DESIGN LAB: EXPLORING SYNERGIES OF OUTREACH, RESEARCH AND TEACHING WHILE INNOVATING CLASSROOM DESIGN

Authors:
Van Den Wymelenberg, Kevin
Coles, Jim, Design West Architects
Djunaedy, Ery
Acker, Brad

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INTRODUCTION
This paper discusses the intimate workings of a university-based design laboratory that is fused with the design profession through outreach activities that in turn pay dividends to research and teaching objectives of students and faculty. A case study focused on the development of an innovative classroom prototype is used to portray the benefits possible through this type of operation to the design community and community at large, the university, faculty and students alike. Ways that research activities can improve the value of design as perceived by many individual parties is also explored throughout the paper.

METHODS

Design Laboratory
The Integrated Design Lab in Boise (IDL-Boise) is part of the Pacific Northwest University Design Lab Network (Lab Network) and is focused on improving the quality of design as it relates to occupant comfort and energy consumption. The Lab Network consists of the Integrated Design Labs at the University of Washington, University of Idaho, Washington State University and Montana State University as well as the Energy Studies in Buildings Laboratory (ESBL) at the University of Oregon. The Lab Network shares a funding source in the Northwest Energy Efficiency Alliance while each lab has several other funding sources at a local, regional and national level.

IDL-Boise is dedicated to the development of high performance energy efficient buildings in the Pacific Northwest. Through research, education and outreach efforts with students, owners and professional design teams we seek to transform design and construction practice and keep pace with the milestones of the 2030 Challenge. We strive to enable our clients to design and construct buildings that are more comfortable for people, require less energy to maintain and operate, and enhance the health and productivity of inhabitants.

To help achieve these goals, IDL-Boise provides project-based education services to owners, designers, and construction teams in the disciplines of daylighting, electric lighting, heating, ventilating, cooling, and other high performance, sustainable practices. This approach creates many synergies between practice, research and teaching and produces benefits for each.

Outreach
Community outreach and engagement serves to extend the scope of impact of a university beyond that of the student body. Strong outreach can improve community involvement within and sense of ownership for a university while improving the financial health of its units. The opportunity for faculty and students in schools of architecture to work hand in hand with design professionals on the design and analysis of both qualitative and quantitative aspects of buildings benefit faculty, students and professionals alike. Much of the work carried out by IDL-Boise is focused on building lifelong learning relationships with the design community by forming a mutually beneficial partnership. We employ a method of design assistance focused on improving human comfort and minimizing energy use described as project-based education. This mode of outreach takes real building projects that design professionals are actively designing and engages the expertise of faculty and students to optimize design for both human comfort and energy savings.

Research Activities
Scholarly and creative activity is an essential aspect of any university and its faculty. The research activities possible in a Design Laboratory setting are unique and extremely valuable to the pedagogical approach embraced by many schools of architecture. IDL-Boise engages in several types of scholarly
activity. Prototype design and analysis is one type and is the subject of much of the rest of this paper. Other types include long-term measurement and verification, post-occupancy survey and evaluation, enhanced systems commissioning, system performance optimization, patterns of use surveys, and visual and thermal comfort threshold analysis. All of these research modes relate to the core mission of improving human comfort and reducing energy consumption.

Teaching
Design education in schools of architecture is typically focused around the studio. At the University of Idaho Boise satellite, the architecture faculty has the luxury of a small focused group of graduate Master of Architecture students. Very often faculty and staff at IDL-Boise will teach a design studio in conjunction with a seminar in either daylighting design or building performance simulation. Furthermore, studios and other supporting classes such as history and theory are co-taught and integrated in such a way that students are able to directly apply technical or theoretical knowledge directly to their studio projects. Often, studio projects are selected to enhance the current research and outreach activities ongoing at IDL-Boise. This mode of teaching provides a dynamic transformation experience for design students and promotes increased engagement from the design community.

Elementary School Prototypes
Elementary school prototypes in Idaho have a long history. There are three prominent design types that have each evolved by one of the three prominent school design firms in Idaho. From the State’s perspective, prototype design is viewed as the most economical approach to school construction because of savings produced by the repetition of design drawings and familiarity of building systems for maintenance staff. However, there are also negative outcomes from this practice such as the potential for old designs to be recycled when beneficial innovations might arise if new design effort occurred. The ratcheting down of design service fees based upon the use of existing designs can potentially devalue the work completed by design professionals in the eyes of the client. The concern for the profession is if clients come to expect these relatively low design fees, then design innovation becomes more difficult or even impossible.

