GREEN CLASSROOM TOOLBOX: APPLICATIONS IN ARCHITECTURAL RESEARCH, TEACHING, AND PRACTICE

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Existing classrooms and educational spaces are problematic. They approximately consume 30 percent of the nation's electricity, generate 35 percent of our waste, use 8 percent of water resources and are responsible for 20 percent of green house gas (GHC) and carbon dioxide emissions. While the new construction sector of the building industry has benefited from green products and building strategies to produce high-performance sustainable schools, existing classrooms have been largely ignored. This is a problem of huge proportions because the amount of occupied classroom space in the US exceeds 20 billion square feet. These existing educational spaces, generally a product of the past 30-50 years, are not energy conscious, and many of the new building products and sustainable strategies are not applicable to existing classroom retrofits. This research project targets this problem by developing evidence-based design guidelines for retrofitting existing educational spaces through the Green Classroom Toolbox (GCRT) project.

The objective of the GCRT project is to develop green design guidelines for retrofitting existing educational spaces based on carbon neutrality metrics and student achievement outcomes. These guidelines were generated from a list of best retrofit practices that were identified by practitioners in a baseline survey and a series of focus groups, in a collaborative effort with academics. The identified best practices were then analyzed for their impact on building energy use and carbon emission using computer simulations. This data was further analyzed together with an extensive meta-analysis of prior studies related to the impacts of the best practices on occupancy health and students' performance. One of the significant goals of this project is to link green retrofit best practices with their energy and carbon emission reductions as well as with their impact on human health and student achievements. The hope is to provide a comprehensive decisions support tool for practitioners and school principals that will help them prioritize and evaluate green classroom retrofit strategies in a holistic way.

This paper gives a synopsis of the project and its application in research and practice. The paper also highlights impacts of this project on future research and practice initiatives. We hope this information would set the stage for future applications and provide a successful model for an evidence-based practice and research in architecture.

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1. Once Upon a Time… An Energy Hog Classroom:

Going green with new schools is a good idea, but what about the 20 billion square feet of existing U.S. public schools, 40 percent of which have 15 million students in poor environmental conditions worse than most prisons? These questions are at the heart of the Green Classroom Toolbox (GCT) Project that received the AIA RFP research award for 2008 (Elzeyadi, in press). The AIA funding was instrumental in supporting the first phase of this project. In that phase, we developed a proof-of-concept application to create comprehensive evidence-based design guidelines for architects and planners to use in their energy retrofits and modernization plans for schools and specifically classrooms. Our findings helped plan classroom retrofits to green aging schools, which are energy and environmentally unconscious. Under the American Recovery and Reinvestment Act of 2009, school districts will have access to federal funding to modernize and green their schools. Our work provides school designers and officials with the needed guidelines to direct this process the right way. It acts as a decision support system.

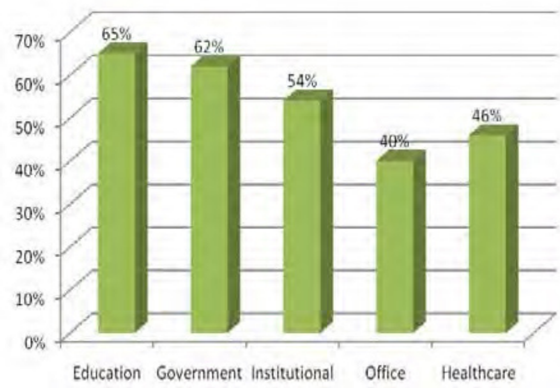

Figure 1: Top five sectors expected to have growth in green construction (source: Green Buildings Smart Market Report, Mc-Graw-Hill Construction, 2007)

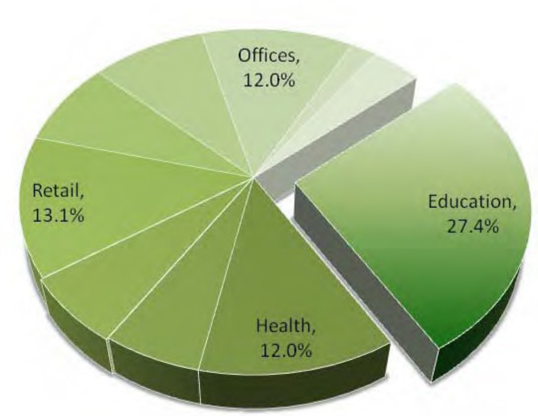

Figure 2: Commercial construction activity by value (source: McGraw-Hill Construction & Analytics, 2007)

