LEEDlab: Design-Build as Action Research; an Interdisciplinary Pilot for Sustainable Architectural Education

The synergy of measures derived from this alternative Design-Build course yield several remarkable impacts to our School of Architecture facility as well as a new platform for sustainable design education, while discovering gaps in the field of building performance evaluation.

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BASIS: FACILITY PERFORMANCE EVALUATION

As the field of sustainable design evolves, designers, engineers and owners are concurrently measuring sustainable benefits in terms of their impact on human health, environment, and cost implications. Many codes are evolving to reflect the significance of building performance. Facility Performance Evaluation (FPE), defined by the National Institute of Building Sciences as a "continuous process of systematically evaluating the performance and/or effectiveness of one or more aspects of buildings in relation to issues such as accessibility, aesthetics, cost-effectiveness, functionality, productivity, safety and security, and sustainability,"[1] improves long-term usefulness of a building decreases operational costs and evaluates energy uses by continually collecting energy and design performance measurements. The information is used not only to perpetuate sustainable operations in the existing building, but also to inform the design of new buildings.

Design-Build is typically recognized as a method in which a firm contracts to provide all of the architectural, construction and engineering services for a new building. It is a project delivery method that combines the design and construction entities, typically for the purpose of integrating contractor experience into the design, decreasing the schedule duration, and decreasing the number of contractual relationships.[2] Currently, it has started to involve sustainability assessment.

A recent study showed that integrated project delivery methods, including Design-Build, are being used to deliver 75 percent of current new construction projects seeking LEED certification.[3] But can a model of Design-Build delivery be used to allow the investigation, diagnoses and subsequent alteration of a facility to achieve greater accommodation to current benchmarking, sustainability and energy codes?

Architects and design criteria professionals such as Edward Wundram say that Design-Build "is an entire range of possibilities".[4] Design-Build can use the platform of a course to coordinate all of the services meant to accomplish FPE and modification. This paper will present a brief summary of a course used as a platform for Design-Build project delivery; its action-research method of evaluation, challenges and tasks, and its impacts to a facility, sustainable design education, citing gaps in the field of building performance assessment.

COURSE: LEED LAB; SUSTAINABLE CAMPUS BUILDING ASSESSMENT

The School of Architecture and Planning at the Catholic University of America (CUA) created an interdisciplinary laboratory course called LEEDlab, based on Design-Build delivery as action research.[5] For the past nine semesters, the course has operated as a single-source contractor. Where a traditional evaluation-design-bid-build method requires outlays of time, LEEDlab overlaps functions of evaluation, design, and construction through multiple semesters *creating a platform for collaboration* between external engineering firms, USGBC, GBCI, mechanical contractors, our facilities management office (FMO), and various students.

Experience gained from this course *qualifies as a prerequisite* for both the LEED Green Associate (GA) and Accredited Professional (LEED AP) examinations, meeting market demands for young professionals. Many students have become LEED GA-certified, and over 10 students have earned professional LEED AP: O&M, CI, and BD&C credentials as a result of their work in this course. Additionally, the course *studies national building performance benchmarking mandates* and *creates a method of hands-on learning* about sustainable potential with immediate impact on design and mutual learning benefits for facilities staff.

METHOD: PEDAGOGICAL FINDINGS

The pedagogical findings of LEEDlab indicate a specific methodology as our framework for conducting research through LEEDlab, and continue to inform development of the methods used in teaching and planning. The methodology, called 'action research,' is a scientific approach utilizing research to solve an immediate condition, or a process of solving problems by people working with teams of other people. It has become an important part of a number of research programs, especially in the field of education.[6]

The phrase 'action research' was first used in 1944 by MIT professor Kurt Lewin to describe "comparative research on the conditions and effects of various forms of social action and research leading to social action".[7] The purpose of an action research strategy has evolved to become a method to solve a particular problem and to produce guidelines for best practice, as in the case of LEEDlab. Professional researchers utilize the method with the aim of improving their strategies and practices, and the environment knowledge within which they practice.[8]

