Matter as Energy

What Architects Need to Know

Dr. Winifred E. Newman, Prof. Shahin Vassigh and Dr. Yimin Zhu
Florida International University
Miami, USA
wenewman@fiu.edu
svassigh@fiu.edu
zsun@fiu.edu

Abstract— **Current advances in technology and cyberspace capacity coupled with emerging research in science education are creating new opportunities to enhance architectural education in the science and technology areas and prepare students for effective collaboration with other stakeholders in the building industry. The project described in this paper addresses the need for the improvement of science and technology education and proposes that using advances in digital technology to engage students in interactive learning is a necessary step. One of the most promising and youngest applications of computer technology has been in developing in educational games. Using new technologies to re-think the education of the architect in the relation to matter as energy reinforces the role of architecture in science, technology and mathematics.**

Keywords-energy; architecture; engineering; cyberlearning

I. INTRODUCTION

If as Martin Heidegger supposed, technology is about anything but the technological, our social construction of 'matter' is largely dependent our social values (Krell, 1993). The question for this paper is: What is the value of sustainable building design and what does an architect need to know to understand the problem? This isn't simply a question of design as it is linked to the broader structure of an architect's education beyond the role of form-maker. It is a question of how our role as form-makers links us to the social values of the early 21st century. In the case of matter, this is arguably an ethics of sustainability.

A robust understanding of sustainability is really a question of being a philosophical materialist in the strict sense where matter as energy is the only thing that exists. In *Matter*, Gail Borden and Michael Meredith argue that new fabrication and construction technologies "have severed the equally illusory ties between 'natural,' or so-called inherent properties and architectural applications." (Border & Meredith, 2011) Our only recourse it to treat of matter as a fundamental building block: matter as material, matter-as-human, matter-as-fabrication and in our case, matter-as-energy.

Among all human activities contributing to climate change, the construction of buildings and their operation is the most energy demanding, resource-intensive, and polluting. The building sector touches nearly every industry – from steel, insulation, and caulking to mechanical and electrical equipment, glass, wood, metals, tile, fabrics and paint. Building construction also involves all sectors of the U.S. economy including architecture, planning, design, engineering, banking, manufacturing, construction, wholesale, retail, and distribution (Architecture 2030 Challenge).

Given the size of the building industry's environmental impacts, the professions involved in building design and construction have considerable capacity to reduce national energy consumption, significantly reduce impact on climate change, improve national energy independence, diminish the adverse impact of buildings on the environment, and improve sustainability of our cities and economy.

Nationally, considerable effort has been made to support the design and development of high performance, energy efficient, and more sustainable buildings, including the development of the *Leadership in Energy and Environmental Design* (LEED) system of building performance evaluation and professional accreditations. However, the impact of current sustainable building design standards and practices have been marginal and limited to the practice of a small, but growing stream of exemplary models of sustainable building design.

Examining the success of such "exemplary practices" leads into two common elements; first that achieving sustainable design is closely linked to "integrated Practice" - a type of practice in which various disciplines involved in building design work together to achieve efficiency and synergetic benefits. Extensive research by the National Institute of Building Sciences has shown that collaboration of various professionals at early stages of a building design project produces better designed, more efficient and lower cost buildings (NIBS, 2011).

The importance of integrated practice has been recognized by the American Institute of architects (AIA) as one of the central challenges facing the profession, and one the most important ways to improve building performance, cost and environmental impact. The AIA, in its *AIA 2030 Commitment*, has challenged the profession to achieve the goal of designing Carbon-Neutral (using no Greenhouse Gas emitting energy) buildings in the U.S. (AIA 2030 Commitment). More importantly, the Architecture 2030 Challenge identified Integrated Practice as the primary vehicle to attain this goal.

The second common element in the "exemplary practices" of sustainable design is the utilization of advanced computational and simulation technologies to achieve superior

DOI: 10.5176/2251-3701_2.2.71

building performance. Recent advances in computing technology and simulation algorithms are enabling various professionals to collaborate, visualize, foresee, and modify building performance with relatively high accuracy. Progress in data analysis, modeling and simulation, data visualization, geo-spatial representation and spatial decision support are creating unique opportunities to promote innovative and sustainable practices.