There are potentially other important benefits of prototype design. This has been an attractive mode of architecture, particularly relative to modular housing, for generations of ‘master architects’. To name a few, Mies van der Rohe, Le Corbusier, and Buckminster Fuller all thought so. More recent examples, such as Kieran and Timberlake, would suggest there is still a great deal of interest in and new ideas about the benefits of this type of architecture. Instead of focusing on the international housing problem using broadly applicable prototype design, we explored the possibility for innovating classroom design by evolving a regionally and site-specific prototype. Unlike ESBL’s work in the arena, where they were working with a clean slate, IDL and Design West Architects worked together on dramatically evolving the prototype that has been in process for several years.

When done appropriately, prototype classroom design should facilitate detailed investigation into each aspect of the performance of the classroom and produce benefits for all parties involved. These benefits need to be measurable (and measured) in order to provide resources for additional investment into future prototype innovation. The most important aspect of successful prototype design is that it must be approached as a process. It is the cyclical process of innovation that leads to real improvement.

Outreach - Project-based education
In 2004, IDL-Boise and Design West Architects began a series of design explorations surrounding the prototype elementary school they had developed for the Nampa School District in Idaho. At the time, IDL-Boise, in conjunction with Solarc Architects and Engineers out of Eugene, OR and Konstrukt out of
Portland, OR proposed a series of design modifications to reduce energy use. Modifications included building orientation optimization, the use of daylight as the primary source of illumination, as well as several envelope improvements including increased wall insulation, improved glazing properties, additional external shading, and reconfiguring the glazing pattern so as to perform optimally based upon orientation. Additional measures included improved lighting design and controllability, and substantially rethinking the approach to space heating, cooling and ventilating. These measures will be reviewed in more detail in the next section.

By including these measures, the classrooms were predicted to use 25-30% less energy than a standard classroom designed to the International Energy Conservation Code in effect at the time. When the first new school, Willow Creek Elementary School, went to bid, these items were included as add-alternates and the price came back approximately $500,000 higher than the $5,750,000 baseline design, marking approximately an 8% cost increase. The District was not able to absorb the cost increase and nearly all the additional efficiency measures were excluded from the Willow Creek project. However, the District was convinced to use the optimal building orientation, elongated in the east-west axis so as to ensure all classrooms were north or south facing. They also maintained the modified window configurations that were optimized for either the south and north orientations because this was a cost neutral measure. Finally, the District decided to absorb the additional cost to include the energy management system because the team convinced them of the maintenance benefits. In 2004, after the bids came back high, last minute efforts were made to include several of the high performance features into just a few classrooms to test the design performance and experience the alternate design, but ultimately this effort was unsuccessful at Willow Creek.

When the next school, Endeavor Elementary, was approaching bidding in December 2005, the team was better prepared. The architects proposed to the District that two classrooms, one south and one north facing, be designed and bid to the high performance standards pursued previously for Willow Creek. This time, the project was proposed as a deduct-alternate instead of an add-alternate and the bids came back much more favorably. However, there were several additional measures that were discussed and ultimately added through the change order process in order to push the performance even further. This included modifying the cooling approach to eliminate compressor-based cooling in favor of indirect-direct evaporative cooling, implementing perimeter fin tube radiators for the heating needs, and utilizing demand-controlled heat recovery ventilation. The change order scope of work also included significantly more detailed systems measurement equipment that would allow long-term detailed analysis of each individual design component. The additional equipment and labor required for the changes orders presented the District with financial challenges. Therefore, IDL-Boise faculty, staff and students led a grant writing effort to cover the cost of the additional equipment.

After several months, and as the project was already under construction, IDL-Boise presented the intentions of the design project, the specifics of the research effort and letters of financial support from the Northwest Energy Efficiency Alliance and Idaho Power Company to the District in an effort to receive final approval to proceed with change orders to the project. Due to the support of Design West Architects, the design team engineers and the evidence presented, the School Board approved the project with three conditions. First, the research aspects must be fully funded by outside sources. Second, the alternate equipment must not slow the final project completion. Third, the District Maintenance Staff must approve all alternate equipment, specifically the indirect-direct evaporative cooling unit.