The need for practical outcomes places action research within a social context where the environment of the ''experiment'' and the experiment itself interact, and in which values place a critical role. Inevitably, this includes interactions between researcher, subjects, and context. An attempt has been made to identify a normative set of criteria that can be used to design and assess action research and, in doing so represent action research as scientifically rigorous.[9]

Leading scientists distinguish action research from basic research by asserting that the intention of the former is to solve an important problem for a client, and not simply to test features of a theory.[10] For example, researchers John Barton, John

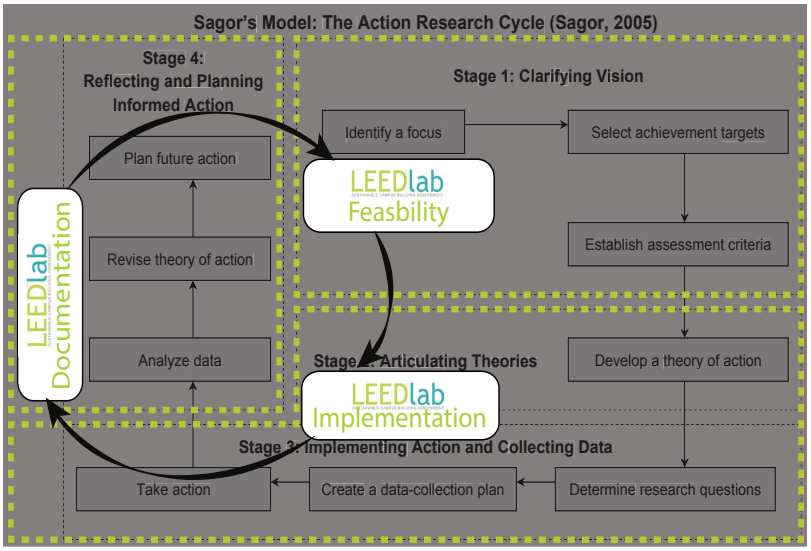

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Figure 1: Action research; a formal premise for LEEDlab 's Design-Build prototype

Stephens and Tim Haslett list criteria which consider each stage in the recursive terms of action research.[11] Pedagogical findings shown throughout all LEEDlab semesters reflect two of their criteria to create a successful building analysis and delivery method in academia: Critical evaluation techniques that include single, double, and triple loop learning, and monitoring processes within action research cycles that inform corrections that can be made/recorded.[12] Critical measurable outcomes to achieve these factors are quizzes, progress presentations and charrettes, which are integrated within a minimum of three specific semester phases: (1) feasibility, (2) implementation and (3) documentation, with actual facility modification occurring between implementation and documentation. Dr. Richard Sagar, Founder of the Institute for the Study of Inquiry in Education, proposes a specific and detailed process for implementing an action research project which we have used as an underlay describing how the three phases of LEEDlab align with this concept (see Figure 1).[13]

In a climate where the need for greener and more sustainable buildings puts pressure on both operational and capital budgets,[14] universities are often in a bind when prioritizing between deferred maintenance and sustainable improvement costs. At the onset of the LEEDlab course, establishing the **feasibility** (Phase 1) of the FPE-based modifications in the first few semesters is therefore critical. Ultimately, the decision of building selection rests with the FMO.

The feasibility of a building is uniquely tied to knowing which sustainable synergies may apply at the onset of a study. Understanding the basics of the LEED rating system is helpful for knowledge of the industry terms and reference standards used in the assessment. Planning and design charrettes, involving many administrative personnel and sub-contractors, engage the requirements of various greening efforts with personnel experienced with campus facility usage. The meeting is also a forum to test knowledge of credits through education of facility managers, and to arrive at a point integration diagram identifying credits and the strategies which establish sustainability goals.

The semesters which comprise **implementation** (Phase 2) focus on preparing processes and procedures for tracking and obtaining data from the facility. As a critical task, performance data collection, not inherently learned in an architectural curriculum, is introduced. How the cited feasibility strategies will be divided among students, what performance periods are necessary for establishment, and which

tasks are required for tracking or analyzing strategies are also important to be determined. We evaluate the steps and processes necessary per task, such as installing data loggers, and running the software for downloading respective psychometric charts which inform how a space may require improvement of thermal comfort features. Learning the specific task, creating methods for future tracking and collaborating with subcontractors for instruction and guidance, and commencing tasks and scheduling for ongoing tracking are important in this phase.

