BUILDING LITERACY: A SIMULATED ENVIRONMENT TO LEARN BUILIDNG TECHNOLOGY

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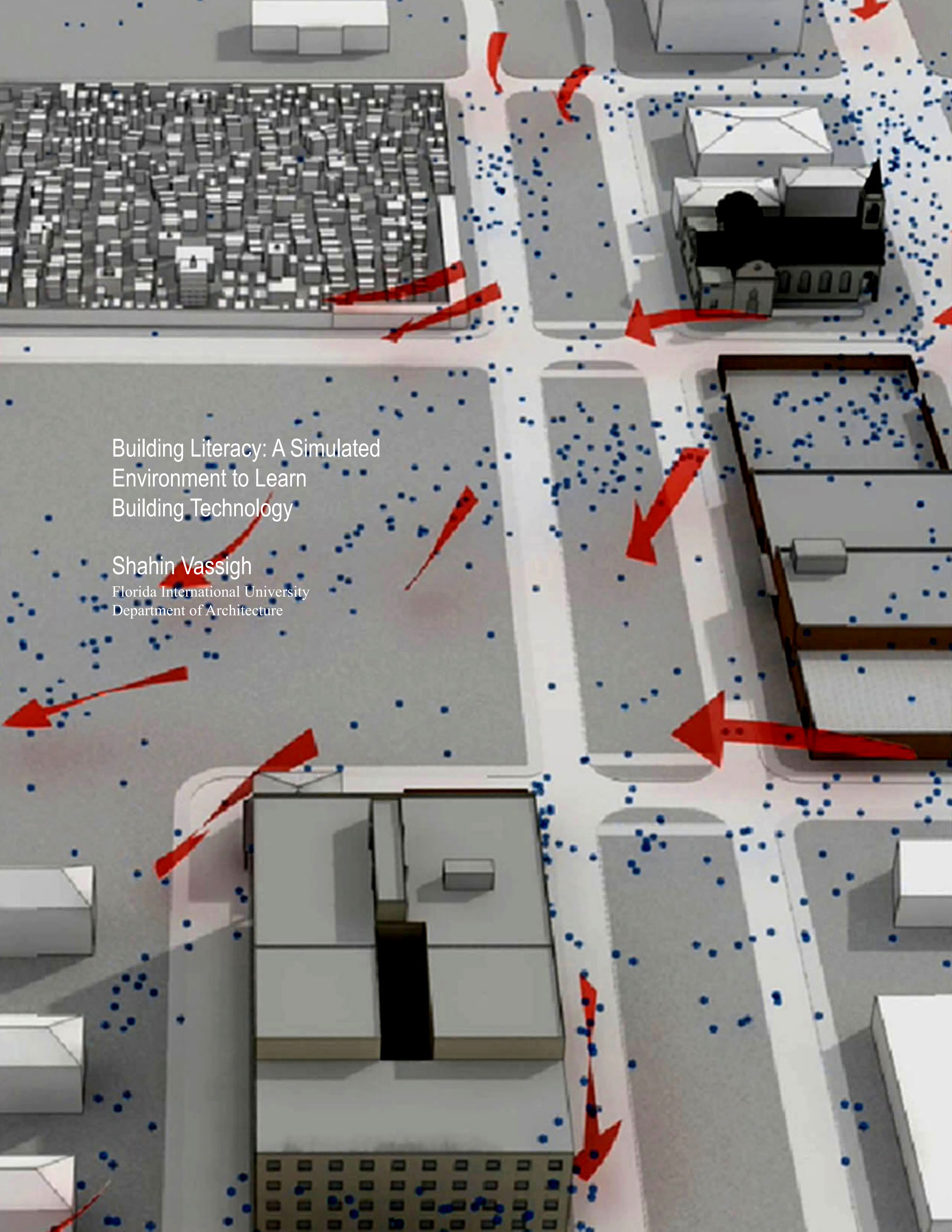
The following paper reports on the development of two consecutive projects which have benefitted from the AIA award. The initial project, "A Comprehensive Approach to Teaching Structures through Advanced Media," was completed in 2005 and the second project, "Building Literacy: The Integration of Building Technology and Design in Architectural Education," is in its final year of completion. Both projects aim at improving technology curricula in architecture programs by harnessing the interactive capabilities of digital technologies including dynamic modeling, simulation programs, interactive images, animations, and audio narration to help students. These projects have collaborative and involved faculty at various disciplines and institutions.