II. Approach

A. Educational Challenge

Improving the architectural practice of sustainable building design and integrated practice starts with a reconsideration of the academic preparation of students. Integrated practice requires providing a holistic view of the building design process as well as an applied understanding of building technology, structural science, construction technology, and environmental systems (lighting, electrical, plumbing, heating, and cooling and ventilation systems. The traditional architectural curriculum based on a schism between "design" and "technology" is inherently in conflict with the principal of integration. Rethinking how we approach sustainable development faces a number of fundamental barriers embedded in our institutional and educational systems and prevents students from developing a holistic and multidisciplinary perspective towards sustainability.

The first barrier is that the building technology curriculum is rarely integrated into the broader architecture curriculum. Architecture design studios are where students learn to apply technical and architectural concepts, but building technology is most often taught outside the studio (Cavanagh & Allen, 2004). When studio and building technology courses are not integrated, valuable opportunities to reinforce and apply technology concepts are squandered, and learning the pivotal importance of technology as a means to drive innovative and creative design is completely missed (Addington, 2003).

The second barrier is that integrated practice requires input of a number of diverse disciplines with broad global perspectives, but many disciplines are increasingly split into specialized and fragmented professional components and knowledge "silos," that fail to communicate and collaborate effectively. These knowledge silos pose significant impediments to attaining a holistic understanding of the broader issues in sustainable building design. Without a concerted effort to utilize novel research and pedagogical approaches exposing students to activities involving people, ideas, and methods these disciplinary boundaries will continue to stand in the way of opportunities for innovative thinking and discovery that could lead to transformational solutions of critical issues.

And finally, the failure to implement integrated computing in the architectural curriculum in an effective way has been problematic. Unfortunately, recent progress in computing technology and its application in the architectural curriculum have made little contribution to reform or enhance education and prepare students for future challenges such as sustainable design. In general, other than a few exemplary cases, advances in digital technologies have largely focused on the formal and representational skills needed to succeed in design. As Renee Cheng states, "The design studio has frequently succumbed to the seduction of new forms or of reinterpreting the established formal compositional principals."(Cheng, 2006) This leaves future professionals unprepared to engage in integrated practice and less likely to participate in the computational and analytical aspects of building design using digital simulation.

B. Theoretical Framework

Though large-scale reform of architectural education is a complex, ongoing national debate; researching effective learning environments that stimulate Integrated Practice is critical to the future of the profession. The paper outlined here describes a project and its theoretical framework designed to prepare architecture students for Integrated Practice. The project "Cyber Learning: Leveraging the cyber-infrastructure to Transform Building Science Education" is a proposal that builds upon the successful completion of a funded project by the US Department of Education, the Fund for Improvement of Post-Secondary Education (FIPSE) in 2007-2011.

The completed project entitled "Building Literacy: the Integration of Building Technology and Design in Architectural Education" produced a software to advance the education of architecture students in climate responsive and ecologically sustainable building design. The project was based on a comprehensive approach to engage students in learning many aspects of building design including structural science, construction methods and environmental systems (lighting, electrical, plumbing, heating, and cooling and ventilation). The core pedagogical principle for developing *Building Literacy* was that a self-directed interactive educational format is critical for engaging students in the process of learning. [1] The new project entitled, Cyber Learning, aims to enhance the interactive learning possibilities of the Building Literacy project by creating a digital game environment.

Building Literacy sponsored by the US Department of Education, the Fund for Improvement of Post-Secondary Education (FIPSE) in 2007, the University of Buffalo and Florida International University.

[1] The software developed under the FIPSE grant was extensively

C. *Learning and the Digital Dialogic Model*

Recent studies show 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 which provide educational materials that are highly interactive, task oriented, and enable students to control the pace of their own learning (Raschke, 2003).

