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Introduction

The American building industry is one of the major consumers of energy. Buildings use 39% of the total energy consumed in the United States, significantly impacting national energy demand and contributing to global warming. The vast majority of architectural practice in US leads to construction of buildings with a little concern to sustainability leading to environmental degradation.

Although the bulk of architecture practice continues to produce unsustainable buildings, there is growing stream of exemplary models of sustainable design. Examining the success of such practices leads into two a two-folded finding; first that achieving sustainable design is closely linked to "integrated Design"[1] - a type of practice in which various disciplines involved in building design work together to achieve efficiency and other synergetic benefits. Second is that the advances in computing and simulation algorithms are paving the way to achieve "integrated design". These technologies are enabling the designers to collaborate, visualize, foresee, and modify building performance with relatively high accuracy. They are increasing used to analyze complex systems to achieve streamlined structures, reduce dependence on mechanical systems, produce more effective construction processes, and reduce waste.

If such practices were to become widespread, the architectural education needs to be restructured. The traditional American architectural curriculum that is based on a schism between "design" and "technology" is inherently in conflict with the principal of integration. Though large-scale reform of architectural curricula is a complex, ongoing, and difficult debate; producing teaching tools that can simulate integrated design can impact and promote an understanding of sustainable practice in architecture.

The proposed paper will present the progress of a multi-disciplinary team of faculty who are collectively working on the completion, implementation and evaluation of a simulation software package in an interactive game format. The project teaches the concepts of "integrated design" through immersing students in a virtual world that imitates the complexity of the real world of decision-making and material choices in design. The project accomplishes this by harnessing the capabilities of simulation and dynamic modeling programs as well as powerful game engines while creating compelling and rewarding reasons for student's engagement in the learning process. The project is funded by the US Department of Education for the period of 2007-2010.

Project approach

The project proposes to develop and test a learning environment that improves building technology education through the use of multimedia software. The project is based on a few pedagogical principles and objectives: First, it is based on a self-directed learning model. Recent research indicates that the passive lecture format or "instructional paradigm" where the teacher lectures and the students listen may not be the most effective setting for learning. Instead, numerous educational researchers have focused on developing student centered learning environments based on a self directed learning system which provides educational materials that are highly interactive, task oriented, and enable student to controls the pace of their own learning. Raschke explains that "…learning, or teaching for that matter, is optimized whenever the inquiring mind is turned loose on a set of tasks or aims, rather than simply loading the brain with a carload of prefabricated materials." [Raschke 2003][2].

The second principle is that the application of appropriate building technology can facilitate design problem solving within the context of sustainable design. This approach requires the integration of technology at the outset of the design process as well as providing immediate access to information that could guide design decisions with respect to the sustainability issues.

Third, the proposed teaching/learning tool should be developed to respond to the needs and capacities of architecture students, using methods that are visually and spatially oriented. In addition, the pedagogy is grounded and referenced to existing building systems, showing how subcomponent analysis relates to the broader issues of building design. Lastly, teaching should aim to increase student interest in the technical aspects of design, particularly as a life-long educational commitment. Creating an interest in integrated design and construction can positively affect students' predisposition to further explore these issues as practicing professionals.

To meet these objectives the project is composed of two major components: first a building design and assembly software called "EcOzone Game" and second an Evaluation Program that allows the development team to gage the success and failures of the software.

EcOzone Game

The EcOzone Game is developed to engage students in a series of scenario-driven building design projects that make a case for sustainable design and construction. These scenarios take on a variety of ecologic and economic issues such as squandering natural resources, fuel and energy cost, volume of waste, and climate change.

The notion of project delivery in a digital game environment directly addresses the digital media literacy of architecture students and learning preferences of the new student generation. This game promotes active experimental learning that is based on problem solving. It allows the students to use creative expression while participating in solving complex problems. It assists students to engage the subject at the level of their individual ability while receiving support for their activities. Continuous feedback is a strong feature of this gaming software, providing many opportunities for learning – on - demand.

EcOzone game revolves around the student playing the role of an architect and developing design strategies, which is similar to the experience of a real-world practicing architect. Each scenario lays out a challenge for designing a building, selecting building systems, meeting a budget, and completion of deadlines. This includes balancing the demanding requirements of site and context, form and geometry, building function, climate, and energy.

The game begins when the player selects a level of difficulty and enters the game by\ choosing a specific building design scenario in one of the seven climatic zones presented in the game. To design the building, the player navigates through a series of choices investigating building components and their relevant properties; selecting building systems; evaluating energy features of the components; and comparing costs. The selected choices are all stored in a library of tools ready for building design. During design, the player can organize, move, group and edit the selected components to assemble a complete building. After the building design is completed the game engine runs a number analysis to evaluate the building performance. These analyses have a two-folded function; first to provide computational support for analyzing capital investment and building life cycle cost; and second to utilize quantifiable measures for evaluating sustainable choices and strategies employed in the design process. A game domain currency or "credit" will be used to increase or decrease an initial credit value provided to each player.