The initial project focused on teaching structures in an effort to transform its pedagogy from the structural engineering model to an architectural model. The project in progress today, Building Literacy, is an expansion of the initial project in which it approaches teaching technology in a holistic manner. As building systems interaction and integration is becoming increasingly important for sustainable design, our pedagogical approach needs to reflect this concern. An understanding of building systems operation, interaction, and the synergetic benefits realized through their proper selection is critical to the future of the architectural profession.

Building Literacy intends to improve student knowledge of how the integration of various building systems can enhance energy efficiency and sustainability of the built environment. The project utilizes a simulation environment based on engaging students in a series of scenario-driven building design projects that make a case for sustainable design and development. The project objectives are to: 1) produce an innovative "building technology" learning environment which takes advantage of the interactive capabilities of state-of-the-art computing technologies; 2) devise a pedagogy which better integrates building technology with the architectural design; and 3) evaluate the project impact on students, and disseminate the project to the broadest audience. The project is its final stages of completion.



Building Literacy: A Simulated Environment to Learn Building Technology

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Introduction

Improving the technology curriculum in architecture programs is essential for the practice of architecture. The various sub-disciplines of the profession have become increasingly fragmented as buildings and their components have grown more complex. In order for architects to be effective coordinators of the design and construction of complex buildings, they must have a sound understanding of its complex systems. Unfortunately, based on many studies in the past two decades, the educational preparedness of architects in the technology area has been questioned, and numerous analysts and writers have documented it as a national weakness.[1]

The project, “A Comprehensive Approach to Teaching Structures through Advance Media,” was designed to examine teaching methods and pedagogy of structures, which is a critical component of the architectural technology curriculum. Since the structure of a building is intimately linked to its form, without a sound understanding of structural principles, the ability of the architect is severely compromised to work within the field.

The weakness in the many current approaches to teaching structures is rooted in the use of an engineering model, which is based on abstraction and reduction of the entire building to diagrammatic elements and symbols, and performing countless analytical calculations. Architects think, learn, and approach the built environment differently than engineers. Most architecture students do not have the required mathematical skills, however they have a strong facility in three-dimensional visualization, are inclined to resolve problems intuitively, and are trained to engage buildings holistically.

To acknowledge these issues, the project aimed to rethink the theory, content, and delivery system of the structures subject and make it keener to the needs, capabilities and perspectives of architecture students. The project began by a seed grant from the University at Buffalo, the State University of New York, and continued through support from the US Department of Education Fund for the Improvement of Postsecondary Education (FIPSE), and an AIA award on University Research.