In addition a basic tenet of recent educational reforms and research in learning science is that dialogue (e.g., engaged learning between students and teachers) plays a central role in the construction of useful knowledge (Innes 2007). The dialogic model of learning occurs through collaborative inquiry that helps learners connect ideas and absorb and reflect on information. Although dialogic learning model has always been the core of architectural design studio pedagogy, science and technology education and their integration into design have hardly benefitted from the same pedagogical model. Technology courses often have a much larger number student enrollment in a single class and as a result they are mostly conducted in the lecture format that makes interaction and dialogic learning difficult, if not impossible.

Dialogic learning correlates to "situated learning" as it models very similar behavior in the learning environment. A digital dialogic model uses cyberlearning tools to enhance the dialog between instructor and learner. The salient characteristic of situated learning is that it emphasizes context-based learning and interaction over individual learning experiences (similar to architectural design pedagogy). While it values a cognitive approach to concept development, it emphasizes *social interaction*, *tutoring dialogue* and *interventions* as critical. Key to the concept is the idea of a tutoring dialogue that is the feedback mechanism between a 'learned other' (Pilkington & Mallen, 1996; Levin & Moore, 1977; MacKensie, 1979; Walton, 1984) and the student whereby answers are not given, but the student is stimulated through clarifying, challenging, justifying and hinting to consider various aspects of how they can address any given problem (Mercer & Wegrerif, 1999; Kuhn, Shaw & Felton, 1997)

III. GAME-BASED CYBERLEARNING

Learning conceptual thinking is key to competence development in technology and the sciences (Strelever et al., 2005) and creating effective cyber learning strategies can potentially maximize our ability to expose and promote conceptual learning earlier and more often. There are two components to the problem of developing a cyber-learning strategy. First is the question of the effectiveness of any electronic learning (e- learning or cyber learning) environment to stimulate conceptual or higher-level cognitive learning- and second is if cyber-learning environments can be designed and constructed based on a theory of learning (rather than a closed-loop or fixed learning environment. It is important to recognize that cyber learning started in the 1950s (Ravenscroft, 2001) and in and of itself is not a new approach. However, the use of computer technology to create new models of learning as a basis for developing e-learning environments presents a great challenge. That is, to consider learning theory, technology and context in the design of educational interactions as something that is developed, validated, evaluated and refined rather than 'delivered' (Ravenscroft, 2001).

Fig. 1 Screen shot of the game interface showing the role selection process.

One of the most promising and youngest applications of computer technology for learning is in simulation games. Because games unfold in self-directed and interactive environments, game-based cyber learning offers a unique opportunity for inquiry and on-demand basis learning. Studies have shown promising results from game-based learning and case-based learning (Raschke, 2003). Building upon these studies, the project described below hypothesizes that by engaging the MORPG, students are better motivated to learn and correct misconceptions by themselves and thus make connections between things they already know and new information they are learning; in short, to learn.

A. *Cyber-Learning: A Multi-Player Online Role Playing Game*

The *Cyber Learning* is a project development proposal for a Multi-Player Online Role Playing Game (MORPG) that simulates the building design and construction process based on *Integrated Practice.* The goal of the project is to create an integrative cyberlearning environment, in which architecture students engage in solving complex sustainable design problems as a team. In the game students or "players" assume the role of a professional and form a team of specialists to solve a common building design problem or scenario. Each scenario provides a mission — a collection of scientific, ecologic and economic challenges including, building programming, structural systems and design, climate control systems, energy consumption, and construction methods.

Each player plays the game by making selections, evaluating alternatives based on researching datasets used in the real world accessed through the game environment and developing solutions with his/her team of fellow players. Players negotiate and modify their proposals for the approval of the team in order to advance through the game and construct a building based on the mission objectives. The ultimate goal of playing the game is to complete, assemble, and evaluate a building design for its performance characteristics.

The *Cyber Learning* game software is organized into the following categories: ***User Interface, Learning Modules, Building Experts,*** and ***Building Performance Simulations***.

Beginning a new game requires that one player assume the role of a *Project Manager* — this is a good role for a faculty member or a player with previous experience with the MORPG. The *Project Manger* responds to a series of choices including selecting a level of difficulty (beginner, intermediate, advanced); type of activity (preset scenario or existing project), a site and location (cold, hot and humid, hot and arid or temperate region); and a building type (school, research center, office building, community center, etc.). Based on the information provided, the game engine will estimate the required number of players for each role (i.e. architect, structural engineer, mechanical engineer, and construction engineer), and provide a budget and timeline for project completion.

