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Expanding the Learning Experience: The Integration of Technology into Architectural Education

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Abstract

With the recent academic emphasis on STEM fields, the integration of digital technologies into the educational process has become a national and institutional priority. As with many fields, this development has the potential of impacting the teaching models and content of architectural courses and related research endeavors. This paper offers a case study of how a variety of environmental-analysis technologies have been integrated within specific technical coursework, student research, and how the resulting feedback has been made visible to the student body and general public.

Introduction

In Winter 2010, a team of NDSU College of Engineering and Architecture faculty and staff developed a proposal for an NDSU Student Technology Fee Grant.[1] The proposal, titled "Technology for Feedback," aimed to benefit students both within and outside of NDSU's professional architecture and mechanical engineering degree programs. As justification for the proposal, the executive summary states:

"This project will benefit all NDSU students by improving their access to a specific category of technology which is presently grossly underrepresented at the University: technology for measuring, displaying, and predicting the energy efficiency of buildings. ... students in NDSU's professional design and engineering programs will benefit from access to technology which improves their ability to design, construct, and manage energy-efficient buildings."

The team's proposal was partially approved in Spring 2011. Among the approved portions of the proposal were several tools and technologies related to the investigation and diagnostic evaluation of environmental conditions. The approval documents emphasized that the funded components of the project be accessible and visible to a broad range of students.

The project components acquired via the Technology for Feedback project are of two types: first, the *interactive tools,* consisting of several sets of hand-held devices and remote sensors intended for proactive environmental investigation, and second, the *interface system*, including electrical meters connected to an existing NDSU building's complex HVAC building management system, in turn supplying information to a digital interface system (a “Building Dashboard”) continuously visible to students and the general public.

This paper begins with a brief discussion of context and then, in subsequent sections, describes how the interactive tools are being integrated within technical coursework, how the project supports student research, how the resulting feedback is being made visible to the student body and general public, and possible directions for future work.

Context

Building performance – the use of energy to efficiently operate a building and provide comfort to its occupants – is a fundamental issue confronting professionals in building design, construction, and operations. It is also of obvious and direct concern to people who use and own buildings. Owners have come to expect architects, engineers and builders to design and build structures that minimize energy and resource use and maximize indoor environmental quality. This usually translates to a much better return on initial investment in terms of operational cost and productivity. Beyond the efficient design, construction and operations of buildings, the factor that ultimately impacts energy efficiency is the end user of the building. Students of architecture, as end users of buildings, must not only learn techniques and strategies for achieving optimal building performance but should be expected to experience and learn from the building performance of their immediate surroundings.

Visualization and interactivity are identified as important components of efforts to educate constituents, including students, about the importance and criticality of building performance.[2] Eco-visualization systems are seen as a means of achieving both visualization and interactivity, with the specific aim of promoting energy-conscious behavior.[3]

The Center for Environmental Design at the University of California Berkeley coordinates a multi-institution project called *Vital Signs* aimed at integrating building performance into architectural education.[4] A key premise of the Vital Signs project is that existing, operational buildings should form a critical component of architectural education, in part because existing buildings constitute concrete examples distinct from the abstract projects typical of architecture design studio curricula. Visibility and sharing of data are also important aspects of U. C. Berkeley’s Vital Signs project, and to this end, research protocols and instrument sets developed through the project were shared with students and faculty in other architecture schools.[5] Participants in the Vital Signs project have gone on to develop similar projects at other institutions, aimed at educating architecture students, faculty and teaching assistants, and practitioners about the critical importance of building performance in architectural design and practice.[6]

Our project begins with the assumption that because all NDSU students are the end users of campus buildings, as such they can be expected to benefit from access to technology which improves their awareness of critical energy-efficiency issues.

Coursework

Acquisition of interactive tools through the Technology for Feedback project continues to support the development and expansion of a number of pedagogical exercises within NDSU’s architecture curriculum. Inspired by U. C. Berkeley's Vital Signs Project, one such exercise is now integrated into the required Environmental Control Systems (Passive Principles) course. This exercise enables students to expand their education beyond the textbook and classroom through the scientific and experiential analysis of existing buildings and spaces.

The coursework begins with readings, lectures, and exercises explaining various contributing environmental factors to human comfort, including temperature, humidity, and airflow. The interrelation of these factors is explained in terms of their implications to architectural design and technologies. A variety of in-class exercises are conducted to develop further understanding of these complex interrelated concepts.

Following an introduction to the environmental tools, students are randomly assigned into small teams of three or four. Each team is tasked with identifying an existing glazed (i. e., windowed) space for further investigation. They must then conduct a qualitative assessment of the space consisting of both written descriptions of perceptual and relative comfort as well as multiple hand-sketches, including of the interior and exterior sides of the glazing. On a reserved date and time, the team acquires a complete 'tool-kit' from NDSU's Architecture and Landscape Architecture Library in order to conduct a quantitative inquiry of the space. This set of investigations includes the manual measurement of acoustics and airflow as well as thermal heat-loss imaging, but also includes the placement of remote data-loggers which track temperature, humidity, and illumination for three diurnal cycles. Students are then asked to compile all of their qualitative data, analyze the findings and to compare these findings with their original qualitative analysis. Finally, each team compiles their analysis and findings into a formal report, including extrapolations of contributing architectural factors (such as window, wall, overhangs, and insulation).

