FEATURE ARTICLE

Strategies to Successfully Navigate the Design of STEM Facilities

A Case Study at the University of Mississippi

by Shirine Boulos Anderson and Maurice R. Eftink

Successfully planning interdisciplinary, inter-college STEM facilities requires a special set of tools to navigate the challenges that arise when dealing with a diverse set of users.

INTRODUCTION

THE GROWING DEMAND FOR SCIENCE, technology, engineering, and mathematics (STEM) facilities in higher education mirrors the national need for graduates (President's Council of Advisors on Science and Technology 2012) not only in the basic sciences and traditional engineering fields but also in emerging technologies and sciences that blur the demarcations between these disciplines, such as biomedical engineering, biotechnology, geochemistry, information technology, and robotics.

What are the key components in planning a successful contemporary interdisciplinary STEM building?

Our discussion focuses on three important aspects of planning a facility of this type, illustrated with examples from the University of Mississippi's new STEM building. We also discuss one operational aspect that university and college administrators must concern themselves with well ahead of the building's opening date.

CASE STUDY BACKGROUND

The University of Mississippi (UM) is a public flagship institution in a mostly rural southern state with a significant disadvantaged population. Yet, UM is the second fastest-growing public university in terms of enrollment in the United States, second only to the University of Alabama (Anderson 2015). This rapid growth needed to be addressed in the university's strategic plan, which is revisited approximately every 10 years.

The UM 2020 Strategic Plan proposed two major goals:

» To lead the state and the region in preparing STEM professionals and leaders—especially from underrepresented groups—and improve the science literacy of the general public.

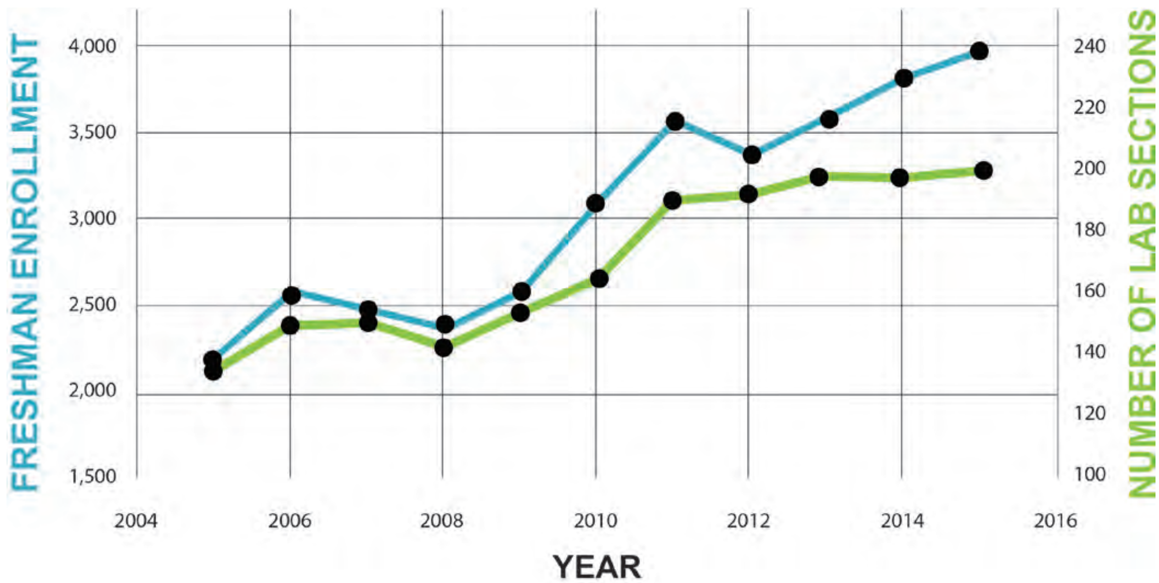
» To construct a state-of-the-art learning facility for STEM and ensure that science, mathematics, and engineering instruction is designed to attract students to these majors, which are critical to the economic competitiveness of the state and the nation.

