From Buzzword to Functional Building:

How the Architectural Design Process Empowers Interdisciplinary Aspirations of Sciences and Technology Learning Spaces in Higher Education

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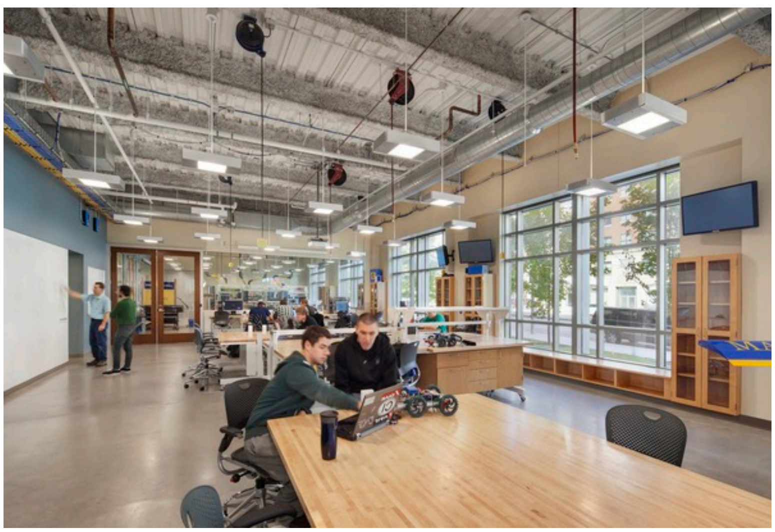

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Abstract
This paper will discuss the design process of science-based interdisciplinary projects in higher education institutions and environments. The challenges of integrating disciplines require creative and collaborative solutions between institutional leadership and architectural designers and planners. This paper explores how the design process can facilitate cultural change in an institution; support an evolving pedagogy for science and research curricula; leverage new technologies and trends in educational design; uncover original insight into an individual institution's needs; and empower students and faculty to cultivate new ideas and solve problems together.

Outline

I. Introduction

“Interdisciplinary” is the new “green,” a buzzword that is fast becoming ubiquitous for higher education institutions, while its meaning forms a catchall for bundling multiple disciplines together in a single environment. And yet, a growing number of institutions are hitting the sweet spot of “interdisciplinarity,” fusing knowledge, methodology, experts and thinkers across backgrounds and disciplines to solve complex global issues with startling results. These efforts result in buildings and inhabitants that transcend definition in program, pedagogy, and physical space types. Most interdisciplinary environments, however, lie somewhere on the spectrum between the fuzziness of a catchall and the fluidity of successful interdisciplinary research and learning. Architects and designers play a crucial role in helping institutions define aspirations and create spaces that allow ideas, learning, and interests to converge and evolve into revolutionary discoveries and innovative pedagogy.

It is necessary to define what actually is meant by interdisciplinary, as universities and higher education institutions demand multimodal teaching spaces. What are educational leaders actually asking for? The complexities of educating today’s students to solve tomorrow’s problems create challenges for universities on many levels, institutionally, departmentally, and culturally. With a clear understanding of interdisciplinary, multidisciplinary, cross-discipline, transdisciplinary, and a host of other ways to mix, integrate and merge traditional silos of learning, institutions and architects can take a sure step toward designing an interdisciplinary space.

The Oxford Research Encyclopedia of Education notes key differences in each of these terms, and defines them as such:

“Crossdisciplinarity” refers to “multiple forms of crossing boundaries” where “the contributing discipline is a passive construct rather than an active point of engagement.” Interaction between disciplines occurs mostly between disciplines that already have a shared focus.

Multidisciplinary studies, according to Oxford, are “encyclopedic,” where “knowledge is sequence . . . but no effort is made to synthesize” it. Here, each discipline remains separate, providing different perspectives rather than integration.

“Transdisciplinarity” creates “frameworks” that encompass “disciplinary worldviews through an overarching synthesis.” This term is more about the inclusion of knowledge, and is “associated with complexity, nonlinearity and heterogeneity.”

“Interdisciplinarity” is defined by the “integration of knowledge from multiple disciplines in pursuit of an outcome that is not possible from a single disciplinary approach.” There are many forms that interdisciplinary education can assume, but the predominant axiom of all interdisciplinary work is that “interaction and integration that occur between academic disciplines and are shaped by the type of question being asked.” [1]

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[1] Karri Holley, “Interdisciplinary Curriculum and Learning in Higher Education,” in Oxford Research Encyclopedia of Education (Oxford University Press USA, 2016), 3-4, education.oxfordre.com.

Each mode of integrating disciplines has its own challenges and obstacles. Furthermore, each also requires a different physical response in the architectural design of a space. The design process that architects and institutional leadership undertake, therefore, is a powerful tool that can facilitate cultural change in an institution, support an evolving pedagogy for science and research curricula, leverage new technologies and trends in educational design, uncover original insight into an individual institution's needs, and empower students and faculty to cultivate new ideas and solve problems together.

II. Exploring the Challenges of Interdisciplinary Environments in Higher Education
   A. Cultural Challenges in Higher Ed Institutions
      i. Disciplinary Silos: Territoriality and Hierarchy
      ii. Institutional Governance: Who's in Charge?
      iii. Understanding Interdisciplinary Spaces

Facilitating interdisciplinary research and learning can be a difficult endeavor. There are many barriers—both culturally and physically—to embracing interdisciplinarity. From the allocation of resources, such as funding and space, to changes in curricula and buy-in from professors and departmental leadership, higher education institutions have a lot of work to do to lay the foundation for interdisciplinary education, let alone the physical manifestation of said environments. According to Robert B. Kvavik, Associate Vice President for Planning at the University of Minnesota and James S. Roberts, Executive Vice Provost for Finance and Administration at Duke University, "The single greatest barrier to developing any space, and particularly interdisciplinary space, on all Consortium campuses is a lack of funding to support space needs."[2] (Consortium campuses interviewed by Kvavik and Roberts include Duke University; the University of California, Berkeley; the University of Illinois at Urbana-Champaign; the University of Michigan; the University of Minnesota; the University of Pennsylvania; the University of Washington; and the University of Wisconsin-Madison.)

"In particular," continue Kvavik and Roberts, "disciplinary and interdisciplinary programs and initiatives directly compete for limited resources, including space and funding." An institution's financial resources are finite, and leadership are often more comfortable rewarding a "known entity."[3] Indeed, some interdisciplinary programs are expected to gain funding independent of their institution.[4]

However, this direct competition between disciplinary and interdisciplinary initiatives points to—and exacerbates—an underlying challenge that is more engrained and potentially more difficult to overcome: institutional culture.