The game Credit values used to design and assemble the building are closely related to the actual dollar values used in the building construction industry. The game Credits used for sustainability assessment will be more complex to quantify. Currently, the project team is considering Whole Building Design Guide developed by the National Renewable Energy Laboratory and the Green Building Rating System established by US Green Council Leadership in Energy and Environmental Design or LEED, as guidelines to establish proper values. The Credits will be used to reward well integrated building systems, efficient energy strategies, green features and alternative sources of energy. Players will be penalized for using materials with high embodied energy, low percentage of recycled materials, and high waste output. EcOzone is composed of the following components:

a) Scenarios are the first introduction to the game. Following a few brief directions, the scenario will be launched with three dimensional graphics and a narrated story line making the case for the player. This will be accompanied by full textual, audio and visual information of the site and the surrounding environment, topography, climatic conditions, building function, and detailed square footage requirements of the building program. Once, the player is given the mandate he/she will move to the User Interface and the game begins. The project team is developing a total of five scenarios to adequately to cover the content. To keep the players continuously involved, each of the scenarios can be played in one of the following seven climatic conditions: hot and dry, temperate and mixed, cold and humid, temperate and humid, hot and humid and cool and dry. This ill allow the students to play the game in 35 different combinations at various times.

b) User Interface includes a main and secondary window. Most of the game activities will occur within the main window. This window is lined with menu bars on the top and bottom. One set of the menu bars are used for operational activities such as filing, drawing, and editing functions. The other set is composed of the modules directly related used for selecting various elements and playing the game. The secondary window is used to exhibit pertinent information such as lessons, required specifications and analytical data and graph exhibits.

c) Library of Building Blocks consists of a number of pre-arranged building blocks that compose the functional elements of a building such as, rooms, public spaces, dining areas, stairs, elevators and etc. The player can investigate each arrangement by placing it on the main window and examining how a particular arrangement responds to site and climate conditions. For example, the player can compose a horizontal arrangement of the building mass and place it in various orientations on the site to examine its energy efficiency in relation to each orientation. In a hot and humid climate, a horizontal arrangement of open spaces such as offices which are extended in the east-west direction will provide for cross ventilation of air from a southern summer breeze, reducing the need for mechanical ventilation. This arrangement will also maximize the utilization of natural day light. The feedback from the game will allow the player to investigate these and many other interactions of the building volume in response to the climate and site. Understanding these complex interactions are a critical component of sustainable design. These interactions will be analyzed with simulation software and exhibited for view in both numerical and graphical format.

d) Library of Building Envelope Elements is a number of detailed computer generated models of building envelope systems such as walls, roofs, floors and windows. Each element is modeled as modules of 8ft x 12ft panels and carries properties of every material used in its composition. For example, a cavity wall is modeled with brick at the exterior surface a layer of air; rigid insulation, flashing, a layer of vapor barrier, concrete masonry, and painted gypsum board in its interior surface. Each material's physical property such as specific weight, thermal resistance, embodied energy, percentage of recycled materials is embedded within the choice and is carried for future performance analysis and game Credits. Once a particular envelope element is selected it can be applied to the previously selected building block. Then the player can adjust the wall for energy efficiency using a limited range of properties of such as exterior wall and interior wall material thickness, insulation thickness and type, and cavity space.

e) Library of Building Systems Components include computer generated models of building systems such as Structural Systems, Heating Cooling and Ventilation (HVAC), Alternative Energy Systems, Lighting Systems, and Fire Resistive Systems. The player can browse the library of systems and investigate a variety of choices. For example, the HVAC Systems selection allows the player to study a series of systems such as Fan Coil Units, Variable Air Volume Units, Water Source Heat Pumps, and Packaged Terminal Air Conditioners. Each unit will have information regarding size, capacity, space requirements, energy efficiency, fresh air intake and exhaust volumes, and suitability for a particular building type. Once a system has been selected and placed in the building, the player can edit a limited number of variables to adjust the efficiency of the system and ask for further analysis.

f) Building Experts is a searchable database presented with icons labeled as Structural Engineer", "Lighting Consultant", "Construction Manager", and "Mechanical Engineer". These icons act as vehicle for learning - on - demand. Clicking any of these icons will enable the student to look up a subject or term and get linked to individual instructional lessons. In addition the Building Experts will be activated randomly by the game engine to create new conditions and introduce anomalies in the game to keep the students alert and the game exiting. For Example the "Structural Engineer" expert may provide warning of a hurricane on its way and ask the player to provide necessary structural precaution or face the consequences.