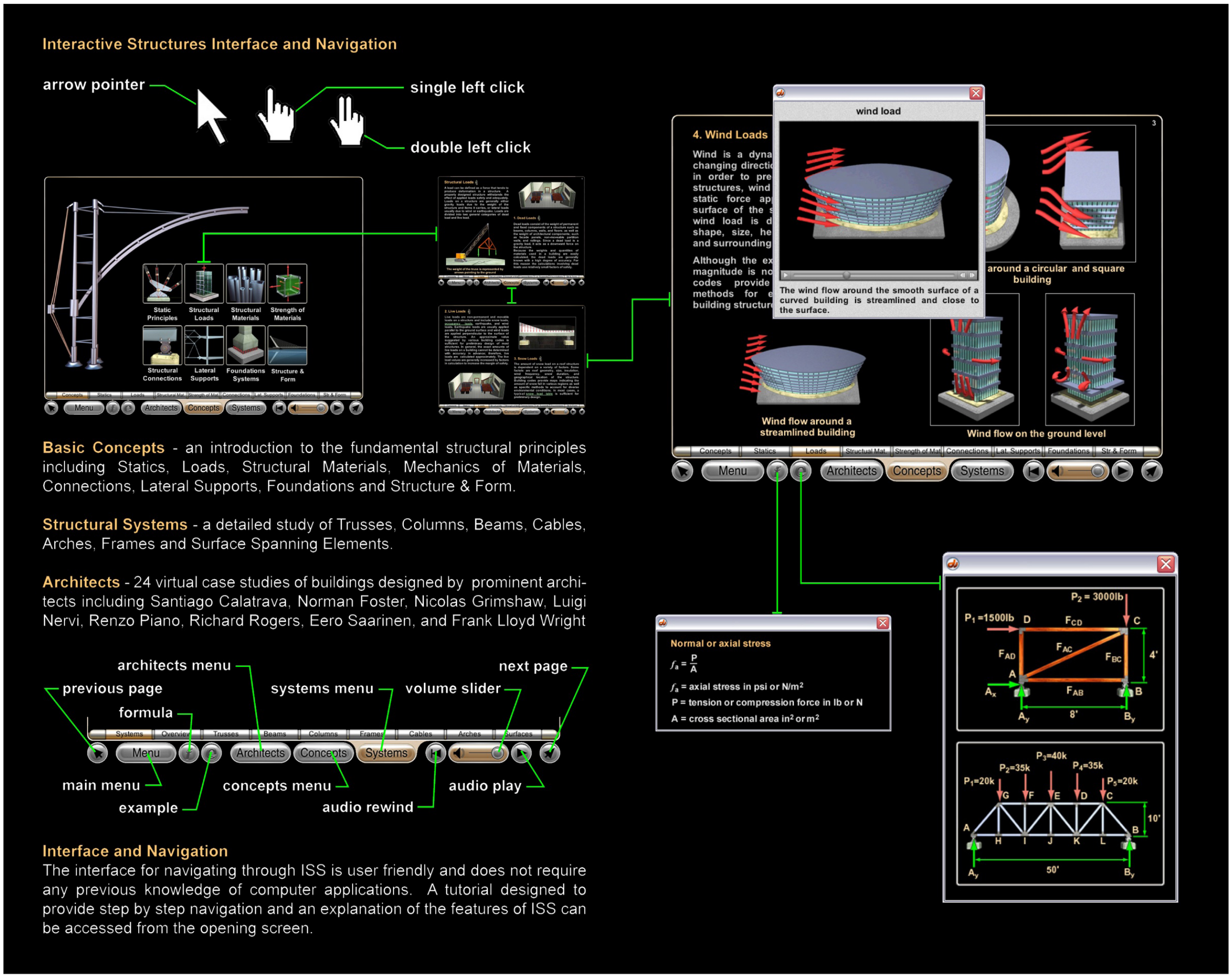

Figure 1: "Visualizing Structural Behavior," a digital learning environment.

The project's most significant outcome, "Visualizing Structural Behavior," is a learning digital environment in a DVD format. The content and design of the DVD relies heavily on the interactive possibilities of digital technologies including dynamic modeling and simulation programs, interactive images, animations, and audio narration to help students visualize structural behavior and principles that are otherwise difficult to comprehend. The content and lessons draw a direct relationship between structural analysis, theory, and its practical applications within existing buildings. The DVD was published in 2005 by John Wiley and Sons Inc. and is distributed both nationally and internationally. The second edition of the DVD with improvement and changes was published in 2008 (Figure 1).

The project research, methods, outcome and effectiveness, and positive impact on students' performance has been published and presented at a number of architectural venues including, the Architectural Research Centers Consortium and the European Association of Architectural Educators conference, Building Technology Educators' Symposium, Association for the Advancement of Computing in Education conference, Association for Computer Aided Design in Architecture conference, and the Association of Collegiate Schools of Architecture national conference. The project has also been published in Architectural Design magazine, ACADIA Quarterly, UB Annual Research Report and the AIA Report on University Research.

Introspective

Following the project completion, through a close examination of the student performance and survey results, and many discussions after presentation of the work in conferences and my own reflection, a few issues were brought into light. First, although the project was extremely successful in helping students to visualize the structural behavior and gain an intuitive understanding in how various structural systems work, it lacked complete interactivity to engage students in a significant way. Second, the project only addressed one aspect of technology education in the architectural curriculum. A similar approach for teaching construction, lighting, and environmental systems was still absent.