It is fair to say that the need for interdisciplinary research and education has far outpaced the rate of change internally at higher education institutions. While industry, workplaces and research entities demand collaborative, problem-solving expertise, unchanged policies, structures, and institutional cultures in higher education "dis-incentivize" interdisciplinary work. A white paper from the Collaborative on Academic Careers in Higher Education (COACHE) found that higher education still rewards work within disciplines with promotions and tenure, merit pay and other incentives more than interdisciplinary work.[5]

This is partly because interdisciplinarity is hard to quantify and evaluate. Many initiatives are on the cutting-edge of research, exploring new territories, often without a guarantee of discovery or results. In

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[2] Robert B. Kvavik and James S. Roberts, "Space and Capital Planning," *Fostering Interdisciplinary Inquiry: Proceedings from a Conference* (2009): 56.
[3] Kvavik and Roberts, "Space and Capital Planning," 56.
[4] Holley, "Interdisciplinary Curriculum," 17.
[5] Collaborative on Academic Career in Higher Education, Benchmark Best Practices: Interdisciplinary Work & Collaboration (Cambridge, MA: Harvard Graduate School of Education, 2014), 1.

other words, it is more difficult to prove value to the institution.[6] These initiatives also are intensely collaborative, where territoriality between faculty members can hamstring efforts and stymie institutional strategies.

The result of this bipolarity is what Jerry A. Jacobs, a professor of sociology and education at the University of Pennsylvania, calls an “inelegant but practical” coexistence of “discipline-based departments, combined with interdisciplinary research centers.”[7]

Reports Jacobs:

> *Data from the Gale research group indicate that nearly 10,000 research centers are based at American colleges. The top 25 research universities average nearly 100 research centers (94.6) per institution. There are thus often more research centers than disciplinary departments on such a campus. The vast majority of those centers are interdisciplinary, at least in name and self-presentation. The point is that they coexist with academic departments.*[8]

This separation, and in some cases pseudo-integration of disciplines and research centers, is also fueled by interdisciplinary education’s own diversity within criteria for success, bodies of knowledge, ultimate goals, student outcomes, equipment needs, and pedagogical structures and timelines.

The disconnection between disciplines and research centers translates into vastly different educational and research environments. Yet, as the nature of research and teaching evolves, these environments are becoming less and less effective, efficient, and desirable. In fact, argues Karri Holley in “Interdisciplinary Curriculum and Learning in Higher Education,” responding to the complex challenges facing 21st-century society “does not diminish the role of the discipline in education, but rather acknowledges that knowledge is unbounded and potential discoveries lie outside compartmentalized structures.”[9]

Put another way, by Gunnar Myrdal, Swedish economist and sociologist who won a Nobel Prize in Economic Sciences for addressing the interrelations of economic, social and political processes, “Problems do not come in disciplines.”[10]

Problem-based learning environments present another challenge: Who’s in charge? When problems require the fusion of knowledge and research from multiple disciplines, who takes the lead? What does the hierarchy look like? Is there a hierarchy at all?

Institutional governance is a necessary mechanism that enables interdisciplinary programs. Without the support of leadership and effective management, interdisciplinary efforts tend to fail.[11] Programs,

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[6] Holley, “Interdisciplinary Curriculum,” 17.
[7] Jerry A. Jacobs, “Interdisciplinary Hype,” The Chronicle of Higher Education, November 22, 2009.
[8] Jacobs, “Interdisciplinary Hype.”
[9] Holley, “Interdisciplinary Curriculum,” 1.
[10] David Gann and Ammon Salter, "Interdisciplinary education for design professionals," in *Interdisciplinary Design in Practice*, ed. Kirkby P, RS, McMillan S, (London, U. K.: Thomas Telford, 2001), 99.
[11] W James Jacob, “Interdisciplinary trends in higher education,” Palgrave Communications, (January 2015): 2, https://doi.org/10.1057/palcomms.2015.1.

institutes and initiatives in this space demand a commitment from senior administrators to be sustainable. This requires an investment in faculty as far as funding and tenure, physical space such as facilities and technology that enable collaboration, and policy.[12]

Making institutional changes in governance and management is a daunting task, risky to both the university and its faculty. But having a coexistence of interdisciplinary institutes and disciplinary programs without true governance also has risks. If faculty members spend time on interdisciplinary projects, how does that count towards tenure? What if those projects aren't fruitful?

Victoria Interrante, professor of computer science and engineering at the University of Minnesota, told the Committee on Facilitating Interdisciplinary Research, "You have to be at an institution where that type of effort is respected and you also have to have enough projects that you know are going to succeed, that you can afford to risk some time on those that you are not so sure about."[13]

Addressing these challenges takes time and commitment from an institution; even more so when a university decides to embark on building an interdisciplinary facility. The design process can support institutional changes, but it cannot force it. Yet, if an institution is fully committed, designers and architects can provide powerful tools to create academic environments that support interdisciplinary initiatives.

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[12] Jacob, "Interdisciplinary trends," 4.

[13] Committee on Facilitating Interdisciplinary Research, *Facilitating Interdisciplinary Research* (Washington, D.C.: The National Academies Press, 2005), 74, http://nap.edu/11153.

B. Architectual Challenges of Interdisciplinary Spaces
   i. Democratization of Spaces
   ii. Evolving Pedagogies and Technologies
   iii. Redefining the Flexible and Adaptable

Understanding how education can and must be responsive to its external environment[14] is a necessary characteristic of any successful interdisciplinary endeavor. And understanding how the built environment influences and supports these endeavors lies at the heart of the architectural planning and design process.

While insight into interdisciplinary education spaces for individual clients originates from understanding of the client's goals, aspirations and needs, architects, designers, and planners bring their own insights from experiences and trends to address the architectural challenges of these spaces. Many challenges stem from the nexus between the physical space and the social structure of users. In other words, how can designers and planners create an innovative, interdisciplinary environment while maintaining the "human-ness" of the connections these spaces must produce? How can these spaces allow for evolving pedagogies and technologies while preserving the potential for discovery and invention?

The importance of architectural design on interdisciplinary spaces is often underplayed. The ideas of flexibility, adaptability, and other responsive design characteristics are "givens" and beginning to be universally accepted across all academic learning environments. For interdisciplinary academic research spaces, though, this flexibility is an imperative that must be understood on a deeper level. Research from the Brookings Institution observes that innovation spaces "are the physical manifestations of broader trends that invisibly steer their development."[15] Spaces influence the behavior of users, and users' behavior affects the spaces they inhabit.