As Phase 3 of the actual coursework, **documentation** is required to confirm the achievement of tasks. This includes the creation of procedures, metrics, and scheduling documents, such as tracking sheets, templates, online calculators, and third-party metric platforms and feedback techniques. In our experience, the accuracy of tasks that occurred in Phase 2 (implementation) was often called into question, and re-evaluated. Much time dedicated to organization, collection and editing is required for this phase, and typically occurs with a few students that are dedicated to a specific knowledge base. Developing communication skills between subcontractors and peers to obtain data culminates in this phase, where the students analyze and help realize low-cost modifications to gap our deficiencies in achieving strategies.

LEEDlab documentation concludes with a submitted project to USGBC. Although actual construction modifications occur through work orders delivered by our FMO, some students are engaged from the preliminary design phase through bidding of design modifications. This is the culmination of Design-Build in action research: watching an investigation and collaboration become a positive design change. Although there are many fruitful pedagogical findings which have led to an academic platform for sustainable campus change, advanced learning, and exposure to real project experience, certain measures of this action research face challenges and shortcomings in applying procedures, maintaining compliance, funding, consultant assistance, facility limitations, and guiding and engaging an interdisciplinary pedagogy.

TASKS: TECHNOLOGY AND TRIALS

Professional engineering consultants, mechanical contractors and facilities personnel were in direct and immediate collaboration with students throughout each phase of our Design-Build platform. We employed donations of consultant services and grants (which fund service) as start-up measures to yield low-cost/high-gain modifications funded by the FMO. One significant endeavor – our energy reduction – is a good example of how the Design-Build process was used through action-research via specific tasks. Our goal was to understand and establish the minimum energy operating level for the Crough Center and to reduce any environmental and economic impacts associated with excessive energy usage.

At the outset of the course, we successfully requested the energy manager from our facilities staff to consult with our class to help navigate the university's benchmarking protocol, serving voluntarily in an advisory capacity for the duration of the project. We quickly learned that the university did not have a protocol. The following spring, with the financial support of our facilities staff, EIG energy, water, steam and irrigation meters were installed in our building and in the central energy plant. The task of pulling data from these meters was accomplished through a third-party engineering firm, and then delegated solely to students the following summer. After calibration, the meters began to track consumption rates using extracted BTU's and KwH towards identifying our energy baselines via Energy Star's Portfolio Manager, the industry benchmarking tool.

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Figure 2: Crough Center for Architectural studies Early 1900's (photo from CUA Archives)

Our first goal was to identify a comparable building type against which to benchmark our metrics. Energy Star uses baseline data collected by the Commercial Buildings Energy Consumption Survey (CBECS), which used a fairly limited range of building types: food sales, healthcare, lodging, mercantile, public assembly, along with other categories admissible to LEED certification using alternative methods of compliance. To ensure national comparability, climate data was used to normalize energy consumption (eliminating potential regional variations) to compare the project building to similar buildings in similar climate zones. CBECS building stock includes a category for education: that is, buildings used for academic or technical classroom instruction in elementary, middle and high schools, and classroom buildings on college of university campuses.[15]

Our case study, the Crough Center for Architectural Studies (Crough), is not a typical campus educational building: originally built in 1919 as a gymnasium, it was repurposed as the School of Architecture in the late 1980's (see Figure 2). The building is a large warehouse, containing 44,700 ft2 with smaller offices around the periphery. It is open 24 hours per day, 7 days per week, and many of the students work in the building until the late hours of the night. All of our labs and studios remain continuously open and the building runs at full capacity almost every day of the year, excepting certain holidays. The building space type was not eligible for Energy Star ratings' CBECS standard "Case 1" method of benchmarking, which assesses the same building space types against each other.