g) Virtual Case Studies are the core educational element of the game. They bring the principles of sustainable building design construction to life through investigating recently completed significant works of architecture that exemplify effective integration of architecture, structure, services, building envelope, construction and energy efficiency. At least one case study will be produced for each scenario and climatic condition. Each Virtual Case Study will be a highly detailed digital model of a precedent which can be "deconstructed" on screen. Each precedent will address a particular aspect of systems integration and sustainability. The precedents will be comprised of interactive and removable layers of graphic and textual information. For example, he users can study the individual building systems in detail or in combination with other systems. As the user selects each building layer or sub-system, information regarding its design and performance is provided.

Evaluation plan for the project

The Project Evaluation Plan will test the effectiveness of the EcOzone. The Evaluation Plan has four objectives, which are to determine: If the project increases awareness of energy consumption in buildings; 2) if the project is effective in improving students' understanding of building technology and systems Integration principles; 3) are the knowledge and skills gained in architectural technology transferred and applied into student's design work; 4) does the project improve student attitudes toward the building technology curriculum. The evaluation plan has a formative and a summative component. The formative component will collect responses from the project team, faculty, and students through the project's web interface. Once the Beta version of the project is completed they will be implemented and in Comprehensive Studios at the University at Buffalo. A parallel evaluation will be conducted in the Senior Comprehensive studios at the University of Utah. Any changes in the student performance will be measured against traditional instructional methods by dividing students at each institution into a control group and experimental group. The experimental group will utilize the game, while the control group will be taught using the traditional instructional methods at the same time. Throughout the evaluation cycle, each group will undergo entry and exit test. Entry test prior to receiving any instruction will be used to establish a baseline of student competency. The exit test will be a repeat of the entry survey, and measure changes in student competency. The Evaluation Program will also measure attitudes towards building technology through by Attitude Surveys given at the beginning of each studio and repeated at the end, with both experimental and control groups. All data will be analyzed using suitable statistical methods with the summative evaluation published in professional venues.

Closing remarks: Opportunities and challenges

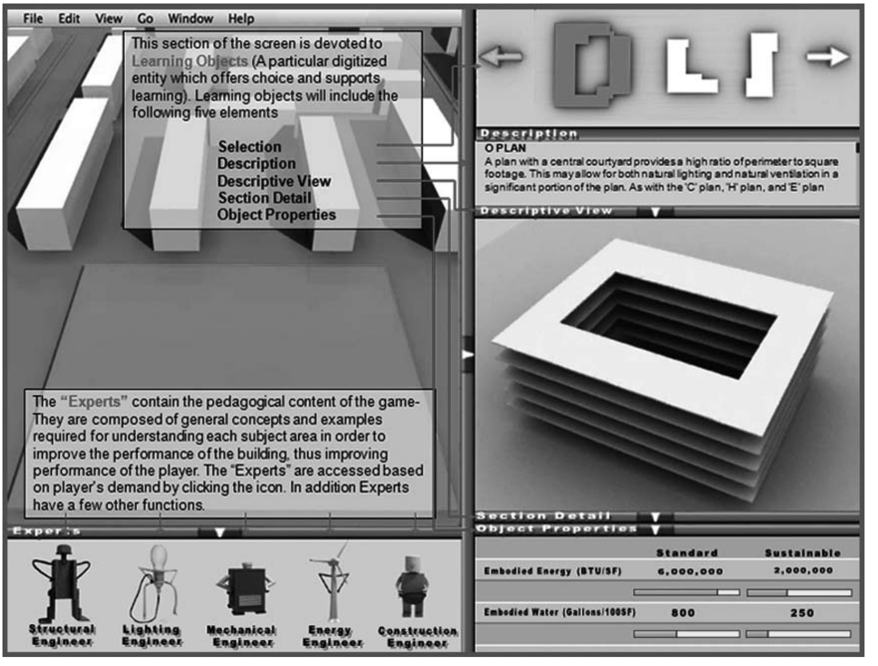
Given the size of the built environment as energy and materials consuming sector, raising architectural capacity to design more efficient and sustainable buildings can have a significant impact on the national energy consumption. The project discussed here seeks to produce a tool for teaching building systems integration by harnessing the capabilities of advanced graphic media and gaming engines. It aims to help students visualize and engage the concepts that otherwise are difficult to comprehend. The project is designed to accommodate the thinking, strengths and interests of architecture students.