The symbiotic relationship between the behavior of users and the function of a space means the design and the design process can leverage the built academic environment to empower students and faculty in three key ways:

1. Create the ability for students and faculty to "co-opt" a space as their own
2. Provide universally-owned social gathering spaces that foster serendipitous encounters
3. Ensure that the space does not dictate or restrict process[16]

In essence, the design of interdisciplinary research facilities at higher education institutions represents the "democratization" of space, where users can assemble their own personal interdisciplinary ecosystem in a way that best functions for their work, research and team. Democratization also has an outwardly facing purpose: to put work inside the facility on display, and to allow the community, other students, and visitors in. Julie Wagner and Dan Watch, authors of "Innovation Spaces: The New Design of Work" for the Brookings Institution, conducted 85 in-depth interviews of top architects and users and

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[14] Holley, "Interdisciplinary Curriculum," 1.
[15] Julie Wagner and Dan Watch, "Innovation Spaces: The New Design of Work," The Brookings Institution (April 2017): 16.
[16] Wagner and Watch, "The New Design of Work," 13.

managers of innovation spaces (such as research institutions and incubators), and found that transparency invites inclusion. In their interview with Tom Osha, Senior Vice President of Innovation and Economic Development for Wexford Science and Technology, he said, "The way to create inclusion is to de-mystify the building. They only way to do this is to make it transparent—where public and private meet."[17] This creates economic and social permeability. For higher education institutions, making interdisciplinary education and research transparent (insofar as security and proprietary information permit) has the benefit of increasing recruitment and retaining of students, researchers and faculty as well as expanding the sense of ownership and pride in these spaces by the university community at large.

While the idea of democratization of space seems cerebral, the physical interpretations are not. They are often complex solutions to the inevitability of change: change in users, pedagogies, and technologies.

The challenge, then, for architects and designers is to develop tangible answers to the questions of interdisciplinary educational pursuits. And these questions are constantly changing. Teaching methods and technologies themselves must adapt quickly to new ideas and shifts. W. James Jacob, professor in the Department of Leadership at the University of Memphis and former director of the Institute for International Studies in Education at the University of Pittsburgh, uses the term eclectic interdisciplinarity because "it enables researchers to examine questions based on specific needs and contexts."[18] Jacob goes on to say:

> *It also emphasizes the need for researchers to be flexible and to draw from the most appropriate research design and analytical methods to best respond to the respective research questions. Because eclectic interdisciplinarity requires researchers to be flexible, it often requires differing sets of expertise and knowledge that can only be achieved through collaboration of individuals from multiple backgrounds.*[19]

This is especially true in educational environments. Shifts in teaching and technology happen so quickly that a single professor can't "keep up with them through the traditional tenure stream faculty lines."[20]

Indeed, many higher education institutions are encouraging faculty members to develop interdisciplinary groups to help develop new courses and programs;[21] to create massive open online courses (MOOCs) for online and distance learning;[22] to connect with teachers and researchers across institutions;[23] and share in the mentoring and advising of students across disciplines and programs.[24]

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[17] Wagner and Watch, "The New Design of Work," 38.
[18] W James Jacob, "Interdisciplinary trends in higher education," Palgrave Communications, (January 2015): 3, https://doi.org/10.1057/palcomms.2015.1.
[19] Jacob, "Interdisciplinary trends," 3.
[20] Jacob, "Interdisciplinary trends," 3.
[21] Committee on Facilitating Interdisciplinary Research, *Facilitating Interdisciplinary Research*, 75.
[22] Jacob, "Interdisciplinary trends," 3.
[23] Holley, "Interdisciplinary Curriculum," 5.

Diversity in collaboration and teaching leads architects and designers to ask what a classroom actually looks like in a problem-based education model. How does a new space become a catalyst not only for new ideas, but for new programs and curriculum?

The challenge of designing an interdisciplinary education space does not end with what the space looks like, either.

Karl Fisch, creator of the video "Did You Know?" and an American K12 teacher said, "We are currently preparing students for jobs that don't yet exist, using technologies that have been invented, in order to solve problems we don't even know are problems yet."[25]

Architects and designers must plan for the usefulness of a building over time, and in the immediate now. That means planning for change and unpredictability, and designing for the "intention of space."[26] Doing so presents an opportunity for innovation and a redefinition of the educational landscape.

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[24] Amy Adams, "Building Collaboration," *Stanford News*, December 14, 2015, https://news.stanford.edu/features/2015/clark/.
[25] Karl Fisch and Scott McLeod, "Did You Know 2.0," updated June 2007, https://www.youtube.com/watch?v=pMcfrLYDm2U.
[26] Wagner and Watch, "The New Design of Work," 21.

III. Design Process for Science-based Interdisciplinary Projects

A. Visioning: The Building Blocks of Consensus

i. Techniques and Methods

Visioning is a primary step in the design process that can make or break an interdisciplinary educational space. It is a chance to address institutional culture questions and challenge the goals, needs and aspirations of both the facility and its users. It is a way to break down barriers, empower faculty, students and leadership, and build consensus and a sense of collective ownership in the project.

It is, unquestionably, the most important step in the design process for interdisciplinary projects.

The visioning process must address physical needs of the proposed facility, but also consider institutional objectives. The successful reconciliation of these two aims results from a focused, managed and highly-integrated dialogue between designers, architects and planners, and institutional representatives.

At the heart of the visioning process are two directives:

1. Establish project goals
2. Define guiding principles

In other words, “Where are we going?” and “How do we get there?” Both directives require consensus from all parties involved. Depending on the cultural and architectural challenges the interdisciplinary educational space entails, building consensus can happen quickly or take longer than expected.

Some institutions have well-baked goals that translate easily into architectural solutions. Sometimes a university struggles with buy-in from its faculty.

The role of the designer and architect is to help guide these stakeholders through workshops, meetings and visioning sessions, the success of which relies heavily on openness, collaboration, and strong leadership from both the institution and the architectural team.

The end results—project goals and guiding principles—are most successful when reached collectively.

One of the most-used methods of reaching consensus is through workshops. Workshops can be organized in many ways, and are often divided up by type of stakeholder (faculty, leadership, students). Workshops for interdisciplinary educational spaces, however, can benefit from diverse stakeholder voices, and one technique to stoke innovative ideas and discover unknown issues or challenges is to include multiple types of stakeholders in the same workshop. Intentionally including different disciplines, users and levels of leadership, when managed effectively, can continuously drive teams toward consensus.