The GCT uses a triple bottom line approach that takes into account the health and well-being of students, teachers and staff, operating expenses, and broader environmental impacts. The research gathers information on a range of disciplines including medicine, educational psychology, and engineering. The toolbox includes a checklist of twenty best practices, pared down from a series of meetings in Portland, Salem and Eugene, all in Oregon, where twenty-four representatives of K-12 schools, architects, engineers and facility managers generated 128 ideas. The GCT team surveyed literature on health impacts of going green and then ran simulations on a prototypical elementary school building. In addition to the checklist, the toolbox features a prioritization guide that alsoprovides comparative analyses and a guide that links best practices to findings on health and performance. While you cannotdrastically change poor early design decisions, our analysis shows that some minimal retrofits in the classroom can have drastic impacts.

Currently, there is a great opportunity to impact the construction boom in schools and educational buildings. Building high-performance schools is reported to be the fastest growing sector of the building industry (McGraw-Hill, 2007), with a projected increase of 65% in the next fiveyears (Figure 1). It is expected to capture 27.4% of the commercial construction market (Figure 2), topping the other market sectors in both value and number of projects. Although green schools provide a range of benefits, there is a current gap in information regarding their energy and CO_2 performance, as well as their impact on sick days, operations and maintenance, life cost, insured and uninsured risks, power quality and reliability, state competitiveness, social inequity, and educational enrichment. The lack of evidencebased design guidelines for this building sector could lead to a devastating missed opportunity in directing that building momentum in the most effective way. We hope that this project will make energy hog classrooms history by modernizing them and turning them into sustainable learning environments.

Figure 3: The Green Classroom Toolbox for the redesign of the Charlemagne school KG classrooms [© Elzeyadi, 2009, all rights reserved]

2. Research Implications and Applications: Action Research Approach of GCT as Model For the Future

This interdisciplinary project targeted this research problem by developing actionable green classroom retrofit guidelines. The design and building professions have not established an agenda for organizing, disseminating, and advancing the state of knowledge on how good design is best employed to create long-term economic and social value. Typically, examples of "best practices" provide little evidence or criteria for what make them "best." For this reason, we developed our tools and tested them based on a deductive approach. First, in a collaborative effort between academia and local building professional organizations, we conducted a base-line survey to identify the best school green retrofit scenarios. This effort resulted in a checklist of best practices of classroom retrofits collected from interviews and focus groups with designers, facility managers, and school principals. Second, this list of best practices was systematically evaluated using the triple bottom line scenario. The practices were tested for their energy and carbon effects as well as their impact on occupants' health and well-being.

Applications in Practice & Public Works

Our Green Classroom Toolbox is taking on the task of trying to make others re-think the way classrooms should be designed and managed. We have tested the guidelines on a couple of classroom retrofits in practice for the Charlemagne kindergarten classroom in Eugene, Oregon (Figure 3) as well as for Portland Public Schools (PPS), office of school modernization in Portland, Oregon. In addition, we are now exploring opportunities for the development of the second phase of the project with funding from PPS. The second phase of the project will expand the current guidelines to five different school typologies for three additional climate zones.