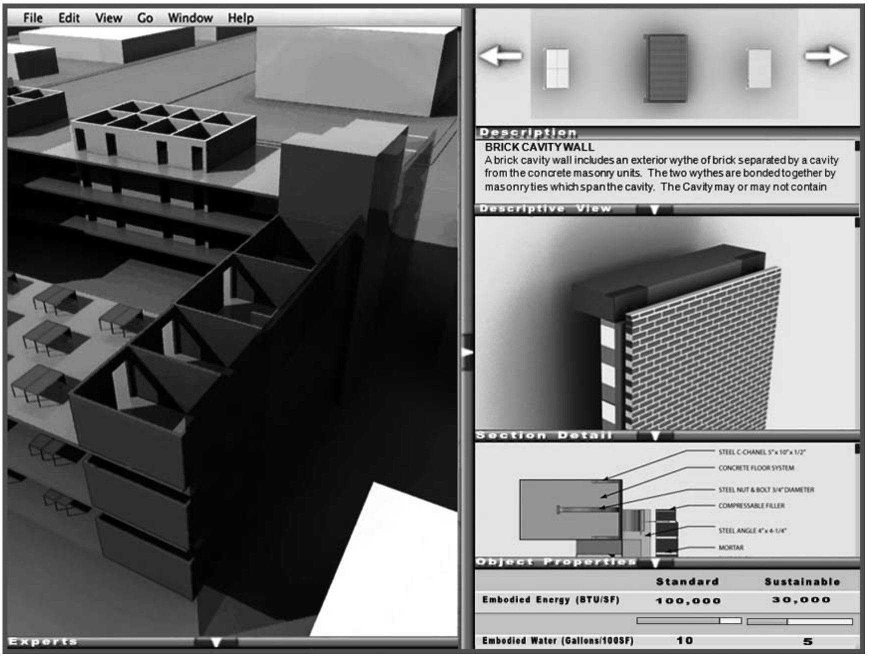
However, developing this tool has presented a few significant challenges. The first challenge has been the struggle to analyze and replicate the design process as a systemic progression of events. Mapping such a complex process cannot be accomplished without major compromises and simplifications that ultimately lead to trivializing the software and limiting its value as a valid design tool.

The second challenge has been to demonstrate the interconnectivity of the building systems and their impact on each other. For example how the selection of a certain type HVAC system will require a particular approach to choosing the structural system and realizing how that structural system will affect the natural lighting within the space and impact the energy consumption. Leading the student to an optimized solution with so many variables has been an impossible task to achieve. The last but not the least challenge has been the decision to limit the expression of architectural form within the tool. Initially the decision was a response to the limitations of technology in hand and the scope of the project. However, as the project progressed it has become clear that it would be virtually impossible to assign a value to the formal decisions and the quality of the architecture that has resulted. This is extremely problematic as the formal architectural expression and experience may be the greatest contributors to the quality of the architecture. A sustainable, well-integrated building may be among the best technically conceived buildings but suffer from producing a meaningful human experience. Although these challenges are significant and may ultimately trivialize the tool beyond the acceptable thresholds of a design tool, the project team believes that it will be an effective tool for learning about sustainability and systems integration.

Notes

1. http://www.wbdg.org/wbdg_approach.php
2 Rachke, K(2003). The digital revolution and the coming of postmodernist University, Routlege Falmer, London, p.38


File Edit View Go Window Help
This section of the screen is devoted to Learning Objects (A particular digitized entity which offers choice and supports learning). Learning objects will include the following five elements
Selection
Description
Descriptive View
Section Detail
Object Properties
The "Experts" contain the pedagogical content of the game- They are composed of general concepts and examples required for understanding each subject area in order to improve the performance of the building, thus improving performance of the player. The "Experts" are accessed based on player's demand by clicking the icon. In addition Experts have a few other functions.
Description
O PLAN
A plan with a central courtyard provides a high ratio of perimeter to square footage. This may allow for both natural lighting and natural ventilation in a significant portion of the plan. As with the 'C' plan, 'H' plan, and 'E' plan
Descriptive View
Section Detail
Object Properties
Standard
Sustainable
Embodied Energy (BTU/SF) 6,000,000 2,000,000
Embodied Water (Gallons/100SF) 800 250
Structural Engineer
Lighting Engineer
Mechanical Engineer
Energy Engineer
Construction Engineer


File Edit View Go Window Help
Description
BRICK CAVITY WALL
A brick cavity wall includes an exterior wythe of brick separated by a cavity from the concrete masonry units. The two wythes are bonded together by masonry ties which span the cavity. The Cavity may or may not contain
Descriptive View
Section Detail
CONCRETE FLOOR SYSTEM
COMPRESSABLE FILLER
MORTAR
Object Properties
Standard
Sustainable
Embodied Energy (BTU/SF) 100,000 30,000
Embodied Water (Gallons/100SF) 10 5
Experts