Since 2006, UM's enrollment growth in STEM disciplines has yielded a rise in undergraduate STEM degrees of eight percent annually, mostly in the School of Engineering. However, this enrollment growth has also resulted in the institution's reaching maximum capacity in its lower-division science courses offered to entering freshmen. The limiting factor was the number of teaching laboratory spaces rather than the number of faculty or graduate instructors. This bottleneck, if not addressed, would

- » Seriously limit the opportunity for students to major in a STEM discipline, as each STEM major requires freshmen to take one or more basic science labs, such as general chemistry, general biology, and general physics;
- » Undermine UM's ability to offer general education science courses to non-STEM majors; and
- » Conflict with the institution's above-declared goal and the needs of the state.

Figure 1 illustrates this teaching lab bottleneck problem by showing that the number of lower-division science lab sections flat-lined around 2011, failing to keep pace with the subsequent growth of the freshman class.

Figure 1 **Freshman Enrollment vs. Science Lab Section Offerings**



As a result, the university made the decision to build a new STEM facility in the spring of 2014 and proceeded with the selection of an architectural team and the appointment of a STEM Building Steering Committee. Since key institutional leaders set a direction to move toward more contemporary modes of STEM education, members of the committee were carefully selected from among faculty and university administrators known to be open to new pedagogical ideas and the concept of cross-disciplinary education.

ARTICULATING A STRONG VISION

The importance of leadership in a project of this type is that it provides the foundation for setting and articulating the new facility's priorities and vision. A well-defined vision provides a framework for

- » Navigating through competing objectives;
- » Balancing the priorities of campus stakeholders (e.g., administrators, teaching and research faculty, students, the physical plant facilities management group);
- » Managing departmental siloed perspectives;
- » Supporting the programming team in exploring all possible opportunities for shared resources; and
- » Establishing parameters for the project that will fully sustain its vision.

While creating a vision for a new building should invite bold ideas, the leadership team must also balance that vision with practical constraints, such as the anticipated budget, calendar, building site, and interests of the governing board, potential donors, and other external constituents.

With the programming and planning team assembled, the two major goals of the UM 2020 Strategic Plan translated into the following vision: To plan and construct an interdisciplinary STEM facility that would (1) increase the number of STEM majors at UM, and (2) enhance the STEM literacy and success of all UM students.

The planning process took a "big-tent approach," eschewing traditional academic boundaries and looking at STEM education in a multi- and interdisciplinary manner.

A clear and compelling vision for a new facility is often accompanied by guiding principles that may be articulated by an academic planning team prior to the actual programming of the building or that may come into focus during the project's programming phase. At UM, addressing the bottleneck of lower-division science teaching laboratories revealed an urgent need to create space for freshman and sophomore functions. Further, the need to accommodate a desired sustained enrollment growth of three percent per year—which would be key to funding the project—meant that the projected utilization of teaching laboratory and classroom spaces had to be analyzed looking 10 years out. The vision also included all of the institution's STEM disciplines, rather than just focusing on biology or chemistry or engineering. Consequently, the planning process took a "big-tent approach," eschewing traditional academic boundaries and looking at STEM education in a multi- and interdisciplinary manner.

EVOLVING PEDAGOGICAL TRENDS

There has been a lot of discussion around the concept of active learning, which is predicated on the idea of engagement and learning by doing—reading, writing, collaboration, and discussion—rather than passively listening; as a result, active learning allocates more of the responsibility for learning to students. As discussed in the literature on active learning (Freeman et al. 2014; Wikipedia 2017), the teacher directs activities that require inquiry and reflection, analysis and synthesis, and peer-to-peer or class discussion. Creating space to accommodate different pedagogical approaches, such as the technology enabled active learning (TEAL) biology lab shown in figures 2 and 3, not only invites experimentation by faculty but also affirms the notion that the institution supports the faculty in risk-taking with regard to exploring new teaching approaches.