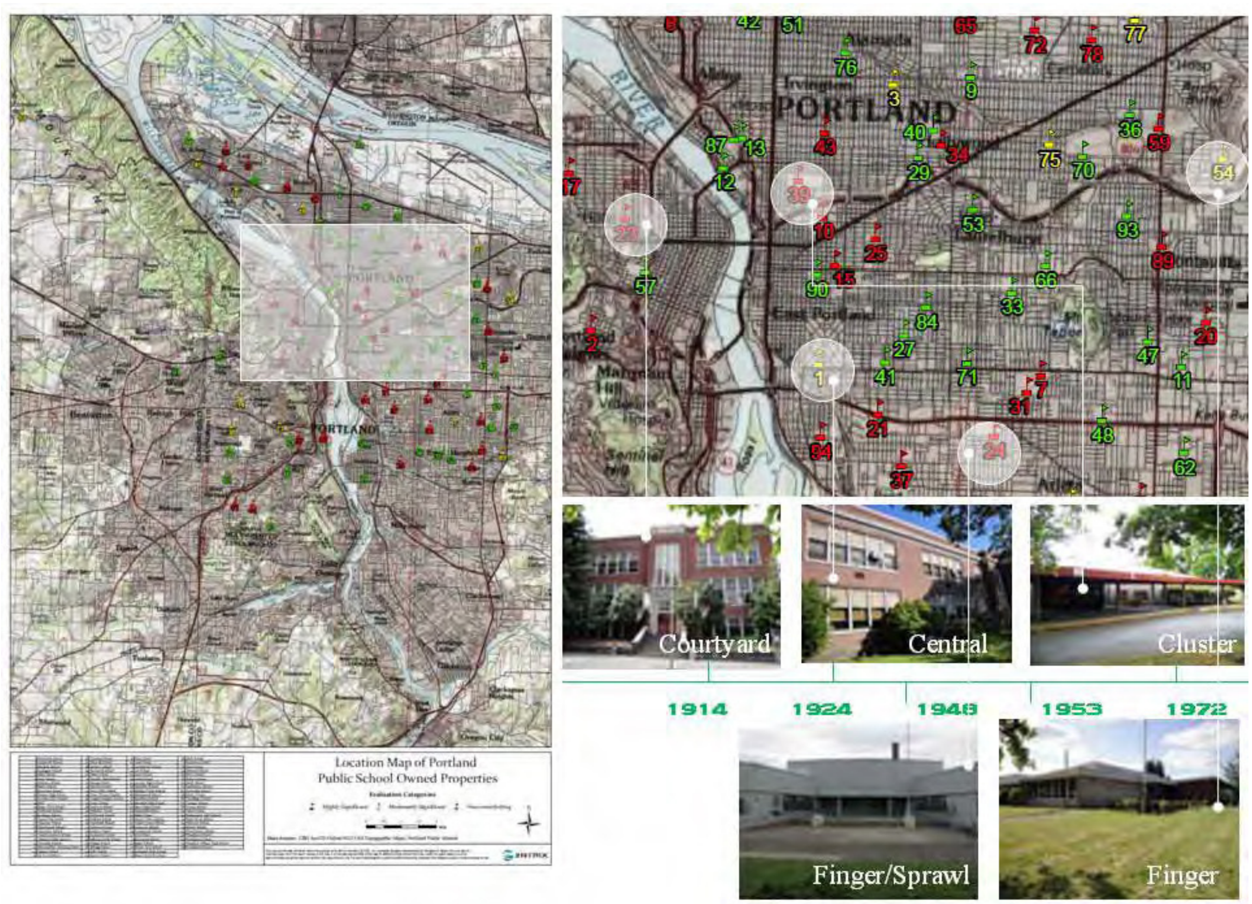

Figure 4: The GCT for investigating retrofit strategies for five Portland Public Schools projects

Figure 5: Daylighting participatory design workshops for the Charlemagne school KG classrooms

With eighty-nine schools in the PPS inventory (Figure 4), our team is analyzing five representative schools. The five schools represent main prototypes in the district, which are: Jason Lee Elementary (finger typology), The Metropolitan Learning Center (multi-story typology), Creston Elementary School (sprawl typology), Abernathy Elementary School (central typology), and Holladay School (cluster typology). The Green Classroom Toolbox is also interested in engaging K-12 students in the architectural modernization of classrooms. We are expanding the project methodology to include participatory design techniques to engage students and teachers in green architecture and the generation of best practices. We are also conducting workshops with PPS to work with classrooms and allow students and staff to use the Green Classroom Toolbox guidelines as textbook for learning about sustainable architecture and the environment. By modifying carbon-guzzlers such as lighting and heating, we are posing questions to students as a learning tool of how negative environmental decisions can affect them, and then showing them the impacts of their suggestions on the environment using simulation models in hands-on learning sessions. Through this “green curriculum” we hope to involve k-12 students and make the classroom a textbook for learning (Figure 5).

Applications in Teaching

In the fall of 2009, we applied and tested the Green Classroom Toolbox (GCT) guidelines and research methodology in both design studios and an advanced research seminar on high performance buildings. Students in the studio tested the design guidelines for actual school retrofit projects. The studio used an innovative research-based design model engaging students in research, design, and verification tasks simultaneously as a way to test the model and train students to use research activities as part of their conceptual design explorations in studio. In the seminar, the students adopted the GCT research methods to critically investigate the role of performance and evaluation in the design process of high-performance schools. They theoretically examined the relationship between technology and architecture throughout the assessment and evaluation phases of a project. The seminar focused this investigation on the post-occupancy evaluation and building-in-use performance assessment of a number of LEED schools in the Pacific Northwest. The seminar culminated in a research practicum final project, applying the seminar knowledge to a detailed building-in-use assessment and post-occupancy performance evaluation of the LEED gold Rosa Parks Elementary school in Portland, Oregon.