Student responses to this exercise continue to be overwhelmingly positive. Student comments – often provided anonymously – frequently address the surprises and consistencies found during the investigations. Students also identify and discuss the intuitive connections made between their findings and the concepts discussed in the course text and classroom lectures.

Invariably, this multi-faceted investigation provides valuable insights for the students. It develops intuitive connections between otherwise abstract concepts and the 'real-life' implications of architectural design decisions on human comfort, and by extension the energy used to mitigate intended or unintended shortcomings – whether designed or not.

Research by Students: Dashboard System Selection

In addition to the mobile analytical tools discussed in the previous section, the Technology for Feedback proposal also included the development of a building dashboard system within NDSU's Renaissance Hall. A building dashboard is a kind of eco-visualization providing a continuous digital interface showing energy/comfort performance of a building in real time. Building dashboards allow occupants to observe and monitor how energy is being distributed and utilized within a building as well as provide information related to thermal comfort. In addition to providing students with a pedagogical awareness of a building's performance, data gathered from such a system can also be analyzed for any number of purposes including efficiency studies, performance evaluations, systems analysis, as well as the research of occupant behavior and response.

The original Technology for Feedback proposal explicitly involved students in research from the project's inception. The project team also decided that student input was critical for determining the appropriate building dashboard product, considered as both a pedagogical interface and a research platform. Moreover, the project provided a beneficial opportunity for graduate and undergraduate research assistants to participate in the development of such an installation.

Two research assistants were initially hired and assigned to develop a thorough critical evaluation of available building dashboard systems. Following an initial cursory investigation of available options, the students developed a framework/matrix of criteria that would allow for an 'apples-to-apples' comparison between product vendors. Analysis revealed that each dashboard system had comparable and quantitative features as well as qualitative features unique to their product (such as appearance, flexibility, and service).

Most of the dashboard options identified by the students were *web-based*, meaning that data from selectively installed meters/sensors is continuously uploaded to the vendor's website via internet. This data is then processed within the vendor's program on their in-house computers. The resulting interface of charts and data are provided to clients as a limited-access website. With the web-based approach, the interface is low-maintenance, but modifications to the graphic interface are limited by the willingness of the vendor. Web-based systems also require a monthly maintenance fee.

A few of the systems identified by the students were *locally-based*, meaning that they did not require a web connection to a central-hub vendor. With such a system, data from installed meters is processed by proprietary programs installed on localized (user-provided) computers. The resulting data is then fed directly to the interface screens. Although not as graphically attractive, the locally-based option gives the user the ability to create unique interface graphics via third-party software.

After much discussion and deliberation by the project team, two vendors were identified as finalists. The first vendor, Noveda, offered a web-based product, while the second vendor, Johnson Controls, offered a recently-developed locally-based product. Prior to a final decision, representatives from each vendor were interviewed separately. After extensive review and discussion the project team decided that the Johnson Controls product would provide the best opportunity for student engagement and learning. Johnson Controls offered a product that would provide students with the capability to change the entire interface design over time, allowing for ongoing student involvement for the life of the project. This option also requires no annual fee for project maintenance. Moreover, as an important contributing factor, Johnson Controls also provided the building management interface equipment and software used by NDSU Facilities Management, easing connectivity.

Research by Students: Design and Development

With the purchase of the software complete, the initiative then undertook two simultaneous directions, with the student research assistants given increasing input and responsibilities. First, the design, construction, location, and installation of the physical interface or 'kiosk' (including monitor screens), and second, the development of the on-screen graphical interface.

During initial discussions on the kiosk design, it was determined that a student design competition be developed to further expand student involvement in the project. With the student research assistants conducting the competition, advertisements were sent throughout the university – a number of small prizes providing additional motivation. The competition itself required competition participants to not only consider the goals of the Technology for Feedback project but also real design considerations such as ADA clearances, visibility, creativity, maintenance, access, materials, connections, and cost. During January 2012, seven student team proposals were submitted. The winning proposal was determined by a popular vote with confirmation by a grant committee. Provided with the necessary funds, the winning kiosk design was then constructed and installed by the winning student team.

The winning design consists of two large flat screen monitors mounted back-to-back. A frame of raw bolted heavy channel steel surrounds the two screens. It is anchored vertically, along one side, onto a prominent heavy timber column within the lobby space of Renaissance Hall. Wood infill accents soften its appearance and tie it visually to the building's wood structure. The required computer monitors are located in an adjacent office space (Fig. 1).