This is a relatively new idea, as Wagner and Watch found out during their interviews for the Brookings Institution:

> Design no longer evolves only from the client or leaders of an organization. Rather, the process now includes those who will use the space. This, in part, moves us closer to the “democratization” of innovation, where [users] are elevated and empowered to articulate how a space should be molded to support their needs and ambitions. Those spaces dubbed to be on

> the cutting edge, more often than not, achieved their greatness by aligning organizational ambition, culture and people to produce a supportive, enabling design.[27]

A variation of this multi-stakeholder workshop method is to overlap members across several workshops. This managed crossover can help stakeholders reach consensus more quickly, create continuity, and facilitate information sharing.

Workshops that need to create consensus among diverse participants with different goals and aspirations demand a delicate balance of listening and leading.

Three techniques help make managing this process smooth and civil, even in the face of opposition and disagreement. First, collaboratively developed agendas help make sure everyone's issues and concerns are addressed. Second, defining "Rules of Engagement" for the workshop sessions gives attendees a common structure to address conflicts. Third, unbiased yet flexible approaches to architectural, cultural and knowledge management solutions create a sense of ownership in the process, and eventually the completed space.

Establishing goals and guiding principles means offering a space for stakeholders create ideas, define mission and determine conditions of satisfaction. That means the design of the interdisciplinary space will illustrate the needs of the users. Its features will support that need, and the success of the space is judged by whether or not it meets the goals and aspirations of the users.

By putting user needs before design, designers and architects can create a radical openness about the design of the space itself. This process takes time and leadership, but produces unique insights into the project, the institution and the users, and builds an enduring legacy for the university, students, faculty, and other stakeholders.

[27] Wagner and Watch, "The New Design of Work," 14-15.

B. The Role of Institutional Leadership

While ensuring all stakeholder voices are considered and heard through the visioning process is a critical component of reaching consensus, an equally important factor is strong institutional leadership. Leadership's role in the design process is to balance power and politics with guidance and collaboration. In this dynamic, designers and architects play a supportive role that manages the process, not the people, to continuously drive leadership and stakeholders towards consensus.

Leadership is the stalwart of the broader mission of the institution. They present a different and necessary perspective than students, faculty, and staff. They are the gatekeepers of long-term goals, institutional needs and strategic vision, offer a wide-angle lens with which to view individual projects, and hold a tremendous amount of power.

Because of this distinction, projects where leadership wields power correctly tend to result in a far more effective design process and final project.

There are several characteristics of effective leadership that appear in successful interdisciplinary projects:

1. Strong and open information-sharing processes

   A main challenge for complex, interdisciplinary projects is how information is shared among users, stakeholders, and other groups of people. Leadership can address this challenge through clear, open and consistent communication with both stakeholders and designers. Design architects can help support this effort with regular meetings throughout the design process.

   Managing the flow of information helps everyone feel connected to the project, and offers leadership and users a chance to check in with how the project is aligning with overall goals and institutional mission.

2. Receptive to stakeholder/user input

   Leadership has the difficult task of weighing individual user input against the aims, aspirations, and limitations of the project. Remaining receptive to stakeholder input, allowing users to be heard and contribute, takes a robust ability to define, communicate, and translate input into the final vision.

   Often, design architects include leadership in general, all-inclusive workshop sessions, followed by a second tier of workshops with leadership and decision-makers to refine and synthesize input into actionable solutions and program. Leadership must be able to be both an advocate for users and a "the buck stops here" authority.

3. Promotes collective ownership of the project

   Higher education institutions have struggled with ownership and hierarchy when it comes to embarking on any type of project. The inherent collaborative nature of interdisciplinary efforts means that interdisciplinary spaces function best when the ego of hierarchy is set aside for collective ownership.

> In this, leading by example is a powerful demonstration of leadership's commitment to interdisciplinarity and support of the democratization of innovation. By promoting collective ownership of the project, leadership also creates space for a collective vision, enhancing buy-in from students, faculty, staff and other stakeholders.

There is no singularly correct role for leadership to take in the design of interdisciplinary projects. Roles are defined by institutional structure and culture, and project goals and institutional mission, as individual and varied as universities themselves.

Yet, defining characteristics of strong leadership trend towards decisive openness and a collaborative ethos.

C. Challenging Assumptions
    i. Getting to the Heart of Client Needs: Original Insight
    ii. Expanding the Vision

While all interdisciplinary facilities should be designed with flexibility in mind, the design response of flexibility is a deceptive solution. Conceptually, it suggests that a flexible space can accommodate anything: any change in programming, use, configuration, and technology—a simple, blank slate, if you will, upon which faculty, students, and the institution itself can impress diverse uses and operations.

Yet this often is not the case. While such flexibility may be desirable for the institution, effective flexibility that supports collaborative interdisciplinary efforts over time and intention comes from "a complex, lengthy and iterative [design] process."[28]

Increasingly, this process blends programming with the design of space, traditionally two separate phases in the design process.[29] This "twinning" of programming and design[30] has several benefits.

First, it allows for real-time refinement of needs and goals, constantly guiding both the program and design toward alignment with the project's vision. It also creates an opportunity to ideate new programming of space, whether for academic functions or networking with outside industries, organizations and institutions.

And, importantly, it provides the designers and architects with an occasion to challenge a project's goals, needs, and assumptions.

For example, through a state-wide health initiative, the University of Kentucky aims to help solve the state's most pervasive health issues by creating a facility that could bring researchers from multiple disciplines and organizations together to develop solutions. The original vision for Research Building 2 was a massive wet lab building. During the design process, HGA, as design architect, and lab planning partner JACOBS Consultancy, challenged the assumption that wet labs alone were needed to solve such complex diseases as diabetes and obesity.

In an impressive realignment of vision and design, the University of Kentucky's Research Building 2 transformed its program from that utilitarian wet lab building to a more diverse, interdisciplinary facility with wet labs, computational labs, social spaces, and areas that invite collaboration.

This shift created a design and program for the Research Building 2 that had the necessary tools and capabilities to better address the health challenges of the state, and meet the overarching aspirations of the university.

Challenging vision and goals is a practical step in the design process that can result in a more effective design solution and an enhanced vision for the project.

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[28] Wagner and Watch, "The New Design of Work," 21.
[29] Wagner and Watch, "The New Design of Work," 53.
[30] Wagner and Watch, "The New Design of Work," 41.

D. The Need for Architectural Patience
   i. Balancing Cultural Challenges with Project Forces
      a. Budget, Schedule, Institutional Goals
   ii. Listening and Allowing Client Voice

The complexity of interdisciplinary projects means that institutional leadership and design architects must sometimes confront non-traditional challenges. These can come in the form of a sudden change in users, a loss of funding, or the advent of a new technology.