Figure 2 **TEAL Biology Lab Plan**

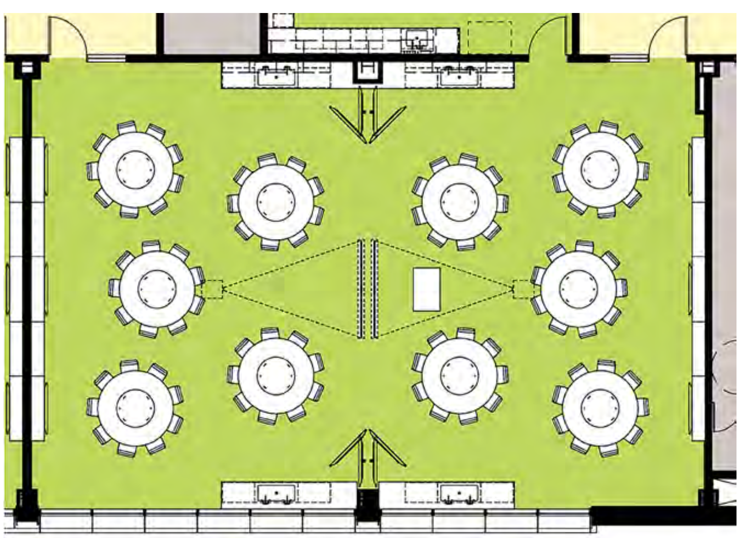


Figure 3 **TEAL Biology Lab**

CROSS-DISCIPLINARY EDUCATION

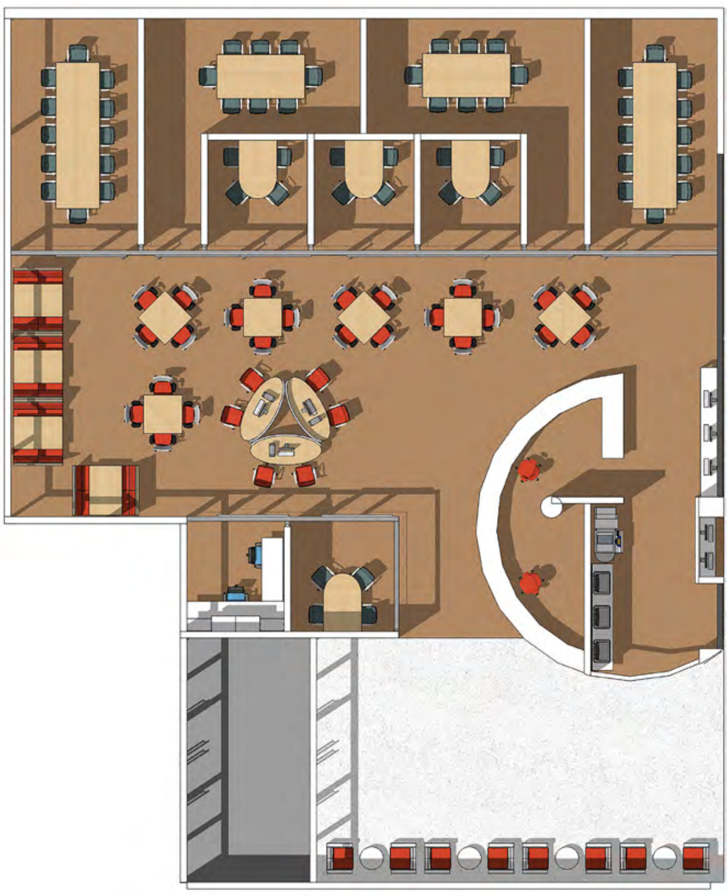
As institutions invest in a new generation of STEM facilities, exploring opportunities for shared resources creates a dialog across disciplines that promotes interdisciplinary problem solving and supports investigative problem-based learning. As an example, an Environmental Lab might explore a problem with a regional body of water by involving a variety of disciplines such as civil engineering, biology, geology, chemistry, and environmental sciences. Showcasing cross-disciplinary lab spaces promotes the notion that these are inquiry-based contemporary teaching environments with richer learning outcomes.

STUDENT SUCCESS

A number of students who enter UM aspiring to complete a STEM degree will switch to a non-STEM field; this is a problem likely shared by many higher education institutions. Student attrition, particularly from STEM fields, is a personal financial loss that also has negative consequences for regional economic development. One can think of higher education campuses as incubators where young adults learn and train in order to contribute to society after graduation. Improving retention and degree completion of students in STEM fields is recognized as a key goal of institutions, states, and our nation (Bureau of Labor Statistics 2014; President's Council of Advisors on Science and Technology 2012). At UM, mirroring greater national objectives, the steering committee intentionally considered STEM student success in the design of the building. Additionally, since the majority of UM's graduates are in non-STEM fields, it was considered important to enhance the STEM literacy of all students as well as be a beacon of STEM knowledge for the community.