After two semesters of calculating alternative categories for submission, each separate option, though a good effort in itself, was rejected by USGBC. We then decided to use the comparative baseline of a K-12 school. Energy Star's Statement of Energy Performance (in conjunction with protocols provided by USGBC) was generated to record our benchmarking calculations and to document energy consumption through "Case 2," which requires a separate template to calculate the Energy Use Intensity (EUI)[16] data generated in Portfolio Manager. We analyzed our building into three parts: Laboratory, Other and Education. 'Education' consists of classrooms, an auditorium, faculty spaces, offices, and conference rooms. 'Other' comprises mechanical equipment, storage, and hallways.

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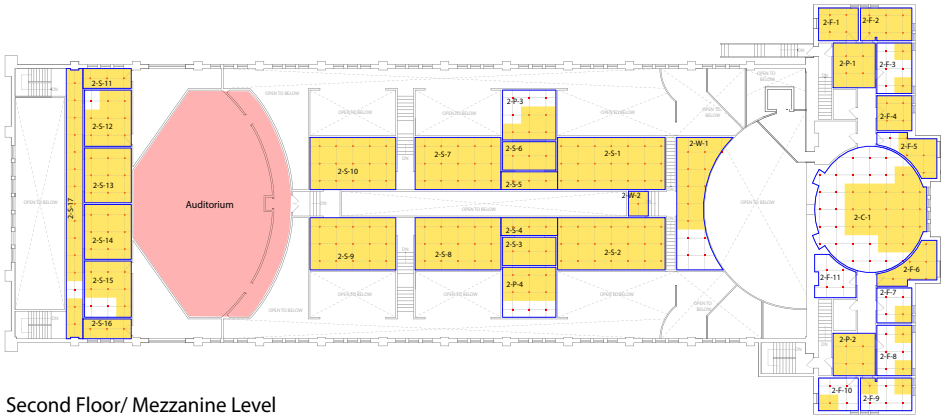
The program for our 'laboratory' consumes much more energy than regular laboratories in K-12 buildings and is unique to architectural curricula. Considered a "dry lab" since the spaces contain an abundance and variety of electrically powered instruments increasing the baseline plug-load, the areas within this category include studios, computer labs, digital media labs, a woodshop, a prefabrication lab, a spray room, and a 3D print lab comprising over 33% of our building square footage. The woodshop includes power drills, routers, computer numerical control (CNC) milling machines, a 3D printing machine, and laser cutters which all students may access anytime. Furthermore, each student is required to have a computer, and many keep their own mini-fridges at their studios. We created a matrix indicating all of the powered-operated equipment and its consumption, including calculations representing the number of computers used, significantly varying from the standard K-12 quantities.

In addition to matters of initial categorization, our steam meter stopped working in November 2012 (during our performance period), and was only re-activated in March 2013 (beyond the performance period). As we reviewed the meter reading program settings, we found that the graphic and charts produced by the EIG program from our consulting engineers scaled the metrics to the unit of pounds of steam, indicating a mistake in our previous interpretation of 1 pulse=10 pounds of steam. After retrieving 12 consecutive months of data from the previous year, were able to record an accurate analysis when comparing energy bills, and revised our original dates for the performance period to January 2012 through December 2012. The culmination of our analysis yielded a total annual site energy usage of 71 kBtu/ft2 EUI with source EUI at 215.4 kBtu/ft2,[17] above the minimum energy efficiency performance prerequisite for LEED certification.

Several other metrics factored into the process of energy evaluation/reduction efforts. We created many standards with our FMO, including the development of a 'sequence of operations' for the building, a building operating plan that provides details such as an occupancy schedule, equipment run-times, and design set points for all HVAC equipment and design lighting levels. We also developed a systems narrative for electrical and mechanical equipment, and established a preventative maintenance plan from observing procedures (see Figure 3). We documented that

Figure 3 Students observe procedures for testing boiler water

First Floor Level



Second Floor/ Mezzanine Level

Legend

Regularly Occupied Space Boundary

Daylit Area

5'x5' Grid Measurements taken at center (Red Square)

Non-Regualrly Occupied Area

Regualrly Occupied Space ID : 2-P-2

Level	Space Type	Room #
0 - Basement	S - Studio Space, Student Workspaces	1
1 - First Floor	W - Student Fabrication/ Work Space	2
2 - Second Floor	C - Classroom, Conference, Meeting	3
	F - Faculty/Adminstration Offices	4
	P - Pin-Up, Presentation, Meeting	...