Finally, a more effective way of presenting structural concepts needed to include a holistic investigation of all building systems and their impact on each other rather than studying structural systems in isolation. Understanding building systems interaction and their integration is becoming increasingly important as energy conservation and sustainable design are rising to the top of the profession's agenda. An understanding of building systems operation, interaction, and the synergetic benefits realized through their proper selection has a direct positive impact on producing efficient and sustainable buildings with minimal impact on the environment.

In an effort to enhance the project, the national urgency for reducing buildings' energy consumption, and the desire of the profession for promoting integrated practice and systems approach to architecture, a new proposal was submitted to the US Department of Education FIPSE program to fund a project for the period of 2007-2010. The project, "Building Literacy: the Integration of Building Technology and Design in Architectural Education," was successful in obtaining a significant award to tackle these issues. [2]

Progess and the New Direction: Building Literacy Simulation Environment (BLSE)

The Building Literacy project develops educational materials to help architecture students better understand the application of technological principles in building design. It intends to improve student knowledge of how the integration of various building systems can enhance energy efficiency and sustainability of the built environment.

The core component of the project is BLSE, which 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 economical issues such as squandering natural resources, fuel and energy cost, and climate change (Figure 2). They take place in a variety of building sites and contexts allowing the students to select the venue for their learning. In each case the scenario lays out a challenge for composing a building through balancing the demanding requirements of site and climate, form and function, energy and sustainability, and building systems. Each scenario is introduced with a movie explaining the details of the required activity. Once the student has selected a mandate he/she will move to the user interface and start to assemble a building (Figure 3).

Figure 2: A Building Literacy Simulation Environment engages students in a series of scenario-driven building design projects incorporating ecologic and economical issues such as natural resource allocation, fuel and energy cost, and climate change.