With these issues in mind, the steering committee and the design team explored several ways of designing the building to enhance student learning and success and attract non-STEM students. The team considered how students learn and retain information, how they study, whether they need tutoring beyond the lab/lecture format (figure 4), what types of informal spaces are conducive to learning and engagement, and how to make STEM topics more attractive to the campus community of learners. In addition to classrooms designed to promote active learning, the steering committee supported the development of innovative pedagogies, including those emphasizing the societal aspects of STEM education, that enable students to better retain and contextualize the theoretical concepts of science.

Figure 4 **Tutoring Space Plan**



A RAPIDLY CHANGING FUTURE

Modularity must be a key design feature, even though this concept may be resisted by individual disciplines.

Given the significant investment required for a new-generation STEM building, an institution should be concerned about functional obsolescence ahead of the facility's life cycle. The digital age, rapid technological advances, and emerging interdisciplinary subdisciplines will shape the demand for modular, flexible teaching environments that can adapt to future directions in STEM education. Put in practical terms, an institution may have a fairly good grasp of how many sections of various STEM courses it needs today to meet educational demands, but what will those demands be in 10 or 20 years? Will it teach more sections of biology and fewer of chemistry, or more of computer science and fewer of geology, or even some new STEM courses? Once constructed, physical spaces, especially laboratories, are costly to reconfigure. Modularity must be a key design feature, even though this concept may be resisted by individual disciplines. Additionally, users of a new STEM building should make effective use of technology in their classrooms and labs while keeping an eye on evolving technological milestones. Teaching and student spaces equipped with interactive and other emerging audio-visual systems will ensure student fluency with digital technologies and prepare new graduates for increasingly technology-dependent careers.

BUILDING CONSENSUS TOWARD SHARED OBJECTIVES

Establishing a program for a multidisciplinary STEM building requires the programming team to structure a process that brings disparate groups together and builds consensus toward shared objectives. This entails somewhat of a cultural change from inward-focused siloed departmental thinking to a more outward-looking, collaborative, cross-pollinating outlook.

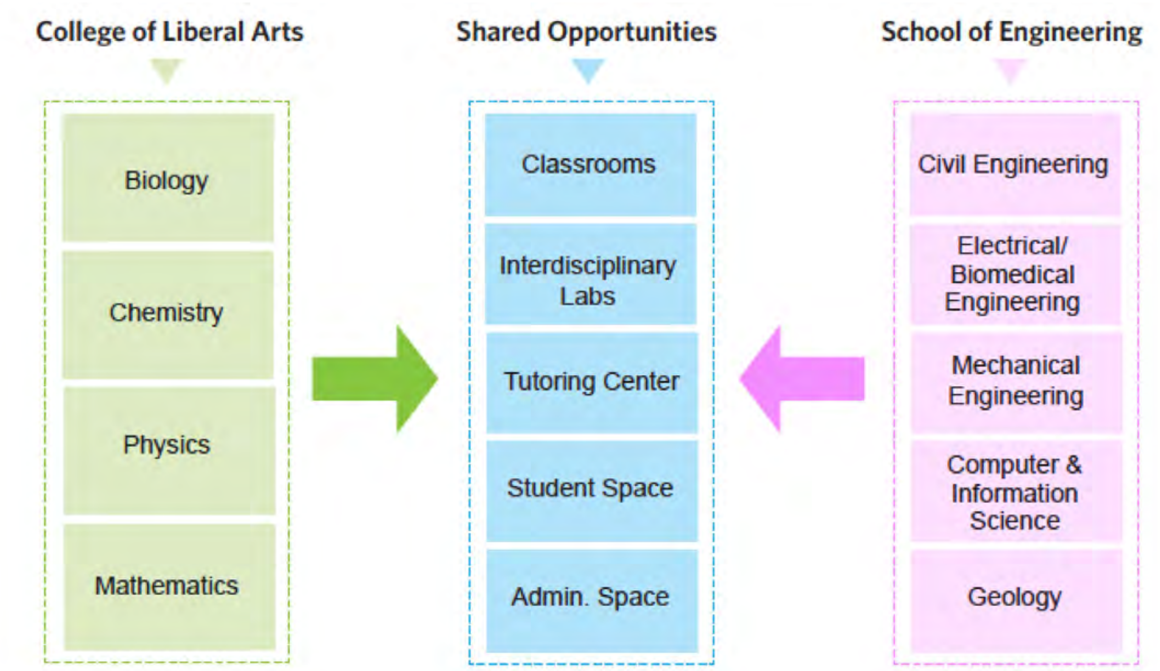
At UM, in planning a building of this type, where everyone eventually wanted in but reality set limitations of budget and area, it was important to take a global view of teaching and research programmatic space requirements for each discipline and to quantify shortcomings and growth needs over the next 10 years, regardless of where the program would be housed. Once those space needs were identified, the team circled back to the guiding principles derived from the project vision to ensure that program spaces in the new building were selected in accordance with those principles and priorities.