The design process, at these times, can be an invaluable source of both patience and certainty. As the design process creates a solid vision, the efforts and solutions used to address difficult challenges can rely on the guiding principles and project goals as safeguards for the trajectory of the project.

Keeping the solutions and goals in alignment grounds the project in a common vision in the face of unexpected challenges, and creates a foundation of strength from which to tackle issues head-on.

This requires a commitment to ideas, not bricks-and-mortars.

Sometimes this requires an acceptance of an alternative reality to the original goals and concepts of a project. For example, Marquette University's OPUS College of Engineering was designed to bring together four engineering disciplines. The project was designed for two phases. The first phase created multiple lab modules that support collaboration and interdisciplinary efforts, introducing pedagogical and cultural changes. The second phase sought to define the ambitions for the future of the College of Engineering, making the college truly interdisciplinary and pushing the department toward problem-based teaching and learning. Through an extensive visioning process, design architect HGA and Marquette University discovered the institution needed time to "live into" the new ways of collaborating the building created, and that they had not fully realized the potential of its current research and teaching spaces completed in Phase 1.

In other words, cultural change takes time.

"Having open-concept interdisciplinary space is a real leadership challenge," says Peter Gillies, director of the New Jersey Institute for Food, Nutrition and Health (IFNH) at Rutgers University. "You need to design a building that allows for the creativity of interdisciplinary work, but you also have a responsibility to manage the inherent chaos."[31]

Balancing ambition and patience is a challenge for universities trying to keep up with fast-paced changes and trends for interdisciplinary environments, particularly when trying to recruit and retain students and faculty and compete with top research universities.

But when weighed against the expense of building and the limited resources for interdisciplinary academic projects, architectural patience within the design and visioning process may actually protect institutional goals and resources.

As architects and designers, listening to the client's voice, allowing time for the visioning process to really hit home, has a major impact on the relationship between the designers and the institution, making the visioning process more important—at times—than the actual design and programming.

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[31] Johnathon Allen, "Transforming Organizational Culture through Building Design," Tradline, Inc., August 10, 2016, https://www.tradelineinc.com/reports/2016-7/transforming-organizational-culture-through-building-design

IV. Architectural Solutions for Interdisciplinary Spaces
A. Case Study: University of Kentucky Research Building 2

Case Study: University of Kentucky Research Building 2

Figure 1 University of Kentucky Research Building 2 Wet Lab Rendering, courtesy of HGA Architects and Engineers

The University of Kentucky is the flagship university for the Commonwealth of Kentucky, receiving $331.3 million in grant and contract awards for the 2017 fiscal year.[32] The university's research goals are to solve local problems by developing solutions with a global impact. As one of only eight public institutions in the U.S. with colleges of Agriculture, Engineering, Medicine and Pharmacy on a single campus, the University of Kentucky has a lot of potential for innovation and discovery embedded into its culture.

This potential is being realized in a new and ground-breaking initiative focused on solving Kentucky's most invasive health issues, such as diabetes, obesity, drug use, and heart disease. Kentucky is currently ranked 45th in overall health in the U.S.[33], and these issues are impacting the social and economic growth of the state. The state suffers from high rates of preventable deaths and a life expectancy below the national average.

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[32] "UK Research: Research Data," University of Kentucky, accessed December 4, 2017, https://www.research2.uky.edu/research-data.
[33] "2015 Annual Report," America's Health Rankings, accessed December 4, 2017, https://www.americashealthrankings.org/explore/2015-annual-report/measure/Overall/state/KY.

In 2015, the Kentucky General Assembly approved $265 million for the university[34] to build a multidisciplinary health science research facility. The facility would bring together research and a variety of disciplines to solve these problems.

The university envisioned a massive "workhorse" of a building, filled with wet labs for research. In fact, university leadership initially wanted 100 percent of the labs in the building to be wet labs. During the design process, HGA, in partnership with Champlin Associates and Jacobs Consultancy, asked the university to tap into what was at the heart of many of these health issues they were trying to solve. They found that many of the causes of these health issues were not just medical-related. Diabetes, for example, is a medical issue, a nutritional issue, and a socio-economic issue. University leadership found that all the health problems the research building intended to address are complex disease types that require a number of different disciplines working in concert to develop solutions. The university and design architects realized this facility would be far more interdisciplinary than originally thought.

This realization fundamentally changed the design of the building and reinforced the need for interdisciplinary research environments. HGA-led workshops and visioning sessions created a dialogue between designers and university leadership that addressed three key design issues:

1. What does resolving big health issues entail?
2. How do the trends in research affect design?
3. How will the university's money be used today?

By thoroughly understanding the University of Kentucky's needs, the design team guided leadership through design solutions that were drastically different from the university's original vision. The "workhorse" building with 100 percent wet labs did not support comprehensive problem-solving research. By shifting the vision to an interdisciplinary solution that combined research lab types, the University of Kentucky would be able to expand the number and type of potential users and tenants. The programming was adjusted to be two-thirds wet lab space and one-third dry lab, computational space.

This major change would allow scientists to work next to nutritionists, economists, and other diverse research personnel to tackle health issues from every side.

The dry lab space also tapped into a major trend that the university's peer institutions were already embracing: more and more research is computational, analyzing and synthesizing data, and allowing for ideas and discoveries to be networked across institutions and geographies. By choosing to adjust the vision for the facility to include computational research spaces, the project became much more future-focused than was originally intended. This decision elevated the facility to be on par with peer institutions, and further supported the shift to problem-based research that is at the crux of interdisciplinarity.

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[34] "UKNOW: At the Intersection of Innovation and Impact," University of Kentucky, accessed December 4, 2017, https://uknow.uky.edu/content/intersection-innovation-and-impact.

The decision also freed up money to be used in other parts of the project. Building dedicated wet labs is expensive and space-intensive. The integration of disciplines and incorporation of research types created highly flexible layouts that promoted more communication. The design team organized the labs into neighborhoods that allow cross-fertilization of ideas, and this resulted in a larger number of researchers inhabiting a smaller amount of building.