Acting on this information, the Project Manager invites, recruits, or selects team members from a stored/compiled list. To keep the recruiting process meaningful, player qualifications will be recognized and stated on the list with rankings based on their disciplinary specialty, previous game experience, and performance.

Once the team is in place and the game project objectives listed (the *mission*), the group begins to design, engineer and construct a complete building by navigating through a series of choices. These activities entail investigating building components and their relevant properties; selecting proper elements and systems, evaluating various construction processes, comparing energy consumption features, considering environmental impact (embodied energy, recycled content, toxins); and comparing costs. The selected choices will be stored in a library of tools.

B. Typical Player Experience: Example

Phase One: Research Structural engineering activities in this phase include: 1) review of climatic and site data (wind loads, seismic activity, hurricane activity, etc.), 2) review of structural codes for the particular building type, 3) review of structural systems, materials and connections systems, 3) research of foundation systems for the particular region and site, 4) selecting the most plausible overall system with the help of the "Structural Expert", and 5) submitting the proposal to the team using the dialogue text box.

During this time all the other players are researching in their own disciplinary area and utilizing their own "Expert" to investigate alternatives and submit proposals. For example, the architect investigates various floor plan shapes, building

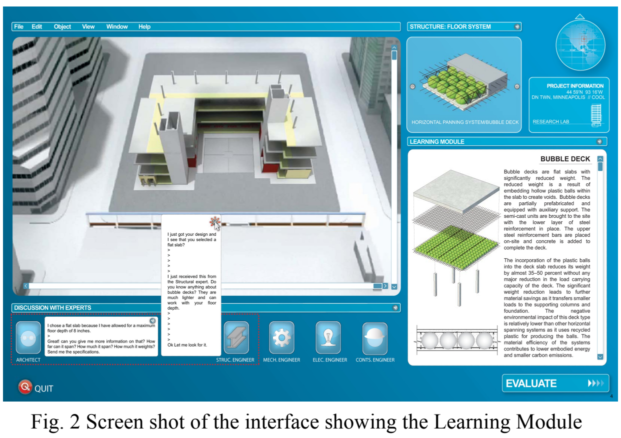

Fig. 2 Screen shot of the interface showing the Learning Module

orientations, façade systems, and so forth. The mechanical engineer investigates the possible passive and active cooling and heating systems appropriate for the building type; and the building systems engineer studies renewable energy possibilities and strategies for improved energy performance.

Phase Two: Planning and Debate Structural engineering activities in this phase include: 1) conducting discussions with the team members to obtain approval of the proposal, 3) highlighting conflicts of game interface showing the "Learning Module" and modeling the building, 2) responding to teams' feedback on the proposal by modifying/changing the proposal or convincing other players to change their proposals to resolve conflicts, 4) resolve conflicts, get approval and submit the proposal.

During this stage players are engaged in documenting and defending their own findings to the entire team. The game engine flags conflicts, and provides a rating of each proposal to help the informed decision making process. The timeline indicates the amount of time remaining in this phase and the penalty associated with missing timely response.

Phase Three: Design and Development Structural engineering activities in this phase include: 1) designing the structural system using proper tools (beam seizer, column seizer, connection maker, and floor system maker), 2) conducting a preliminary structural analysis to determine safety and efficiency suing the preliminary analysis icon, 3) Use the provided analysis as a basis to assign priority levels to the decisions submitted to the team, 4) respond to feedback on any new conflicting decision and, 5) resolving new conflicts prior to submitting final design. All the other players will be given the proper disciplinary set of tools to design their own components. For example the architect with an approved L shaped building form will have a plan layout tool, window making tool, façade making tool and the mechanical engineer who has an approved hybrid cooling systems will have a system sizing tool, specification tool, and placement tool.

In this phase, the game engine compiles an axonometric model of the entire project under progress, showing all the submitted components by various team members. This model will highlight all possible areas of conflict using color-coding and designate the priority level as indicated by the responsible professional.