Given the bottleneck problem identified earlier, it became clear that lower-division basic science courses offered to freshman and sophomore students took precedence over courses offered to upper-division students. For the UM School of Engineering, where most courses are offered at the junior and senior level (students are required to take basic science courses in the lower division to be admitted to an engineering major), the opportunity to be included in the building program was found through pursuing the notion of theme-based teaching labs that could be shared among several disciplines. This was in keeping with the new paradigm of the STEM facility, where cross-disciplinary space would be showcased.

SHARED OPPORTUNITIES

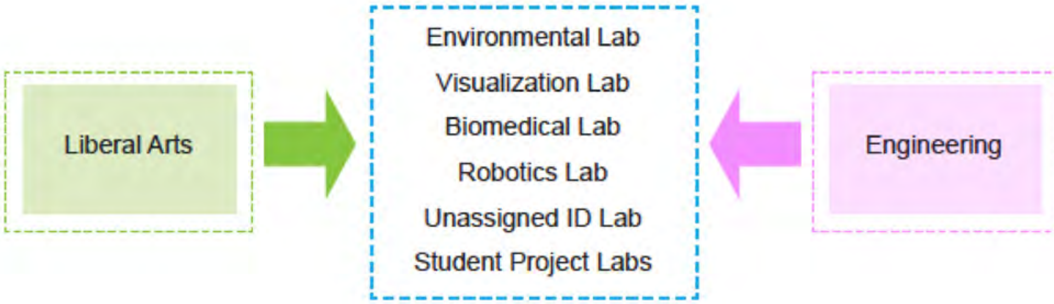
The shared opportunities that garnered the most buy-in included the usual classrooms and student spaces as well as a collection of interdisciplinary labs and a supplemental instruction center designed to foster student success (figure 5).

Figure 5 **Shared Opportunities**



» *Interdisciplinary teaching labs.* Of particular interest in the list of interdisciplinary labs (figure 6) is the Visualization Lab, a digital projection theater for the use of specialized 3-D and 2-D images and videos. The "Viz" Lab, which is shared among all disciplines, accommodates 24 persons and offers an opportunity for outreach and participation by other university constituents in various programs and events. Capstone design student project labs and a small fabrication shop are also included to showcase *makerspaces*, incubators of future engineers and entrepreneurs, displaying their activities to younger students in the building.

Figure 6 **Interdisciplinary Labs**



- *Student spaces*. Given the goal of attracting and retaining more students in STEM disciplines, it was considered essential to create a student-centric program with spaces students would gravitate to when not in class or lab. Study spaces in the UM building layout include media-rich rooms for two to four students to do group work, quiet study spaces with student carrels, and open collaborative study spaces equipped with Wi-Fi and electrical outlets (figure 7). Informal breakout spaces, daytime storage lockers, and a food service venue are also included in the program.

One particular type of student space idiosyncratic to colleges and universities with academically underprepared students is a center for individual or small group tutoring. The UM STEM program includes such a center, which has access to 30-person classrooms nearby for supplemental instruction sessions for math and science courses.

Figure 7 **Breakout Space with Group Study Rooms Beyond**

EVERYONE BENEFITS

In addition to the theme-based interdisciplinary labs proposed by the School of Engineering that might be used by different constituents or shared in a problem-based learning format, other opportunities for sharing space and resources were identified. These included a variety of classrooms, non-departmental administrative spaces, and building support spaces (discussed later in this article). During the course of the project, it became clear that everyone at the university would benefit from this collaborative, inclusive way of thinking:

- » Faculty benefit from having access to a variety of classroom sizes and configurations.
- » Departments (and their budgets) benefit from the more efficient use of shared resources, which are more fully utilized by a larger group of users.
- » Shared interdisciplinary spaces promote contemporary teaching modalities, inquiry-based thinking, and problem solving, which benefit students.