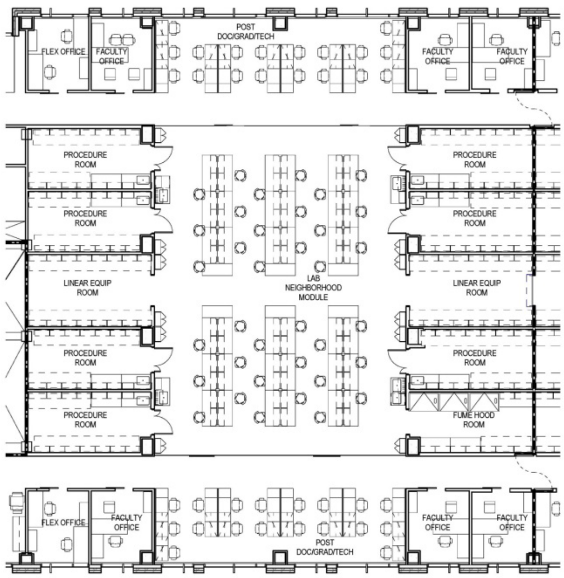

Figure 2 University of Kentucky Lab Neighborhood Module Option

That meant that the University of Kentucky got more program than they thought they could have in the buildings, and allowed for the inclusion of other key interdisciplinary facility components, such as shared spaces.

As part of the vision, the design team wanted to incorporate a cafeteria and other physical opportunities for researchers to meet. With a building that was 100 percent wet lab, the budget would not have been enough to include these amenity spaces. As the design moved to a mixture of spaces, the university could fund significant public open spaces, such as a cafeteria, public corridors that put research on display, and other social gathering spaces that support the chance of spontaneous collisions that are so necessary for interdisciplinary discoveries.

The inclusion of a cafeteria also sparked the idea that all spaces can be a laboratory. Throughout the visioning and workshop process, the idea of a cafeteria became a place to study eating habits and choices. This tapped into one of the main drivers for this building: to create a center to address key health challenges in Kentucky, such as cardiovascular issues, obesity, diabetes and others. This crucial insight turned an amenity into a "must-have" research component.

Figure 3 University of Kentucky Research Building 2 Cafeteria Rendering, courtesy of HGA Architects and Engineers

With the massive shift in programming, the University of Kentucky also realized they would have to create spaces for yet-to-be-determined grant-based researchers and tenants. This unknown tenant-ship forced designers and leadership to consider both flexibility and how best to spend money.

Interdisciplinary spaces are inherently flexible, and must have the ability to adapt to many functions and tenants as the needs of researchers and the university change. This level of flexibility required two things from the university, its leadership and the design team:

1. Powerful institutional leadership that supported and fostered the shift from the traditional siloed , territorial hierarchy to a collective "ownership" of the building
2. Design leadership that pushed the University of Kentucky to consider the future of research

As the university realized the value of a more blended research facility in terms of lab type, the research spaces became more universal. HGA's design team worked with UK leadership to find the right balance of fit-out versus shell space. During Phase 1 of the project, HGA and the university fit out two floors of labs, leaving the remaining four floors as core and shell space that can respond to whatever future tenants needed.

This solution of finished and open space spent the university's funds wisely, creating fully functional spaces while capturing the kinetic energy of future research needs and the inevitable changes that come with interdisciplinary research.

The design process for the University of Kentucky Research Building 2 did not just play a significant role in the project—it fundamentally changed the building and its capabilities. Through the collaborative process of workshops and visioning with university leadership and users of the facility, HGA's design team tapped into primary goals of the University of Kentucky and the Commonwealth at large, and revealed unique insights into the aspirations of the university. These insights guided the Research Building 2 project to embrace the future-focused, interdisciplinary potential for solving local problems by developing solutions with a global impact, ultimately creating an enduring legacy for the University of Kentucky.

B. Case Study: Marquette University College of Engineering

Case Study: Marquette University

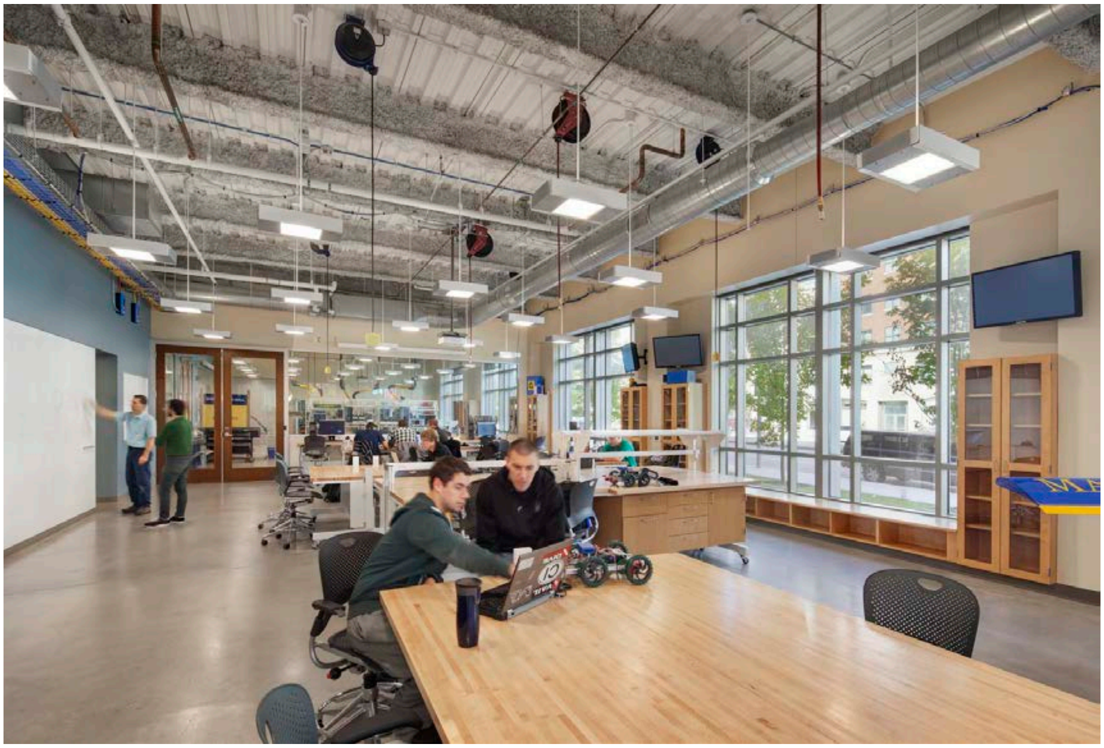

Figure 4 Marquette University's OPUS College of Engineering Lab Module

Marquette University's College of Engineering was led by Dr. Stan Jaskolski, a visionary Dean that had come out of retirement as Eaton Corporation's Chief Technology Officer to lead the College's transition to a more hands-on pedagogy he described as "Discovery Learning." Dr. Jaskolski's vision for the future of engineering education, particularly at Marquette University, was an interdisciplinary, experiential, transparent experience where engineering was proudly put on display.

