The evolution of academic research facilities: workplace trends and emerging technologies reshape laboratory design

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In the past few decades there has been a significant shift in the approach to laboratory design. The inclusion of important design principles—such as modularity, sustainability, access to daylight and views, energy efficiency, and spatial flexibility—contributed to that shift. As we approach the start of a new decade, a question appears timely: What will be the guiding design principles that will help ensure research environments meet the needs of an ever-evolving scientific community?

A look at current workplace preferences and emerging technology trends might help answer this question. Shifting workplace structures are increasingly impacting the spatial relationships of lab functions. As young scientists enter the doctoral, post-doctoral, and faculty ranks cultural and generational preferences will continue to influence how we plan and design academic research environments. The development of emerging technologies and how these technologies are adopted by the research community will have a tangible impact on research environments, functional adjacencies, and building metrics.

Workplace Preferences and Collaborative Environments

It is likely that the traditional organizational pyramid will continue to level to give place to a more horizontal workplace culture in which team work prevails over old hierarchical structures. As recent graduates begin their careers, their influence will lead to a structural re-assessment of the scientific workplace. Current laboratory planning trends hint to a preference for environments where the boundaries between the lab, the office, and the social hub blur to accommodate spaces able to be reconfigured to variety of work styles. The compartmentalization of lab functions is rapidly being replaced by multi-functional spaces, with labs extending into public and social areas to help foster interaction and collaboration. Such spaces can be found at the University of California San Francisco's Regenerative Medicine Building, where the labs seamlessly morph into social hubs. Another example of this trend can be found at the University of California Merced's Science and Engineering Building II, where prototyping labs are open to the larger academic and research community. Through Large glazed folding partitions, the engineering labs open into a colonnade that is part of the campus' primary pedestrian system. This planning scheme merges a busy social hub on campus with the college's engineering labs, allowing robotics fabrication and testing to "spill" into the colonnade and creating opportunities for spontaneous collaboration among researchers, faculty, and students.

Virtual Reality and the Mobile Scientist

Academic labs have long relied on graduate students and post-doctoral researchers to perform repetitive, tedious experimental tasks. Younger scientists expect more autonomy and greater opportunities to participate in the creative and intellectual phases of research. The development of lab automation and informatics systems, such as Laboratory Information Management Systems (LIMS) and Electronic Laboratory Notebooks (ELNs), are facilitating the cultural shift. While the use of LIMS and

ELNs is widespread in the pharmaceutical and biotechnology sectors, adoption by academic labs has been slower. The inclusion of ELN content in undergraduate curricula and the availability of systems specifically developed for the academic sector are changing this trend. In recent years, major universities, including Yale, Cornell and the University of Wisconsin have adopted web-based ELNs to serve their research and teaching labs. The most basic ELNs replace the traditional lab paper notebooks, allowing scientists to digitally log, track and search experimental data. More sophisticated systems can be programmed to set up, run, control, and analyze experiments through automated workbenches and to receive experimental data directly into mobile devices. ELNs can be set to track chemical inventories, allowing to reduce the size of costly chemical storage rooms and making the lab a safer place to work.

Instrument automation will lead to the miniaturization of lab processes, allowing experiments to run using smaller amounts of compounds. Miniaturization will result in inherently more sustainable and environmentally sound research processes, as the amount of toxic chemicals, compounds, and waste discharged into the environment will be substantially reduced. Decreasing the amount of chemicals used in the lab will also allow to reduce costly ventilation systems, and in turn help reduce energy consumption.

Process automation and miniaturization will free lab space for other critical uses. As lab equipment and instruments become smaller and more automated, the lab spaces will become increasingly compact, with areas for interaction and idea exchange taking center stage. Widespread adoption of laboratory informatics systems and instrument automation will allow researchers to spend less time on repetitive tasks and more time collaborating and brainstorming. Automation will enable researchers to link instruments situated in remote labs, share experiments through global platforms, and collaborate through virtual environments and among different scientific disciplines.

Virtual reality (VR) and Augmented Reality (AR) are slowly making their way into research labs. VR applications in biology and chemistry allow scientists to visualize, dissect, and manipulate cells and complex structures in a 3D environment. VR allows scientists to modify research parameters and create collaborative environments using multi-user application. AR, while not as immersive as VR offers 3D capabilities at a lower cost. We can expect to see some of the traditional wet lab space replaced by VR labs. These spaces will provide ample open areas for scientist to move across as they "virtually" walk and immerse in their subject research. VR labs are typically equipped with monitoring cameras that interact with VR headsets. Because VR labs are by nature flexible environments, they can double as multi-use spaces and interaction rooms.

Wet and Dry Lab integration

The use of artificial intelligence on lab processes will lead not only to a shift of open lab, support, and interaction area ratios, but also to new spatial relationships between the computational and the experimental lab. Recent trends indicate that computational simulation and prototyping will not be exclusive to engineering or material sciences labs. We will likely see an increase in simulation and prototyping in biological labs as well. 3-D printers are used in labs to create prototypes to engineer the architecture of organs. These "molds" are then combined with live cells to grow small organs and tissue primarily used for research. The interplay between computational and experimental research will dictate a higher integration of the wet and dry lab. This integration will bring new design challenges.

While much of the latest trend in lab design has been to separate computational and wet labs to attain energy and cost efficiencies, designers will need to figure out how to efficiently integrate these two lab types into highly flexible spaces that can function as dry labs, wet labs or a combination of both. And it might be emerging technologies that will allow designers to solve this conundrum: Similar to wireless data transmission, wireless power transmission will allow the reduction of fixed utilities in the lab. Advances in the development of ductless fume hoods, which rely on carbon and bonded gas phase filtration to remove chemicals before discharging air back into the room, will enable mobility of a traditionally fixed piece of lab equipment. Benches and sinks mounted on wheels, equipped with highly flexible piping allow portions of dry laboratories to be reconfigured into wet labs in a snap. At the University of California San Francisco Cardiovascular Research Building, lab services are supplied from ceiling service panels equipped with quick disconnects. The absence of fixed umbilicals and the availability of movable casework allow to quickly reconfigure the lab spaces to best serve the researchers' immediate needs.

Conclusion

As the academic research environment rapidly evolves, workplace preferences and emerging technologies will continue to impact laboratory planning and design. Instrument and process automation will shape the next generation of research environments. As the use of automated workbenches, robotics and virtual reality becomes widespread, opportunities for virtual collaboration and remote experimentation will increase. It is likely that moving forward we will see a higher integration between the computational and wet laboratory, as well an increase in the number and size of multi-functional spaces. The introduction of Virtual Reality in research processes will likely accelerate this trend. Mobile research environments that accommodate the desire to work in teams, both physically and virtually will become common place. The new spatial model will call for innovation hubs where multiple functions, such as basic experimentation, computer simulation, prototyping, and interaction, are accommodated in one space. Transparency will provide desired connectivity when acoustical controls are a must. Movable partitions will provide opportunities for space reconfiguration—from private to semiprivate to open and back—as needs dictate. Flexibility and adaptability will be less about movable casework and "plug-and-play" systems, and more about research processes and the ability of spaces to adapt to evolving technologies and preferred workplace styles.

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