PROGRAM DISTRIBUTION

The planning process yielded the program distribution shown in figure 8, which indicates the percentage of the building that will be initially allocated to each major functional area. This distribution reflects the needs of lower-division basic science labs, select engineering spaces, and cross-disciplinary teaching labs, with a significant (39 percent) allocation for shared spaces, primarily consisting of classrooms and student spaces.

Figure 8 **Program Distribution Percentages**

PROGRAM TYPE	% IN BUILDING
College of Liberal Arts	42%
School of Engineering	19%
Shared Space	39%

DEVELOPING LAYOUT STRATEGIES THAT SUPPORT THE BUILDING'S MISSION

After determining who will go in the building, the next predictable question is, where will they go? Here again, revisiting the guidelines and parameters previously discussed helped inform a layout strategy all could rally around. It is key that the process from program to layout be iterative and inclusive in order to build consensus among all the project's stakeholders. In the case of the UM STEM building, the winning strategy was not one that segregated disciplines by floor nor was it one that segregated students by academic year (freshmen, sophomores, juniors, seniors); the strategy all rallied around was one that integrated the various disciplines throughout the building in reasonable functional clusters to meet the criteria established earlier:

- » Cross-disciplinary teaching labs are showcased on the ground level adjacent to the largest social and breakout space.
- » The student tutoring center, which provides the academic support students need to succeed, is strategically located in an attractive central space adjacent to a printing center and general IT help desk so these functions can take place decoupled from the stigma of tutoring and supplemental instruction.
- » Breakout space is planned at every level of the building with connectivity and power always provided.
- » A variety of study spaces are included within the building to accommodate different styles of studying and learning.
- » Each teaching lab has vision glass, thus putting "science on display" and demystifying science, engineering, and technology.
- » All teaching labs are designed using a common module that allows future retrofits should enrollment demands change from projected utilizations.

» The building is zoned such that energy-intensive wet labs are grouped together; dryer, less energy-intensive labs are clustered together; and office and classroom functions are huddled together (figure 9).

Probably the most promising feature of all is that all the functions described above are arrayed around a social hub that serves as the heart of the building (figures 10 and 11), with open communicating stairs and touchdown stations that not only enhance serendipitous encounters and interaction but also create a sense of place and ownership for students and instructors alike.

