. These students are tech savvy having grown up in a world that is saturated with electronics and digital media. These students are affluent, connected, and demand instant gratification. They will enter higher education well equipped with computers, PDA's, PDA cell phones, DVD's MP3 players and other peripherals. Universities will become increasingly focused on providing the means for docking and networking with less emphasis on hardware. In this digital age of instant messaging, videogames, easily accessible information, and entertainment, students are accustomed to consuming information quickly and require more challenging and stimulating material to capture their interest. Courses must be transformed into dynamic multi-sensory experiences. Students will also expect a less structured and more flexible education that can be customized to accommodate their diverse interests. For example, students may wish to combine disparate majors such as Sociology and Engineering. This ability to cross disciplines will promote cross-pollination and infuse the sciences with new perspectives. This not only serves the interests of the students but also fosters creativity and the advancement of knowledge, which is critical to generating scientific breakthroughs and advancements.

The Laboratory of the Future is Social....

Universities and commercial laboratories have recognized the value of creating environments, which promote both serendipitous and formal interactions and activities. The students of the future will require a new type of space – a “third place”, not the dorm room and not the classroom. It would be a place where students go to learn, play games,

and to be a part of a group where social interaction is overwhelmingly important. This would be similar to the PC Cafes found in South Korea, which are essentially on-line game rooms packed with honeycomb like compartments for computer stations with high bandwidth connectivity. In the past, going on-line has not typically been a group social experience. If you are on-line, it has usually been assumed that you are not talking to someone in the room. With the “hive-like spaces”, the on line experience can be transformed into a social activity. The technology of the future will need to be integrated with the environment to promote the connectivity of students digitally ,physically as well as socially.

The Laboratory of the Future is a Destination...

The laboratory of the future will be the Hypermedia Science Studio. It will be a place where students will have 24/7 access to dynamic media rich course software and content. They can take their courses on-line and learn at their own pace. Instructors would only need to be accessible for questions sent by e-mail, instant messaging, or by appointment. This will assist universities in their goal to foster the student’s ability to be independent and self-educating. The on-line format will also allow students greater freedom to customize and structure their education. They can earn a hybrid degree combining multiple disciplines such as Computer Science and Chemistry or Material Science and Genomics. Students with these new hybrid degrees will then be able to contribute new ideas and unique perspectives. This will generate creativity, energy, and enthusiasm that will begin with the individual and ripple through to their classmates. The atmosphere of the lab must be lively and exciting in order to encourage social interaction between classmates so that they may share knowledge and ideas.

The Hypermedia Science Studio will be flexible beyond anything to which we are currently accustomed. We will no longer depend upon the module for flexibility. There will no longer be any plug and play capability as the outlets and tethers will no longer be necessary. It will be a liberating space allowing for movement and multiple configurations within environments that are not limited by shape or function. It will draw students because of their desire to be near others with similar interests, the excitement of the activity, information, and sound, as well as the physical necessity of connectivity. The space will be blanketed with wireless nodes allowing students and researchers complete freedom to work anywhere within the influence of the signal – even outdoors if desired. Given the speed limitations of wireless technology, high-speed cable connections will also be required. Since most science will be conducted with some form of PDA or laptop, the indoor spaces will require indirect lighting to prevent glare. The walls will be lined with plasma screens and LED displays. They will present current news in science from across the globe and other items of interest including pop culture. The environment will be visually rich and stimulating with sounds to draw people in to “see what all the buzz is about”. Individual students or lecturers, whether on site or in Hong Kong, can present and demonstrate their work to individuals on their personal screens or a large format display for larger audiences.

In the future, students who require a high bandwidth connection can use a “tech board”, which is a workstation with seating and bench space attached to a skateboard-like structure that can seat one or two people comfortably. It will be lightweight and completely mobile. Students can position these boards in a quiet alcove for studying or group them together for collaborative projects. The “tech board” would also provide built in task lighting and will draw its power and data through direct contact with special conductive channels incorporated into the flooring system, not unlike the slot cars that children play with.

When on-hand experiments are required, students can check out materials, chemicals, and equipment at a dispensary. The dispensary is similar to a pharmacy where items that are checked out must be returned so that they can be recycled, cleaned, and stored. The dispensary will be automated with robots and overhead cranes used to assemble the specified “lab in a box” and attach it to the students “tech board”. The “lab in a box” consists of a bench top fume hood, clean bench, or bio-safety cabinet, pre-measured chemicals and materials, bottled water, gasses provided by small single use cylinders, glassware, equipment, and instrumentation. Any instrumentation provided will also utilize the “tech board” to supply power and convey data. The dispensary will also provide a digital file containing experiment instructions and methods, links to supplemental information, and an alert identifying the relative hazard level for the student or researcher.

Based upon the hazard level, students and researchers may be directed to special rooms. In instances of extremely low or minimal hazards work can be done in the open in the general science studio. Fume hoods and safety cabinets will be self-contained with a recirculating system or provide such a level of filtration with HEPA and carbon filters that special exhaust will not be required. With higher levels of hazards, students and researchers must conduct their work in specially rated chambers, which are visible from the general studio. These chambers are specifically designed based upon the hazards anticipated such as a pathogen, radioactivity, or toxicity. They can incorporate items like lead or shielding, UV sterilization, air locks, and other conditions necessary to ensure a level of safety that is not achievable at the bench top level. They can also provide exhaust ports that the fume hoods can connect into when the filters are insufficient to handle an air born hazard.

The Hypermedia Science Studio will introduce a new type of architectural space – a responsive environment where science and technology merge with the digital and physical world. It will require a more efficient and appropriate learning environment - space where students will work together and professors will take on roles similar to consultants or coaches. Our challenges as lab planners will be to create digitally enhanced spaces where there will be freedom to assemble students in new ways. We will need to design laboratories, which embrace the convergence of various media from print to graphics to sound to sensory experiences through virtual reality, and will be supported by robust networks providing access to the growing knowledge of the world.