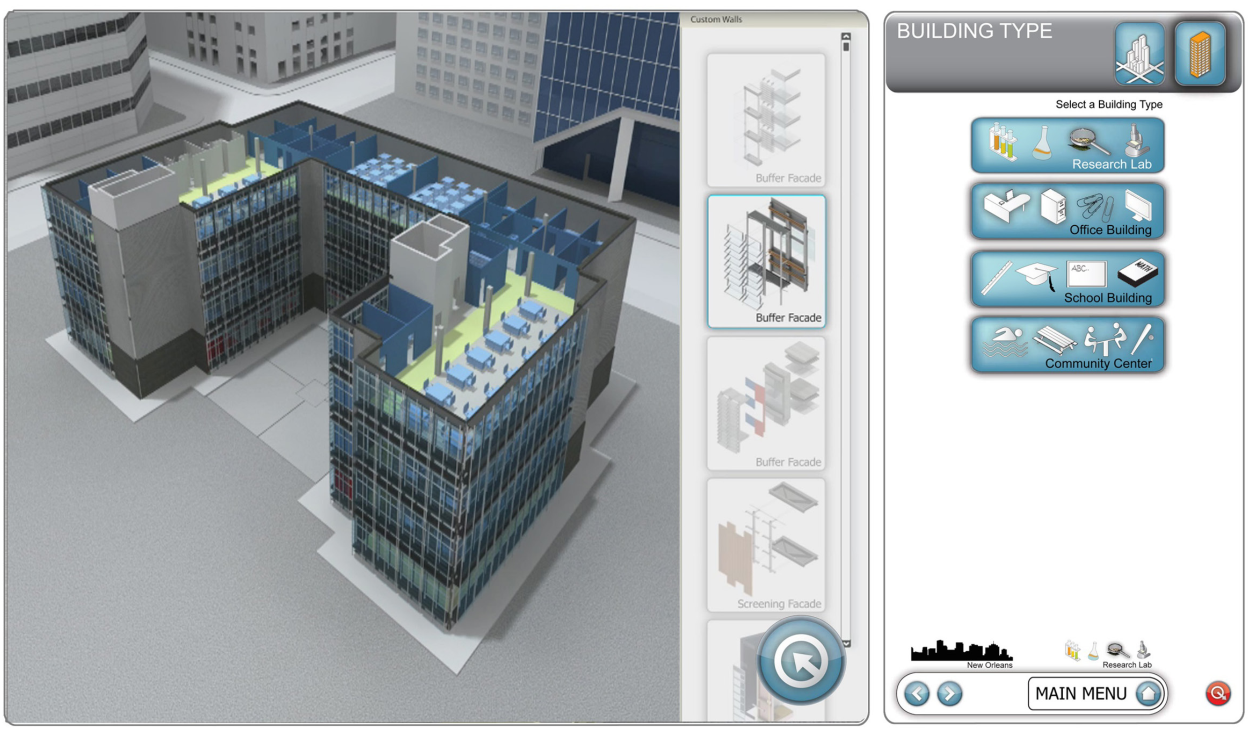

Figure 3: Each scenario requires a specific activity that the student selects in beginning to assemble a building.

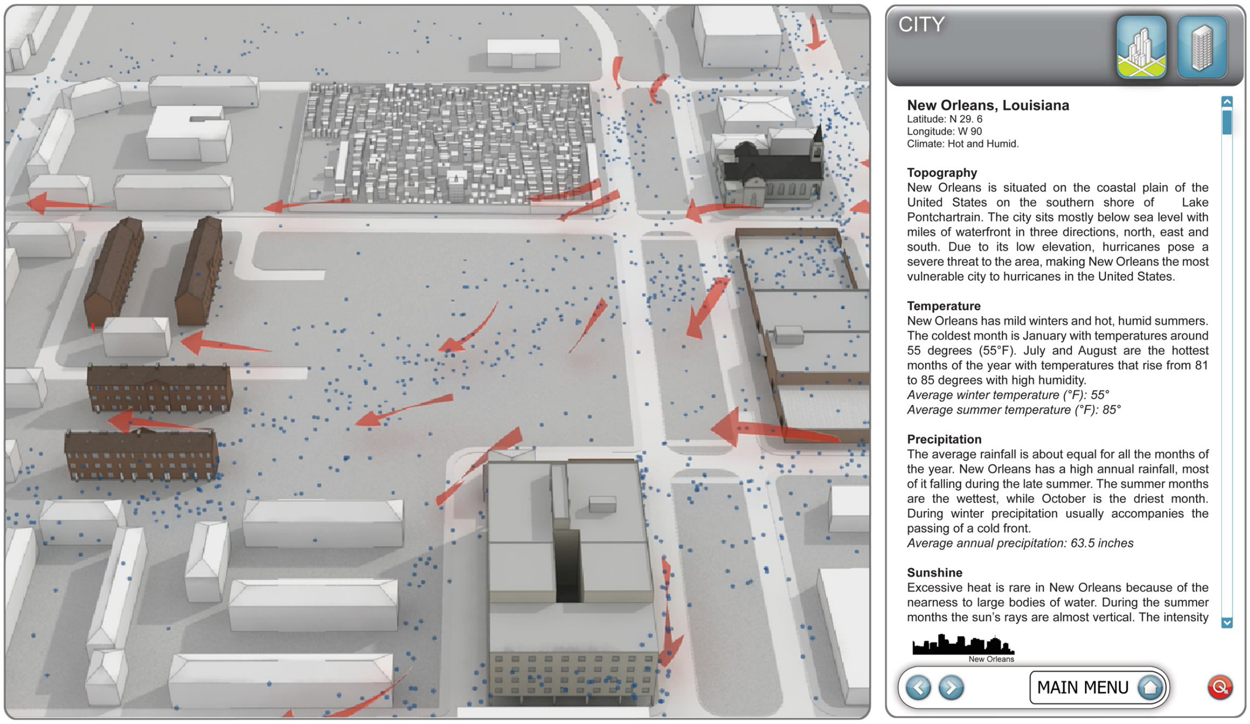

Figure 4: Once the initial climate selection is made, a brief movie will launch a scenario with a narrated story and three-dimensional graphics introducing the entire project.