The team was quickly able to comply with the first two items, while the third was more challenging. To assist with the third condition, IDL-Boise found several school districts in Utah, Colorado, Oregon and California that had deployed similar evaporative cooling systems and made contacts with maintenance staff at each school district. This information was provided to the Nampa School District Maintenance Staff, and after discussing the proposal with the other districts, final project approval was gained.
Research - Classroom design and monitoring

Building on Previous Work of the Lab Network
The design process for the Endeavor high performance classrooms benefited from several previous and concurrent projects underway by the Lab Network. The lead author had worked for the Daylighting Lab at the University of Washington for four years prior to opening IDL-Boise in 2004 and during that time had worked on many designs for well daylit classrooms. These experiences prompted the efforts leading up to the first high performance classroom demonstration proposal for the Willow Creek Elementary School. During 2004, much of the Lab Network was involved in the design for the Willow Creek prototype design. When the Willow Creek project did not move ahead with several of the energy efficiency measures, the idea to explore an even more advanced classroom design was carried forward by ESBL.

In 2004 and 2005, ESBL developed a classroom prototype for the Pacific Northwest that was modeled to be 70% better than Oregon’s energy code when optimized for the Portland, OR climate. This design influenced some of the design modifications for the Endeavor Elementary School high performance classroom prototypes. Care was given to make design modifications specific to Southeastern Idaho’s climate and several aspects of the design were not warranted, feasible given the constraints, or acceptable to the District.

For instance, ESBL’s high performance classroom design was a complete design effort, beginning with a clean slate at Endeavor however, we were dealing with two classrooms down a wing of classrooms designed with a specific profile and depth. This dictated that several items, such as shape of the room, shape of the roof and the profile of the perimeter windows were fixed. The District was also cautious about any exterior modifications. Skylights were designed to be inconspicuous and the District determined that additional perimeter solar shading would appear out of place on just one south facing high performance classroom and it was therefore eliminated. Furthermore, ESBL’s classroom was designed without a cooling system by employing aggressive night flush cooling in conjunction with massive floor and walls and a hybrid passive/active ventilation system. The Endeavor high performance classrooms, for many reasons, including those just listed could not perform within the District’s comfort criteria for school-year cooling design days without some form of mechanical cooling. Thus a hybrid, indirect-direct evaporative cooling system with energy recovery was designed and installed at Endeavor.

Load Reduction Measures
- **Orientation** The school is built on an elongated and rotated H-shaped plan with all classrooms facing either due north or south. This ideal orientation makes good daylighting design and load reduction much easier.

- **Envelope** The south classroom is designed to minimize heat gain early and late in the school year by using mostly high clerestory type openings that are shaded by the roof overhang. Spectrally selective high performance glazing was used throughout to keep heat outside in the summer and inside during the winter while allowing a large amount of visible light to penetrate the building. The north classroom uses standard low-E glazing, as heat gain from perimeter windows is not a concern.

- **Daylight design** The high performance classrooms are designed to take advantage of generous perimeter daylight windows by balancing the daylight at the back of the classroom with
several translucent skylights. These skylights wash the back wall with daylight, increasing space brightness while also minimizing the potential for glare from contrast.

- **Electric lighting design** Indirect-direct electric lighting fixtures are controlled by a daylight sensing photocell in an open-loop format. Dual technology vacancy sensors sweep all lights off after 15 minutes of vacancy. When entering the room, electric lights require a manual switch on since daylight is so abundant. Because of the good daylight design and choice of indirect-direct fixtures, the installed electric lighting was reduced from 1.2 Watts / FT² in standard classrooms down to less than 0.8 Watts / FT² in the high performance classrooms.

- **Ventilation** The single largest heating use in classrooms is the heat loss due to ventilation requirements. Demand control ventilation was used so that instead of a constant ventilation rate during occupied times the appropriate amount of ventilation is provided based upon occupant need. Further, energy recovery is used on the ventilation exhaust air, capturing either the cool energy or the heat energy, depending on the season.

**Efficient Thermal Comfort Systems**

- **Cooling** Due to the synergies of several of the load reduction measures, an alternative cooling system was possible. The typical split system with direct expansion compressor cooling was eliminated. As the District does not have intentions of using most classrooms for summer classes, the hottest days of the year are eliminated from design consideration and the cooling needs early and late in the school year could be met with a hybrid evaporative system. To meet the District’s approval, the evaporative cooling system was designed to keep the classrooms below 78 degrees Fahrenheit and below 55%-60% relative humidity on the hottest days early and late in the school year. The evaporative system uses a multi-stage indirect-direct approach with energy recovery ventilation built in.