Figure 9 **Organizational Plan Diagram**

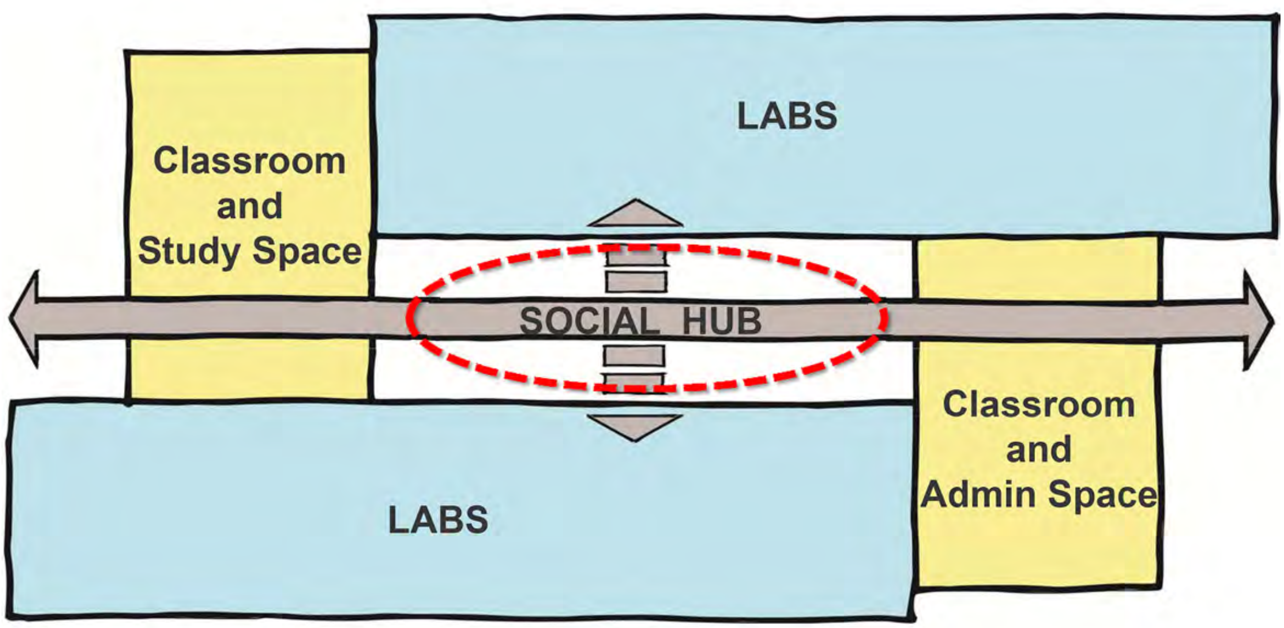


Figure 10 **Building Section through Social Hub**

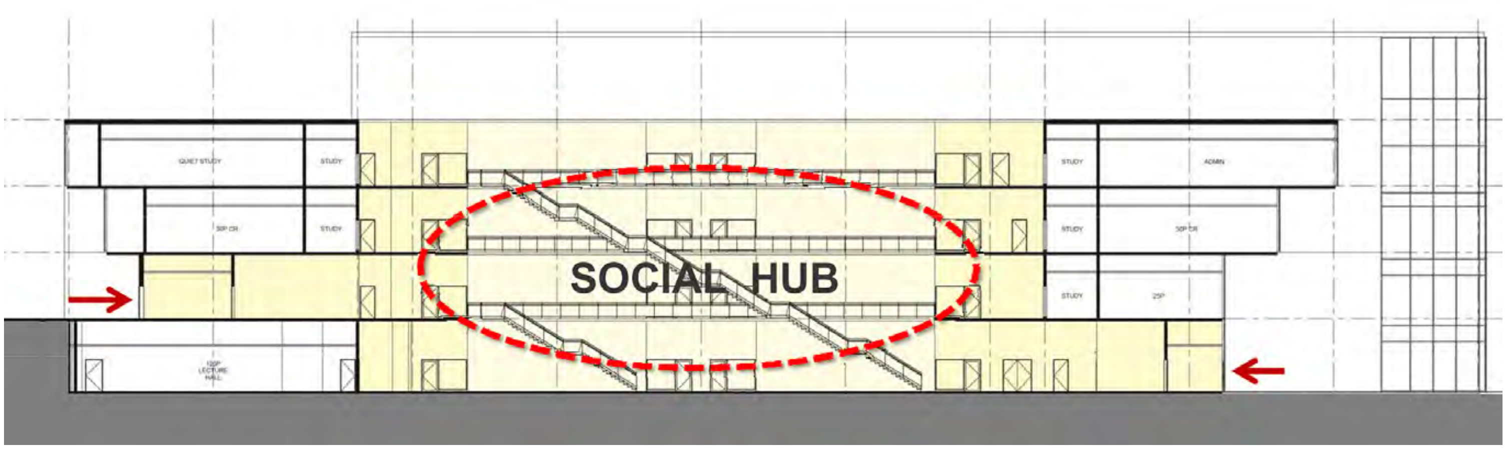


Figure 11 **Social Hub**

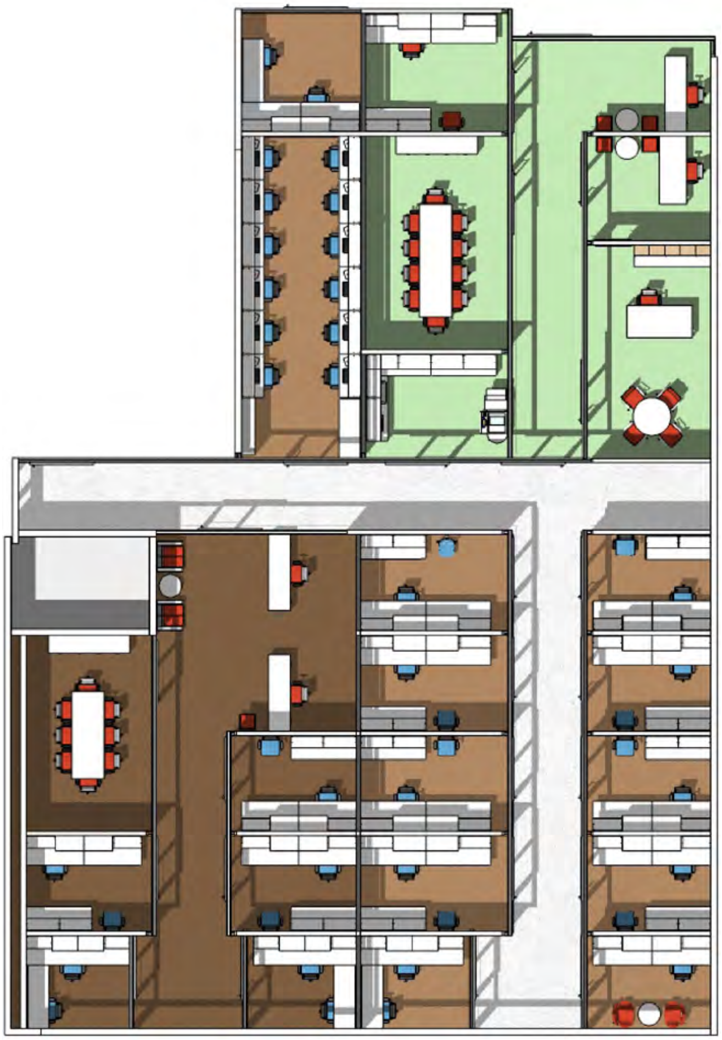
MANAGEMENT STRUCTURE

Once the above parameters were met, an important question remained regarding the operation of a facility with such diverse constituencies: Who will be the adults in the building?

In discussing this question with the steering committee, it became clear that this large interdisciplinary building would serve all STEM departments within the College of Liberal Arts and School of Engineering and be “owned” neither by the dean of either academic area nor by an individual academic department. It also became clear that research faculty would prefer to remain close to their research laboratories, embedded in their respective home departments. However, most instructors do not have research endeavors and so would be an ideal group to be allocated office space in the new building. Student advising counselors, such as those for science and the health professions, are another group that would have a natural home in the new building (figure 12).

The steering committee proposed the need for a new entity—a STEM administration—to oversee all matters related to the complex functionality of the building. These include the operation and scheduling of all non-departmental shared functions; outreach events such as tours for visitors and high school recruits; budgeting and accountability; building service and operation including loading, receiving, chemical storage, and hazardous materials removal; trash and recycling management; food service oversight; security; crowd management on football game day (the new building is planned right across the street from the football stadium); and potential occasional usage of the social hub.

Figure 12 **Instructors', Advising, and Executive Suites**



The steering committee proposed the need for a new entity—a STEM administration—to oversee all matters related to the complex functionality of the building.