The BLSE provides access to a library of building tools that contains a wide range of preconfigured building components to be used to assemble a building. Navigating through these choices enables the student to investigate and learn about each building component and their relevant properties. Each building component is tagged with a series of metrics and attributes which are imported to the interface when the component is selected. All selected choices are all stored in the library of tools ready for assembling the building and running the analysis function. During the assembly, the student can organize, move, group and edit the selected components. Specific components of the BLSE are the following:

a) Scenarios provide a choice of architectural programs such as Visitor's Center, Research Laboratory, School Building, etc. Once a choice is made the next menu will allow the student to select one of the four climatic conditions of hot and arid, hot and humid, temperate, and cool as the context for their building assembly. Once the initial selections are made, a brief movie will launch a scenario with a narrated story and three-dimensional graphics introducing the entire project (Figure 4). The movie will include full textual and visual information of the site, the surrounding environment, topography, climatic conditions, and a detailed square footage requirement of the building program. Once the user is given the mandate, the building assembly begins.

b) Library of Building Blocks includes a number of pre-arranged computer generated models of various building components including floor templates and program elements that are used to make a building assembly. Floor templates are the initial step for creating floor plans. They indicate the shape and the exterior boundaries of the floor area, and once a selection is made the floor plan can be laid out. Program elements compose the functional components of a building such as, rooms, public spaces, dining areas, stairs, elevators and etc. The student can investigate each arrangement by placing it on the main window and examining how a particular arrangement responds to the site and the climate conditions. For example, the student 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 solar 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 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 this simulation environment will allow the student to investigate these and many other interactions of the building volume in response to the climate and the site. Understanding these complex interactions is a critical component of sustainable design. These interactions will be analyzed with simulation algorithms and exhibited for view in both numerical and graphical format.

c) 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 properties or attributes such as specific weight, thermal resistance, embodied energy, and percentage of recycled materials is embedded within the choice and is imported for future performance analysis. The student could use the imported values from the pre-configured data set or enter another value to modify the design conditions. The attributes of each component will be added and editable for analysis once the building is completed (Figure 5).

d) Library of Building Systems Components includes computer-generated models of building systems such as Structural Systems, Heating Cooling and Ventilation (HVAC), Alternative Energy Systems, and Lighting Systems. The student can browse the library of systems and investigate a variety of choices. For example, the HVAC Systems selection allows the student to study a series of systems such as Fan Coil Units, Variable Air Volume Units, Water Source Heat Pumps, and Packaged Terminal Air Conditioners.

e) Analysis

Once a building is completed the student can run a few different types of analysis. The main analysis is the solar radiation simulation. This is designed to provide a better understanding of performance of the building fenestration and envelope systems. The results of the analysis provide the students with an understanding of how the location, orientation, window selection, shading, lighting and exposure will affect building heat and cooling load. The other analysis include a summary of embodied energy, embodied water, percentage of recycled material, and an estimate of materials cost that were used in assembling the building. This information will allow the student to understand the impact of their choices and tradeoffs in cost versus environment.

The project is in its last year of funding. Once completed, it will be formally tested and evaluated, and the results will be disseminated to schools of Architecture across the nation.