- **Heating** Also thanks to the load reduction measures described previously, the heating system could be redesigned without conventional gas-fired forced air heat. Instead, a gas-fired hot water heater is used. Hydronic heat is circulated through a baseboard fin tube coil at the exterior wall. The supply air needed to meet ventilation demand is tempered with a coil located in the supply air stream, also served by the hot water heater. The strategy of tempering incoming ventilation air and supplying perimeter heat to overcome envelope losses allows for more effective use of internal gains from people and equipment.

**Measurement and Verification Plan**

In order to justify the design innovations of the modified prototype we needed to develop a list of metrics and devise a plan for verification. Classroom performance could be based upon several different metrics. Student performance and teacher recruitment and retention would likely top the list of critical factors. However, justifying an alternate prototype cannot be based upon these metrics directly since a large sample would be necessary and such a sample would not be available until after the new prototype was implemented on several new projects. We can, however, measure key student/teacher comfort indicators on one or two new prototype spaces, such carbon dioxide levels or daylight levels; these may have performance ramifications. But even these indicators will be debatable at best when trying to tie them to performance benefits. On the other hand, energy consumption can be measured in detail and therefore help to justify implementation of the innovative prototype design.

The two high performance prototype classrooms were therefore designed with long-term data collection in mind. The energy management system standardized for Willow Creek was adapted with more than 30
additional monitoring points per classroom. This approach is providing reliable energy use data and comfort indicators that the entire team is using to commission building systems, develop energy savings trends, and continue to inform future design decisions. The results of this work will be presented in a future publication.

**Teaching - Engaging the design studio**

In Fall 2006, as Endeavor was under construction and additional school projects were in design stages with Design West Architects, IDL-Boise faculty led a graduate design studio to design a new public charter school in downtown Boise. The desired program for the Anser Charter School was similar to the prototype design then in evolution with IDL-Boise and Design West Architects. Graduate students of architecture had the benefit of learning about previous design choices in detail from Design West Architects and by touring several schools IDL-Boise and the Lab Network had consulted throughout the Pacific Northwest. Students were specifically challenged to push the integration of aspects of climate and patterns of use to further reduce energy loads and be able to innovate the overall design, including the approaches to lighting, heating, cooling and ventilating, well beyond what was possible at Endeavor Elementary School. Several of these ideas, specifically several of the daylighting innovations were brought to bear on new projects for McCall-Donnelly Joint School District and other elementary school projects in which Design West Architects were involved.

**RESULTS**

**Benefits to Students**

*Lab Staff*

The staff at the IDL has had a diverse range of experiences related to this project over the five-year duration. Their work has encompassed aspects of building performance analysis including energy modeling and daylight modeling related to several design iterations, presentations to design team members, presentations to owner representatives and the District’s School Board, grant writing, equipment specification, system design and equipment sizing, system commissioning and troubleshooting, instrumentation specification and installation, data analysis and performance verification, report writing and finally the process of publishing a research paper. The type of work available at a design lab like the IDL provides a transformational experience for design students that will prepare them to lead a process of change in a profession that needs to get even more serious about designing for energy efficiency and human comfort simultaneously. Graduates of the IDL staff have had the opportunity to take high paying jobs with more responsibility and with a higher level of technical expectation due to the experience provide through the design lab.

*Studio Participants*

Studio participants benefited from the previous experience of Design West Architects, the demands of the Anser School staff, and the technical knowledge and expertise in building performance analysis available through IDL staff as they wrestled with their studio project. The academic exercise required students to design an elementary school that would approach net-zero energy use. The luxury of an academic exercise combined with the specificity of conditions surrounding the Endeavor prototype design and realities requested by the Anser School staff forced students to consider innovative approaches in order to satisfy the complex requirements. If the academic exercise were not balanced by real constraints and supported by the capabilities of IDL technical staff and the rest of the design team, students would not have learned the skills necessary to deal with these critical issues as the move into practice.


**Benefits to Professionals/Practitioners**

The whole of the design team had the opportunity to try several new design elements in a small-scale project with external support from IDL technical staff and funding partners. The direct-indirect evaporative cooling system, certain aspects of the daylighting design and the hydronic heating system were design elements explored for the first time by the design team in classroom applications.