The timing of the appointment of the STEM administration needed to be carefully considered so that protocols required for the smooth operation of the building are in place well ahead of its occupancy; as an example, on opening day a protocol needs to be in place regarding the operation of the Stock Room, a lab support space that will provide dry materials to all instructors in the building: Who will operate the Stock Room? How will goods be paid for? Who will manage the inventory? How will communications be handled with the instructors?

One can also imagine less operational and more mission-driven management responsibilities that might include

- Helping faculty convert to new teaching modalities, including active learning;
- Mediating the culture of a changing academic work setting that will result from bringing together instructors and staff from over a dozen academic departments;
- Promoting the outreach potential of the building; and
- Accommodating changing enrollment patterns over time.

UM has not yet addressed these management issues but is certainly aware of the challenges presented by an interdisciplinary STEM building and the need to plan for a management structure.

CONCLUSION

Many challenges will be encountered along the way in successfully navigating the design of an interdisciplinary STEM facility. Among these are obvious ones such as the inability to accommodate all needs and the uncertainty of funding sources. Others may require a culture change, beginning with breaking down academic silos and converting faculty to practitioners of active learning. Projecting enrollment patterns and growth relies on data driven by past experience that do not necessarily reflect future educational trends and emerging programs. Satisfying the design sensibilities of a variety of constituents is a challenge that requires patience, careful listening, and delicate steering in order to maintain a cohesive and bold concept that all will eventually be proud of.

In the final analysis, the strength of a well-articulated vision is the foundation of a project all can rally around, and a focus on shared objectives enables the generation of a layout that fully supports the STEM project's mission.

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