During this activity the corresponding lessons will automatically open in the secondary window to provide guidance. The "Structural Expert" will be activated to warn of mistakes and issues, highlighting relevant text to study. A structural analysis icon will assist in evaluating building safety and assign proper scores for structural efficiency, resource efficiency, and environmental sustainability.

Phase Four: Construction and Finishing Structural engineering activities in this phase include: 1) investigating construction methods, 2) collaboration with construction engineer to identify an efficient construction plan, 3) sharing constraints and priority levels of constructing the structural systems to the entire team.

In this stage all the other players are investigating construction methods for their particular schemes, for example the architect is investigating the best method to construct a curtain wall system in consultation with the construction engineer. Once the Project Manager submits all the final construction documents, the game engine will load up proper settings and stage the construction of the entire project, beginning with excavation, placement of the foundation, structure and so forth.

Phase Five: Performance Evaluation After completing the construction phase the team runs a number of simulations to measure building performance. This analysis provides computational support for evaluating the architectural configuration, structural and environmental systems, and life cycle cost. In addition, the simulation will provide quantifiable measures for gauging sustainable and innovative choices and strategies employed in the design process and sustainability rating used to evaluate the final design. All evaluations will be quantified and translated to game scores and currency. The game engine will also evaluate the contribution of each individual player to the entire project.

Phase Six: Post Construction Each player's score is permanently logged under the "Players Profile" and can be used as credit for future and more advanced games. Once a player accumulates adequate scores playing a certain role he/she will advance to a higher level. The best performing projects are logged in the "Hall of Fame" of buildings used as case studies or buildings to compete against in future games.

Student "players" assume the role of a professional and form a team of specialists to solve a common building design problem scenario. Each scenario provides a mission — a collection of scientific, ecologic and economic challenges including, but not limited to, engineering design, building systems selection, limited natural resource availability, fuel and energy cost, waste management, and climate change.

Each player plays the game by making selections and evaluating alternatives based on researching datasets used in the real world accessed through the game environment and develops solutions with his/her team of fellow players. Players negotiate and modify their proposals for the approval of the team in order to advance through the game and construct a building based on the mission objectives. The ultimate goal of playing the game is to complete a building design, assemble it, and evaluate its performance characteristics.

Fig. 3 Screen shot of the interface showing the Building Module.

IV. CONCLUSIONS

Current advances in technology and cyberspace capacity coupled with emerging research in science education are creating new opportunities to enhance architectural education in the science and technology areas and prepare students for effective collaboration with other stakeholders in the building industry. The project described in this paper addresses the need for the improvement of science and technology education and proposes that using advances in digital technology to engage students in interactive learning is a necessary step. One of the most promising and youngest applications of computer The project Cyber Learning is an educational game that provides a novel context for learning that facilitates student interaction through dialogue, cooperation and competition aimed to facilitate Integrated Practice while improving science and technology education. The intention is to develop an innovative disciplinary content and delivery system that integrates simulation applications, complex 3D-visualizations, real-time feedback from learner-peers, and a learned instruction simulator into a complete Integrated Practice educational experience. The project builds upon educational research in cognitive, social, and self-directed learning models to develop a complete cyber-learning platform designed for students that based on interdisciplinary and interactive participation.

REFERENCES

[1] AIA2030Commitment, http://www.aia.org/about/initiatives/AIAB079544

[2] Architecture2030Challenge, http://architecture2030.org/2030_challenge/the_2030_challenge

[3] Border, Gail Peter and Meredith (2011), M. *MATTER, Material Processes in Architectural Production*, Routledge, pp. 1

[4] Building Literacy Project, supported by the US Department of Education, the Fund for Improvement of Postsecondary Education from 2007 to 2011. The project was implemented and tested in parallel institution. The project evaluation results showed statistically significant improvement in students learning outcome.

[5] William A. Wulf and George M.C. Fisher (2002), "A Makeover for Engineering Education", *Issues in Science & Technology*.