In the beginning of the transition, Dean Jaskolski's vision was not yet widely understood by the College of Engineering's stakeholders. To address this, Design Architect HGA started by conducted an initial day-long Visioning Workshop—with participants including the Dean, faculty, students, industry partners, and design-build partners—to lay the ground work for a broadly shared vision for engineering education and specifically a new Engineering Hall at Marquette.

The result of this initial visioning workshop was a common understanding of the Dean's vision, made real by a shared development of a set of Guiding Principles for Phase 1 of a new Engineering building.

The Vision created by the participants in this work session led to more detailed discussions to define space needs and design criteria for the project:

- Multiple work sessions with each engineering department slated to occupy the new building produced initial space needs.

- Work session with the steering committee composed of the engineering department heads and the University Architect, where we reviewed and prioritized space needs, adjacencies, and design criteria.
- The ideas and recommendations from the departments and the steering committee were reviewed with the Dean on several occasions.

The result of these meetings was a preliminary definition for Phase 1 of the new Engineering Building—the Vision, the Guiding Principles, space needs, project size, and potential timing. This ultimately led to approval to move to full project design, followed by construction of Phase 1 of the Engineering Hall as funding was secured. Since the total space needs initially identified for the project exceeded the University's funding capacity, the project was partitioned into two phases, with Phase 1 completed in 2011. Phase 2 is a potential future phase.

One important aspect of the planning work sessions became key to the success of this project: The process forced everyone to rethink their existing department-based silos and engage in a new direction for the project—one of integrated, cross-disciplinary engineering education that created connections between students and faculty, undergraduate and graduate students, and teaching and research. In short, Engineering Hall was built to prepare students to be leaders in technology and innovation on the global stage.

This approach varied from other projects in that it included a broad cross-section of interested parties, including people outside the College working in industry, and a broad range of ages from students to senior engineering leaders. Cross-disciplinary engagement resulted in a cross-disciplinary design, and supported the pedagogical changes Dean Jaskolski envisioned.

Phase 1 of Engineering Hall introduced pedagogical changes, and cultural changes in the ways the engineering departments collaborate. One challenge in creating an interdisciplinary facility was to facilitate intermingling between faculty and students and between faculty across departments, with a focus on project-based problem-solving. To achieve this, the building creates small-scale suites of faculty offices, student meeting spaces, classrooms and research labs that are grouped by areas of interest. This was termed the "House Concept," and Phase 1 is built around the idea of a small group of faculty offices from different disciplines collocated with a pocket lounge for students, and teaching and research labs. The houses blend disciplines to create centers of learning based on shared topics such as bioengineering, water resources, etc. To support the learning and research occurring in the "houses" that reside on the upper floors in flexible modular zones, highly visible large-scale labs, shops and meeting rooms were located on the lower floors, providing convenient access for students, faculty and guests. This provides a vehicle for interaction between faculty of different disciplines, whether serendipitous or scheduled, as they investigate and discover ways to solve real-world problems that require multiple disciplines—a convergence of previously separated people and ideas.

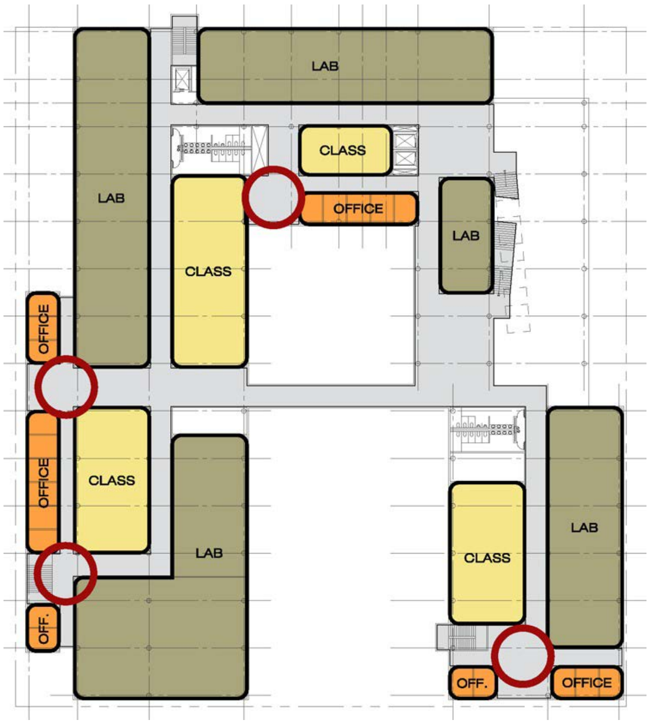

Figure 5 House Concept at Marquette University's College of Engineering

The cultural challenges of breaking down silos is challenging, but approaching this process with a unifying vision and engaging others in that vision in a way that builds consensus—even if not everyone adapts to the change at the same time—is a massive step in true and lasting change.

Following the completion of Phase 1 of Engineering Hall, the University sought to envision what a future Phase 2 of the building should be. It could not be a replica of Phase 1; it needed to be a facility where engineering students could, through learning, experimentation and research, learn to solve the world's biggest engineering challenges of the future. To provoke original insights into how this could be accomplished, we conducted a series of Visioning Workshops with the theme "Engineering 2050." These visioning sessions focused on expanding the cross-disciplinary focus of Phase 1 to address the world's biggest challenges in 2050. As we conducted interactive work sessions with students and faculty to define what the future engineering challenges will likely be, and modeling the types of teams engineers would need to participate in to design solutions to those challenges, several insights became clear.

- The future of engineering will be based on team-based solutions.
- Engineering education will continue to evolve along the path of problem-based teaching and learning, supported by experiential, hands-on projects to facilitate team-based solutions.
- Engineers of the future need to be "integrators"—attuned to and fully capable of integrating with a much broader set of specialties at a wide variety of scales, from nano-scale to galactic scale.

- The specialties with which future engineers will collaborate include scientists, economists, politicians, physicians, technology experts, communications experts and many others.
- Collaboration will occur physically and virtually across disciplines, specialists, peer institutions, industry and government agencies.

The result of the Phase 2 Visioning sets Marquette University's College of Engineering up for the next steps in the evolution of engineering education. One discovery after the College moved into Phase 1 is that cultural change takes time—it took students and faculty some time to "live into" the new ways of collaborating, new pedagogies, and the new physical settings that the building created. We discovered that the architecture can enable—but not change—culture. As the world's engineering challenges continue to evolve, as pedagogies and technologies change, and as the demand for high quality forward-thinking engineers increases, the visioning and exploration conducted for Phase 2 of Engineering Hall will allow Marquette University to move forward with confidence.