Lessons learned during the commissioning process have proven invaluable related to building the case for commissioning in the first place, understanding the level of detail necessary when writing design specifications, performance specifications and operation and maintenance documentations for innovative systems. Also important is the understating gained about the development of fair and adequate fees for service related to the design and implementation of innovative systems. These findings will be discussed in a future publication.

**Benefits to Faculty**

The opportunity to work on actual design projects and with complex design teams including members from architectural, engineering, and general contracting disciplines along with owner representatives provides a unique knowledge set that establishes a solid foundation for teaching and research. As academic faculty in architecture, having research rooted in the design profession is extremely rewarding and improves the quality of education available to students. Pursuing the research objectives specific to this project has provided the type of publication opportunity necessary for promotion and tenure. Combining teaching and research through outreach activities ensures that each will be more relevant and of higher quality than if pursued individually. Strong connection with the design profession strengthens the experience of an academician’s career.

**Benefits to the University**

The University of Idaho received positive exposure related to the project in several capacities. IDL staff represents the University to owners and design team members in regular meetings and the project was highlighted in at least two local periodicals. Additionally, components of the project have been presented at several local and regional conferences by the design team, including university staff.

**Benefits to Community**

The project has had several ripple effects in the design community and the general K-12 academic community. Tours of the classroom have helped to educate staff and teachers at the Nampa School District about the value of design and the energy impact of their buildings. Maintenance staff and design teams from the neighboring school districts have also toured the facility and specific aspects have been adopted. As the work is presented at regional conferences for school design it will raise the expectations of students, teachers and facility administrators. As the new prototype is implemented with improved daylighting design and indoor air quality, elementary school students are likely to perceive improved self worth because of the improved quality of their living environments. This effect could potentially lead to other more important societal improvements.

**DISCUSSION**

This paper supports the case that innovation in design is crucial to the long-term success of the design professions. The methods described here are one of many possible avenues that design innovation can follow. However, we believe that university-based design laboratories can serve to connect research and teaching with outreach activities in a way that few other modes can produce. The synergy provided exemplifies and even strengthens, the university’s mission while also directly benefiting several
individual groups. The benefits described above to a university, their design students and faculty and the professional design community are unique and valuable.

Prototyping is sometimes viewed negatively within the design community because it can be interpreted as a cookie-cutter approach to architecture. This paper outlines another interpretation while still acknowledging the potential pitfalls of the method. When prototypes are considered to be always evolving and when they can have the regional specificity that responds to patterns of use and climate concerns, they can foster real innovation.

The method of combining research, teaching and outreach that is employed by the Lab Network is unique and noteworthy. Coupling project-based education with long-term measurement and verification research creates an opportunity for ongoing innovation that can solidify relationships between the design community and the university.

In the example of Endeavor Elementary School, there were transformative experiences for all parties involved. The mechanical engineer had never designed a direct/indirect evaporative cooling system and the electrical engineer had never designed an indirect-direct daylight-controlled lighting system for classrooms. The architects became more aware of the role that iterative energy and daylight modeling can play in evaluating the effectiveness of high performance designs and their benefit as a teaching tool to help the client understand the potential benefits and prove feasibility of the design. The process raised the designers’ awareness of daylighting and high performance design in general and many of these elements have become standard in new school designs. The architects also noted that the integrated design process is a necessity, not an option, as more innovative designs are considered. IDL staff learned the importance of detailed specifications for installation and operation of innovative systems, the complexity involved when making design changes, and the benefits possible through applied research activities. Finally students were challenged with pushing classroom performance to a new level while working within the context provided by a real clients and a real design problem.

Everyone involved in the project agrees that the concept of designing and monitoring the high performance classrooms in a side-by-side comparison with standard classrooms has provided invaluable data that will help to continue design innovation and inform future design decisions. The concept of installing energy efficiency measures on a small sample project to prove their worth can increase buy in from all involved parties, help to make better final designs, aid in cost analysis and justification, aid in installation, commissioning and operations procedures, and finally provide detailed data for comparison with future design innovations and predictive modeling results.

Other researchers interested in employing some of the methods outlined in this paper should be advised to realistically consider the time commitment required to engage in the process. This type of project does not lend itself to typical funding mechanisms, rather requires at least a two year time commitment while three years of funding would be preferable. This allows the time necessary to building trusted relationships, work through the design and construction process and finally have time to record and analyze data over a one or two year period for commissioning and performance justification. Additionally, most of the work occurs in short intense bursts with longer periods of smaller commitment.

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REFERENCES


iv Ibid.