4

LEEDlab **IEQ Credit 2.4 Daylight and Views**
LEED 2009 for Exisitng Buildings: Operations & Maintenance

Crough Center Floor Plans
Catholic University of America 620 Michigan Ave NE, Washington, D.C. 20064

Figure 4: Diagram indicating most-occupied spaces naturally lit between 25-500 FC.

over 75% of the total building energy use is met with Green-e accredited tradable renewable certificates, and through the assistance of our volunteer mechanical engineer Westlake Reed Leskosky, conducted an ASHRAE Level 1 energy audit.

Portable light meters were manually used to calculate footcandle (FC) levels in Crough to determine adequate light levels. Students also trained on Solema's DIVA for Rhino modeling program to simulate daylight,[18] and then determined compliance with minimum requirements for daylight autonomy to receive LEED credit. We evaluated the current lighting levels[19] (see Figure 4) and found that our daylighting potential was sufficient without the antiquated mercury halide fixtures in the main studio spaces. Working with our facilities department, we proposed the installation

of a shut-off switch (at the cost of $120) to automatically control the lights, yielding an immediate reduction of over 20% in electricity usage, and peaking at 30% just last summer after tracking energy for the subsequent year.

As a campus, CUA is required to disclose aggregate data for building performance (energy and water consumption) to the District of Columbia's Department of the Environment (DDOE) per the Clean and Affordable Energy Act of 2008; final regulations were published in January 2013 and the first reporting deadline was April 1, 2013.[20] Student research efforts and accomplishments from our LEEDlab course contributed to this initial report submitted by our university.

IMPACTS: DESIGN, EDUCATION, RESEARCH

The long and arduous process of our energy reduction efforts culminate to only one example of the many topics of our program as a Design-Build endeavor through action research. The synergy of improvements derived from this alternative Design-Build course yielded several remarkable design impacts to our building, as well as a new platform for sustainable design education, while discovering missing gaps in the field of building performance evaluation.

Design: From a design perspective, energy reduction occurred as a result of behavioral changes and minor facility modifications, and spawned a revised lighting design currently in proposal phase. Data loggers which measure thermal comfort and produce psychometric charts were installed, tracked, and aligned with questionnaires which together became the catalyst for the replacement of our air handling units. We initiated and implemented a Waste Management Policy, Green Cleaning Policy, an Integrated Pest Management Policy, and a Landscape Management Plan with our FMO, which they are now using campus-wide to impact future design and documentation decisions (see Figure 5). The students' water calculations helped to justify aerators for the faucets, reducing our water consumption rates by 10%. LEEDlab students used this information to launch a student-driven initiative called "CUARain" to design and install cisterns across the campus http://vimeo.com/85171300) (http://vimeo.com/85171300).

Education: LEEDlab has sprouted many tangents of future growth and has gained popularity at various levels as a course, including interdisciplinary studies at CUA, university recognition, and national inquiry. Our local public affairs office has been instrumental in describing the impact of this student-driven research on campus.[21] Last year, LEEDlab was considered as one course which helped to give rise to a new proposal for a Sustainability Minor within the Interdisciplinary Studies minor in the School of Arts and Sciences, which encouraged our team to change the syllabus to be multi-disciplinary. Joint-degree (BArch / Civil Engineering) students have taken advantage of the integration of their discipline's focus within the class, and in recent semesters, students of facilities management, chemistry, and politics have enrolled. The course satisfies both our School of Architecture's new Master of Science in Facilities Management and the existing Master of Science in Sustainable Design degree requirements, as students learn about sustainable operations.