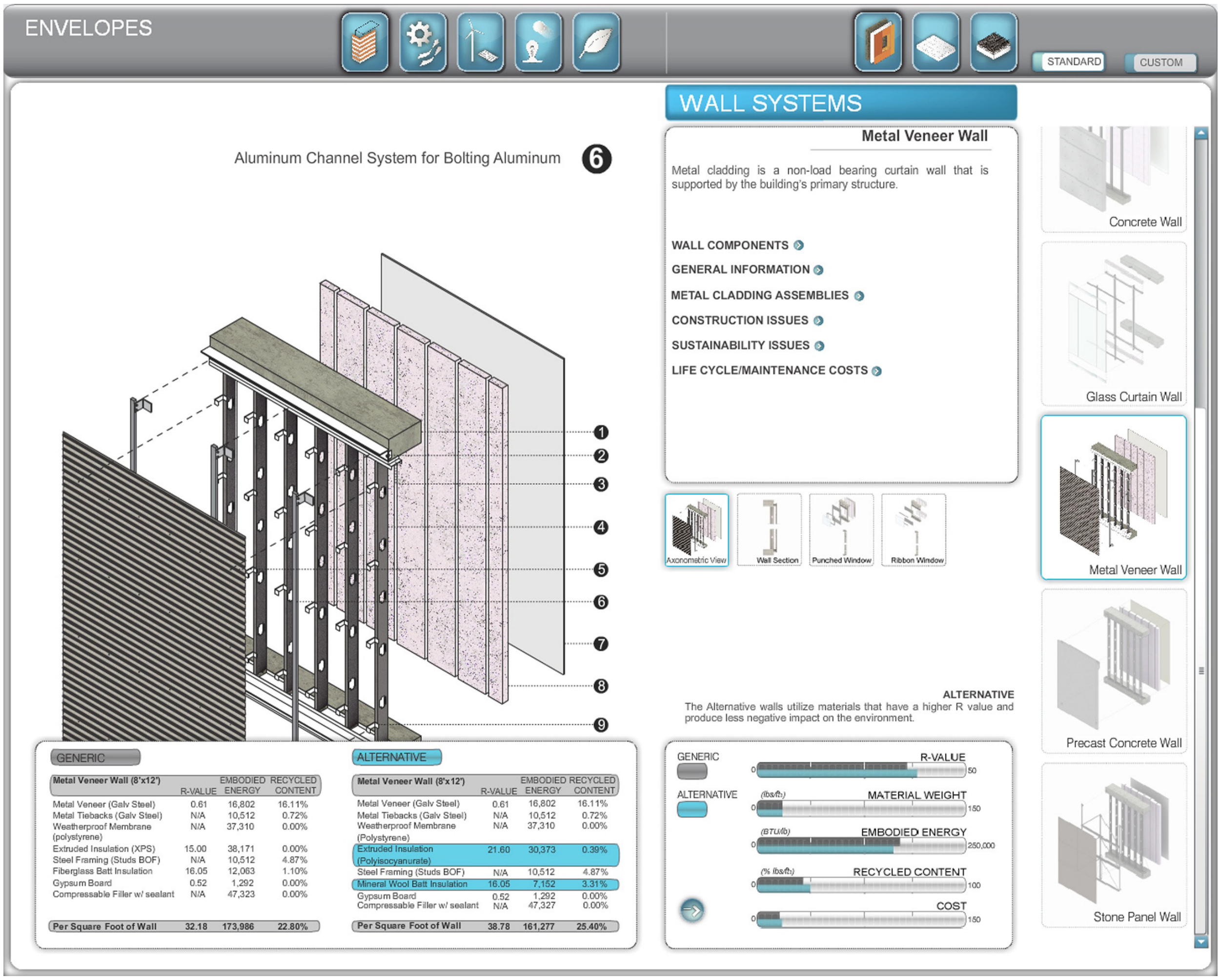

Figure 5: A Library of Building Envelope Elements combines detailed computer-generated models of building envelope systems such as walls, roofs, floors and windows. Each material's physical properties or attributes such as specific weight, thermal resistance, embodied energy, and percentage of recycled materials are embedded within the choice.

Closing Remarks

Given the size of the built environment as energy and materials consuming sector, raising students' awareness and technological competency to design efficient and sustainable buildings can have a significant impact on the architectural profession as well as the national energy consumption. The two projects discussed here seek to address technology education within the architectural curriculum by producing tools that harness digital capabilities of advanced graphic media and simulation applications.

Producing these tools has required engagement of a number of faculty and students, which would not have been possible without the support of the all the funding agencies.

References

[1] For detailed discussion and appropriate references see The American Institute of Architects 2005 Report on University research, vassigh p.133-140

[2] The project was awarded $537,000 from the US Department of Education, FIPSE program. The project includes an inter-institutional and multidisciplinary team of faculty. The Faculty are Shahin Vassigh (PI) and Jason Chandler at the Department of architecture at Florida International University, Ken Mackay, Omar Khan, and Dr. Scott Danford at University at Buffalo, the State University of NY at Buffalo, Dr. Ken English at The New York State Center for Engineering Design and Industrial Innovation, and Dr. Eliot Winer, Department of Mechanical Engineering at Iowa State University.