C. Trends and Solutions
    i. Designing for "Problem-based" Research
    ii. Inter-institutional Networks
    iii. Convergence of Education and Industry: Higher Ed Institutions as Innovation Incubators

The idea of hands-on and applied learning has been embedded in many science and engineering disciplines. These areas of focus have an inherent need to learn by doing. This concept is now growing beyond these disciplines, and beyond the traditional idea of applied learning.

What is perhaps the biggest trend in interdisciplinary research and education facilities is the shift towards problem-based teaching and learning. Forward-thinking changes in curriculum are introducing "project-oriented learning" (POL)[35] or problem-based learning that challenges a group of students to solve a specific problem.

These problems require using knowledge and skills from different disciplines to arrive at a solution, such as with the University of Kentucky's Research Building 2.

Karri Holley noted in her Interdisciplinary Curriculum and Learning in Higher Education:

> Borrego and Newswander [authors of "Definitions of interdisciplinary research: Toward graduate-level interdisciplinary learning outcomes" for *The Review of Higher Education*] examined graduate-level interdisciplinary curricula in STEM (Science, Technology, Engineering and Math) fields. Aspects of the curriculum unique to graduate-level studies in STEM fields included an emphasis on teamwork and communication skills. The authors concluded: "Skilled interdisciplinarians explicitly reflect on the challenges and processes of integration, including the limitation of various disciplinary perspectives and the synergistic values of the interdisciplinary approach."[36]

Succinctly, interdisciplinary problem-based learning explores questions and problems that do not existing with a single discipline.[37] This is important to note for two reasons:

1. The flexibility that needs to be built into interdisciplinary research spaces should serve both a diverse skill set during a project and the sometimes-rapid changeover from project to project.
2. Problem-based research gets students ready for corporate and institutional work.

Problem-based learning occurs in a number of forms, from classes and programs to student clubs and organizations. For example, California State Polytechnic University in San Luis Obispo (Cal Poly) has a robust engineering program and has put forth a big pedagogical push for "Learning by Doing." In support

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[35] Pasternack, Peer, Roland Block, Claudius Gellert, Michasel Holscher, Reinhard Kreckel, Dirk Lewin, Irene Lischka, Arne Schildberg, Current and Future Trends in Higher Education, trans. Michaela Ott-Spracklin (Vienna: Federal Ministry for Education, Science and Culture), 10.

[36] Holley, "Interdisciplinary Curriculum," 11.

[37] Holley, "Interdisciplinary Curriculum," 9.

of this effort, the university is creating the Engineering Projects Center, a hands-on hub open to every engineering student to come build something.*

It will be far more than a makerspace. They are serious, fully-functioning shop spaces, equipped with CNC machines, lathes, cutting and welding equipment, sanding and painting equipment to provide the students the means to create, build and test full-scale models of their engineered solutions to the learning problems presented to them.

It is where Seniors will go to build their Capstone projects, where interdisciplinary engineering clubs can host competitions, and where students will come to ideate, implement, and test full-sized projects.

Not only will the Engineering Projects Center be a big source of pride for the university, it will offer students the opportunity to create connections between institutions, departments, schools and industries, and contributes practical experience that prepares students for industry work.

These last points—inter-institutional connections and the convergence of academia and industry—are two more major trends in interdisciplinary research facilities in higher education, and there is significant overlap between them. Collaboration on research, discovery and innovation, whether between disciplines at a single institution, between multiple institutions, or between a conglomerate of companies, universities and other organizations, is becoming more and more pervasive, and seeping into the very ethos and philosophy of research.[38]

Tech-rich environments are enabling universities to collaborate across institutions. Online classes and resources, access to faculty with dynamic teaching approaches, and a student body with diverse backgrounds create opportunities for students to immerse themselves in multiple points of view and a variety of instruction methods and expertise.

This creates the well-rounded and experienced graduate that industries are demanding. In fact, these types of students are so important to industry that companies are collaborating with universities to craft the spaces and facilities most conducive to molding graduates and making the transition from higher education to the workplace seamless and productive.

According to the research Julie Wagner and Dan Watch conducted for their, "Innovation Spaces: The New Design of Work" with the Brookings Institution:

> Companies are leveraging relationships with government and universities to strengthen convergence. This comports with a recent finding from Michael Crow, president of Arizona State University and William Dabars in their book, *Designing the New American University*, suggesting that university-industry-government partnerships are the strongest avenue to driving innovation.[39]

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*Students using the Engineering Projects Center must pass safety and skills tests in order to use the equipment.

[38] Wagner and Watch, "The New Design of Work," 18-20.

[39] Wagner and Watch, "The New Design of Work," 19.

That means interdisciplinary research facilities in universities and colleges are starting to look and function more and more like the industries they support.

Not only are university spaces looking more like industry spaces, true research partnerships between industry and higher education are sparking a boom in projects and facilities on campuses. At times, corporations or organizations are providing funds for new projects, or sponsoring a building or program. At times, they may provide lab equipment, internships or other opportunities in support of a partnership. Avenues such as public-private partnerships are becoming more prevalent, and help institutions stretch budgets and programs. It is also a way for corporations to create a pool of qualified graduates.

Increasingly, trends in interdisciplinary facilities are embracing partnerships and, essentially, people. Whether between disciplines, institutions or industries, the “democratization” of innovation and discovery is manifesting itself in everything from the authorship of research papers, to no names on laboratory doors, to building a facility for multiple disciplines and tenants.

V. Conclusion

The essence of interdisciplinarity is integration. The next generation of professionals—whether engineers, scientists, researchers, or even economists and business people—will be “integrators,” bringing diverse ideas, skills and knowledgeable people together to solve problems.

They will also have the ability to differentiate between what is complicated and what is complex. Complexity is a very powerful state. It is unpredictable and hard to define. It needs elegant simplicity, and a radical commitment collectiveness—or, at the very least, the capacity to capitalize on a range of knowledge bases to find creative solutions and revolutionary discoveries.

Designers and architects also need to be integrators. Design success relies on a deep “knowledge-meshing capability,” just like the success of the research and learning in these interdisciplinary spaces.[40] The role of the designer and the design process is to provide a pathway and a platform to a unified vision that supports an evolving pedagogy for science and research curricula, leverages new technologies and trends in educational design, and empowers students and faculty to cultivate new ideas and solve problems together.

These efforts result in buildings and inhabitants that transcend definition in program, pedagogy and physical space types, and are becoming a critical nexus for the convergence of disciplines, ideas, people, and pedagogies.

[40] Wagner and Watch, “The New Design of Work,” 27.