A major consideration in the development of the on-screen graphical interface was to determine the content and scope of information to be displayed on the building dashboard. To an extent, content and scope were practically limited by the numbers and cost of the installed meters. However, because the dashboard system could be connected with Johnson Controls' building management system, other information could be displayed, such as room temperatures and HVAC equipment functions.

With student participation, the project team decided to provide a minimal and clean look to the interface, avoiding unnecessary content or graphics. For example, the team decided that simplified graphic floor plans would best contextualize the building performance data. Such plans are characteristic of architectural communications and are a simple but effective way to display information for people to recognize and understand the buildings they inhabit. Given the scope and content of the data, the team further decided that cycling display pages were required. As designed, the on-screen graphical interface currently consists of six separate pages which cycle and update every few seconds. The first page consists of a summary of the building's energy use with small key floor plans. The subsequent five pages show data related to each individual building floor with an enlarged plan of each floor.

Future Work

One of the primary goals of the Technology for Feedback project was to involve students into the design, purchase, and installation of a building dashboard system. However, much like the interactive tools, the interface system offers ongoing opportunities for further investigation. The building dashboard also provides a variety of other collateral pedagogical benefits that engage current and future students, staff, faculty, visitors, as well as the general public.

Although the building dashboard described here was installed within Renaissance Hall, it can be utilized by students and research initiatives from a variety of fields. One example of student/faculty research already undertaken has been the use of acquired data to produce a comparative evaluation of an energy simulation software model to the actual energy performance of Renaissance Hall.

The installation and use of the building dashboard system has also led to a number of proposals for future developments such as adding more meters to investigate energy-use in more depth, adding various other systems (water, gas, etc.) to the interface, or possibly monitoring indoor air quality. Also, the development of a more dynamic graphical interface would allow occupants to better understand the connection between the data and the resulting savings in financial and environmental costs. The graphic display might also be fed and publicly displayed within the NDSU Memorial Union or on various university websites.

Beyond the research potential, the building dashboard also has the ability to impact building occupants by increasing their personal awareness of energy use. The public display in Renaissance Hall has already become an impetus for the installation of energy meters in more buildings across the NDSU campus. It may also inform key decision-makers within the university, informing their decisions regarding facilities management, social behavior, and environmental impact. Increasing the overall public awareness in this manner allows people to make educated and informed decisions on these increasingly relevant issues.

Conclusions

Through the funding associated with the Technology for Feedback grant, students have been provided with a variety of didactic technologies. As integrated into coursework, the interactive tools provide students with the ability to conduct highly immersive environmental investigations allowing for the acquisition and processing of quantitative data accompanied by qualitative observation and analysis. Although certainly passive in its interface, the building dashboard provides a consistent and public pedagogical presence as well as a potential platform for research. As this initiative is ongoing, we will conduct evaluation of its impact in the next stage of the project.

Although it is difficult to fully quantify the successes (or failures) of such ongoing initiatives, at this point it can be said that the overall project goals have been achieved. With the acquisition and availability of these investigative tools, student access to technologies relating to measuring, displaying, and predicting the energy efficiency of buildings in buildings has indeed been improved. However, only the future will tell whether or not these technologies will improve students' ability to design, construct, and manage energy-efficient buildings.

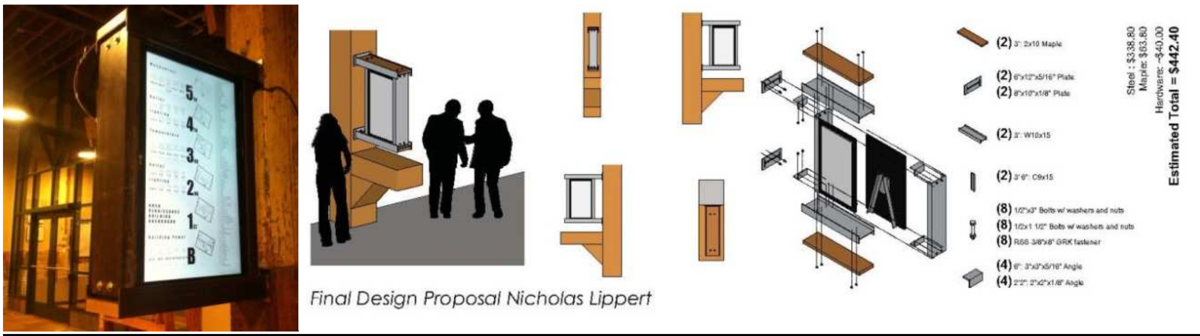

Fig. 1. The dashboard kiosk design: The final dashboard kiosk as installed in Renaissance Hall, and design assembly diagrams.

Bibliography

[1] The original project team consisted of Dr. Bakr M. Aly Ahmed, Mike Christenson, David Crutchfield, and Malini Srivastava, faculty in NDSU's Department of Architecture and Landscape Architecture (A/LA); Ben Bernard, Computer Services Specialist in A/LA, and Dr. Sumathy Krishnan, faculty in NDSU's Department of Mechanical Engineering.

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