On national and global platforms, the USGBC has officially launched LEEDlab as a new offering available to colleges and universities across the country. Colorado State University, the University of Florida, North Carolina State University, and the University of California Santa Barbara are establishing similar courses as a result of our pilot. Christ University in Bangalore, India has already contacted our team about implementing LEEDlab. Consequently, we are working on our first book publication due to the many inquiries for guidance implementing such a course.

ENDNOTES

(1) Craig Zimring, "Facility Performance Evaluation (FPE)," Whole Building Design Guide. January 31, 2014. http://www.wbdg.org/resources/fpe.php.

(2) American Society of Civil Engineers (ASCE) 2000. Quality in the Constructed Project: A Guide for Owners, Designers, and Constructors. (ASCE Manual No. 73—2nd Ed.). American Society of Civil Engineers, Reston, VA.

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(4) Jeffrey Beard, Edward Wundram, and Michael Loulakis, Design-Build: Planning Through Development (New York: McGraw Hill, 2001).

(5) Action research is a form of investigation designed for use by teachers to attempt to solve problems and improve professional practices in their own classrooms. It involves systematic observations and data collection which can be then used by the practitioner-researcher in reflection, decision-making and the development of more effective classroom strategies.

(6) Michael Glassman, Gizenn Erdem, and Mitchell Bartholomew, "Action Research and its history as an Adult Education Movement for Social Change," Adult Education Quarterly 20, no. 10 (2012): 1-17.

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(9) John Barton, John Stephens, and Tim Haslett, "Action Research: Its Foundations in Open Systems Thinking and Relationship to the Scientific Method," Systemic Practice and Action Research 22, no. 6 (2009): 475-488.

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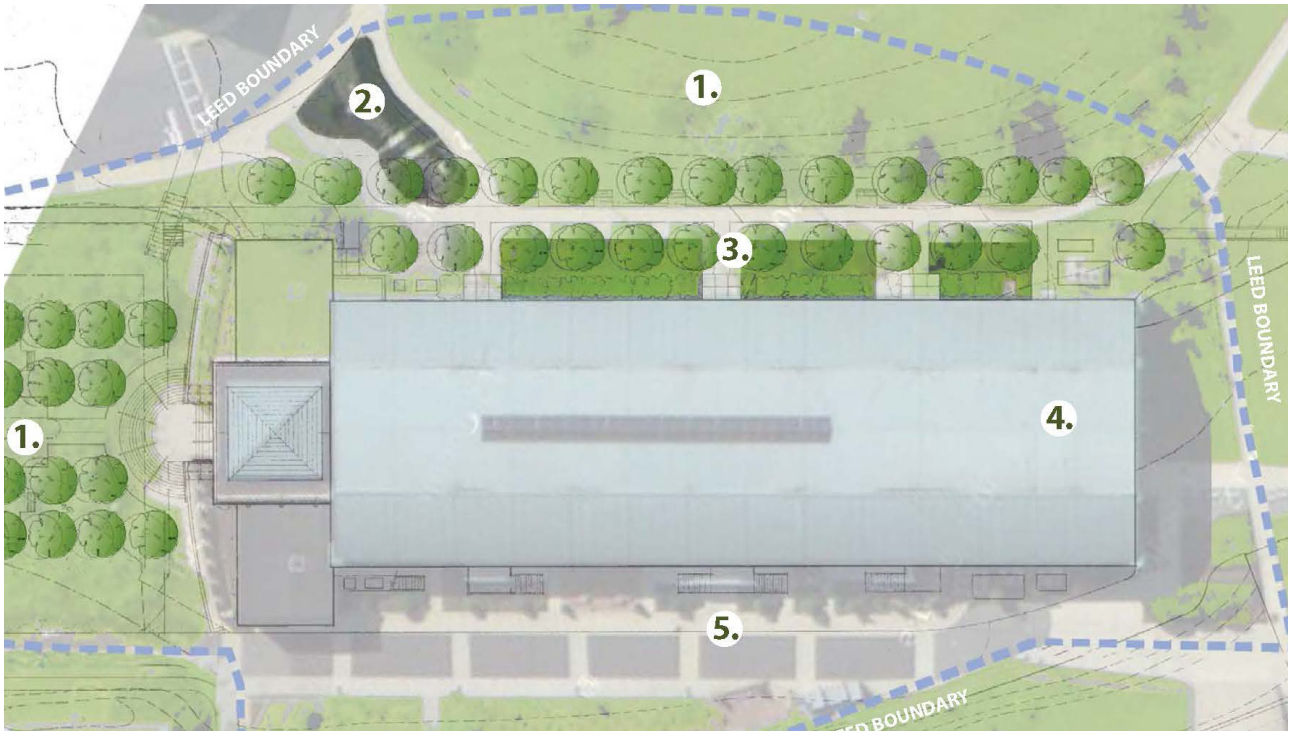