[6] Addington, M. (2003) Energy, body, building rethinking sustainable design solutions. *Harvard Design Magazine*, n. 18, pp. 1-6

[7] Cheng, Renee (2006), Suggestions for an integrative education, Report on Integrated Practice, p.2

[8] Cavanagh, Ted & Allen, (2004). Architecture, Technology and Education, Journal of Architectural education, 58,n1, P.3

[9] Hong, N. S., Jonassen, D. H., and McGee, S. (2003). "Predictors of well-structured and ill structured problem solving in an astronomy simulation." *Journal of Research in Science Teaching*, Vol. 40, No. 1, pp. 6–33

[10] Innes, Robert B. (2007), "Dialogic Communication in Collaborative Problem Solving Groups", *International Journal for the Scholarship of Teaching and Learning*, Vol. 1, No. 1 Georgia Southern University

[11] Krell, D. ed. (1993), Martin Heidegger "The Question Concerning Technology," *Basic Writings,* Ed. David Krell, and New York: HarperCollins Publishers, 1993, 340. The exact quote is as follows: "Likewise, the essence of technology is by no means anything technological. Thus we shall never experience our relationship to the essence of technology so long as we merely conceive and push forward the technological, put up with it, or evade it. Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it. But we are delivered over to it in the worst possible way when we regard it as something neutral; for this conception of it, 2 to which today we particularly like to do homage, makes us utterly blind to the essence of technology. "

[12] Kuhn, D., Shaw, V. & Felton, M. (1997) Effects of dyadic interaction on argumentative reasoning, *Cognition and Instruction*, 15, pp. 287-315.

[13] Levin, J.A. & Moore, J.A. (1977) Dialogue-Games: Metacommunication Structures for Natural Language Interaction. *Cognitive Science*, 1, pp. 395-420.

[14] MacKensie, J. D. (1979) Question-begging in non-cumulative systems, *Journal of Philosophical Logic*, 8, pp. 117-133.

[15] Mercer, N. & Wegerif, R. (1999) Children's talk and the development of reasoning in the classroom, *British Educational Research Journal*, 25, pp. 95-111.

[16] Merrill, M. D. (2002). First principles of instruction. *Educational Technology, Research and Development*, *50*(3), 43–59. *Performance Improvement, 41*(7), 39–44.

[17] National Institute of Building Science (NIBS), *Moving Forward: In-depth Findings and Recommendations from the Consultative Council*, 2011.

[18] Pilkington, R. M. & Mallen, C. L. (1996) Dialogue games to support reasoning and reflection in diagnostic tasks. Proceedings of European Conference on Artificial Intelligence and Education, Lisbon, Portugal, September 30- October 2, pp. 220-2253-298

[19] Raschke, K (2003). *The digital revolution and the coming of the postmodernist university*, Routledge Palmer, London, p.38.

[20] Ravenscroft, A. (2001) Designing E-learning Interactions in the 21st Century: revisiting and rethinking the role of theory, European Journal of Education, Vol. 36, No. 2, pp. 136-38, 149-50

[21] Van Merriënboer, J. J. G., & Stoyanov, S. (2008). Learners in a changing learning landscape: Reflections from an instructional design perspective. In J. Visser & M. Visser-Valfrey (Eds.), *Learners in a changing learning landscape: Reflections from a dialogue on new roles and expectations* (pp. 69-90). Dordrecht, The Netherlands: Springer.

[22] Walton, D. (1984) Logical Dialogue-Games and Fallacies (published thesis) (Lanham, University Press America).

AUTHOR PROFILE

Winifred E Newman, Ph.D., Associate Professor and Director of Advanced Studies, Florida International University. Areas of specialization: Neuroscience and Architecture, Space Perception, Neuroaesthetics, Mapping and Data Visualization, Technology Education and Histories of Technology and Science.

Shahin Vassigh, Professor and Co-Director Structures and Environmental Technology (SET) Lab, Florida International University. Areas of specialization: Structures and Technology Education, Building Technology, Sustainable Buildings and Environments,

Yimin Zhu, Ph.D., Associate Professor and Graduate Program Director. Areas of specialization: Product and Process Modeling, Information Standardization, IT Applications, Cost Analysis and Control, Construction Productivity and Energy Efficiency.