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Figure 5: Strategies derived from LEEDlab for Crough's site and water conservation: 1. open space 2. rain gardens 3. irrigation efficiency 4. non-potable water use 5. hardscape management program

Research: This summer, the Crough Center was the first architecture school in the world to achieve EB: O&M certification, and the first curriculum-based, student-driven certification in history. Rick Fedrizzi, President of USGBC, recently wrote a letter to our team commending its incorporation of LEED within a curriculum, and as a pilot course; thus the research derived from this study has been formally acknowl-edged as a high-caliber analytical achievement, and has served as a basis for our team's continued research.

This past summer, we were awarded grant-in-aid seed funding to propagate research in specific critical areas of LEEDlab which warrant further probing: (1) the process of LEED EB: O+M implementation on university campuses; (2) the databases used for determining baseline metrics for energy consumption (e.g.: What are the best management practices for quantifying energy baselines of campus buildings that use Energy Star Portfolio manager and that currently are not on the CBECS database?); (3) the methods used for testing each strategy, such as air quality (e.g.: What are recommended alternative methods and instruments for testing air quality in various building types on campus?); and (4) the calculations used for assessment.

Current areas of research include the link between operating LEEDlab and its out-comes as a way to improve sequel courses through action-research. We also have identified specific gaps between the cycle of operations and feedback which and are being investigated through grant pursuits and research papers such as those in progress with APPA's Leadership in Educational Facilities' Center for Facilities Research (CFaR). A Return On Investment (ROI) for specific measures derived from our course has not yet been quantified by our university, but has been presented to our central administration.

The Design-Build model for implementing action research with realistic outcomes involves people, processes, and performance. Thus, both open and tacit knowledge in an academic forum need to be acquired through LEEDlab for it to function as a Design-Build vehicle; "the collaborative character of action research aims at generating both theoretical understanding and practical impact".[22] Ultimately our goal is to establish a long-term strategy for a building performance process that makes continuous optimization a regular part of building management, informing new building design and sustainable education alike.

(6) Michael Glassman, Gizenn Erdem, and Mitchell Bartholomew, "Action Research and its history as an Adult Education Movement for Social Change," Adult Education Quarterly 20, no. 10 (2012): 1-17.

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(14) Chris Hodges and Mark Sekula, Sustainable facility management: the facility manager's guide to optimizing building performance "Most improvements require some amount of capital to implement, though there are many which do not pose this requirement"(Alexandria, VA: Vision Spots Publishing, 2013).

(15) "Building Type Definitions," Commercial Buildings Energy Consumption Survey (CBECS), U.S. Energy Information Administration. January 31, 2014. http://www.eia.gov/consumption/commercial/building-type-definitions.cfm

(16) This is the expression of a building's energy use as a function of its size or other characteristics.

(17) EPA has determined that source energy is the most equitable unit of evaluation. Source energy represents the total amount of raw fuel that is required to operate the building. It incorporates all transmission, delivery, and production losses. By taking all energy use into account, the score provides a complete assessment of energy efficiency in a building. http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/difference

(18) DIVA-for-Rhino is a highly optimized daylighting and energy modeling plug-in for the Rhinoceros - NURBS modeler.

(19) Using a Light Meter, an instrument used to calculate manual footcandle (FC) or lux levels.

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