The following goals and objectives guided the application of the GCT project in teaching:

- Develop tools that will analyze the impact of separate green retrofit strategies while also acknowledging the larger effect of the interrelationship among these strategies on the building and its occupants' performance.
- Identify not only design retrofit strategies and best practices but also operations and maintenance ones, which have typically been neglected by previous design guidelines.
- Provide evidence-based tools that have clearly specified attributes and practices.
- Classify the researched best practices and strategies based on categories that are relevant to building professionals. These are: (1) Energy & Atmosphere (Envelope, Lighting, HVAC, and Ventilation); (2) Materials and Resources (Site construction, Structural and non-structural); (3) Environmental Quality (IAQ, Comfort, and Acoustics); (4) Sustainable Sites (Density, Light Pollution, and Transportation), and (5) Water and Waste (Building fixtures, Landscaping, Recycling).

The success of both studio and seminar have been outstanding and are established to occur on a yearly basis as part of the regular course offering at the School of Architecture and Allied Arts, the University of Oregon.

Applications in Research & Future Projects

The success of this project has been a catalyst for the following funded research projects and awards:

1. Oregon Schools Energy Modernization (OSEM): Evidence-based design guidelines for classroom modernization and retrofits for Oregon – Funded by Portland public Schools and School of Architecture and Allied Arts.
2. Green Schools in Gray Zones: Assessing Transportation, Land Use, Indoor Environmental Quality Impacts in LEED and Non-LEED Schools in Oregon – Funded by Oregon Transportation Research and Education Consortium (OTREC).
3. Green Affordable Teaching/Learning Environments (GATE): Developing Prototypes and Pedagogy for Green Classrooms Learning – Funded by MulvannyG2 Architects, Bellevue, Washington.
4. Benchmarking and Evaluation of LEED Schools (BELS): Seed funds from Faculty Summer Research Award & Office of the Provost for Research and Faculty Development, University of Oregon.

Figure 6: Teaching application of the Green Classroom Toolbox in architectural studio for the redesign of Jason Lee Elementary School in Portland, Oregon [Design by students Caitlin Gilman and Anna Friend]

3. Anatomy of Evidence-based Design Guidelines: Redefining Research Standards and Translation to Practice

The challenges of creating evidence-based design guidelines and best practices are threefold. First, identifying best practices based on expert feedback can lead to mixed and contradictory lists. This is due to the fact that experts usually rely on their own anecdotal experience, which lacks verification and external validity. Second, computer simulations of energy use and carbon emissions have limitations in modeling certain scenarios and practices, especially passive energy conserving strategies. Third, given the complex relationship between people and buildings, it is hard to isolate the impact of a specific design strategy on human performance in a cause-effect relationship. The project has been developed with these limitations and barriers in mind. The evidence-based design guidelines were developed following a rigorous scientific approach to test and quantify the impacts of retrofit design strategies on the triple bottom line of people, planet, and profit.

The project sets new standards for the application and dissemination of evidence-based design guidelines in many ways. The tools developed were made accessible to architects and school designers as well as school principals so as to help them make informed decisions about green retrofitting their classrooms. To that end, we have developed three main decision support tools. The first is an evaluated and verified checklist of best practices based on inputs form focus groups and interviews of twenty-four school building designers, facility managers, and principals. The second tool is a prioritization guide that provides some comparative analysis and ranks the best practices based on their impact on building energy consumption and carbon emissions. The third tool is a meta-analysis guide that links these best practices to their impact on occupant health and performance in schools. These tools provide supporting documentation for the triple bottom line impacts of the green retrofits best practices on the planet (emissions), people (health and performance), and profit (energy savings). It should be noted that the tools were developed based on opinions, contexts, and climates of the Pacific Northwest and a specific school typology. The future phases of the project mentioned earlier are intended to replicate this study to other contexts, climates, and classroom/school typologies on a national level. We hope this information will aid school designers, facility managers, and principals in making informed decisions for retrofitting existing classrooms to meet the Architecture 2030 challenge.

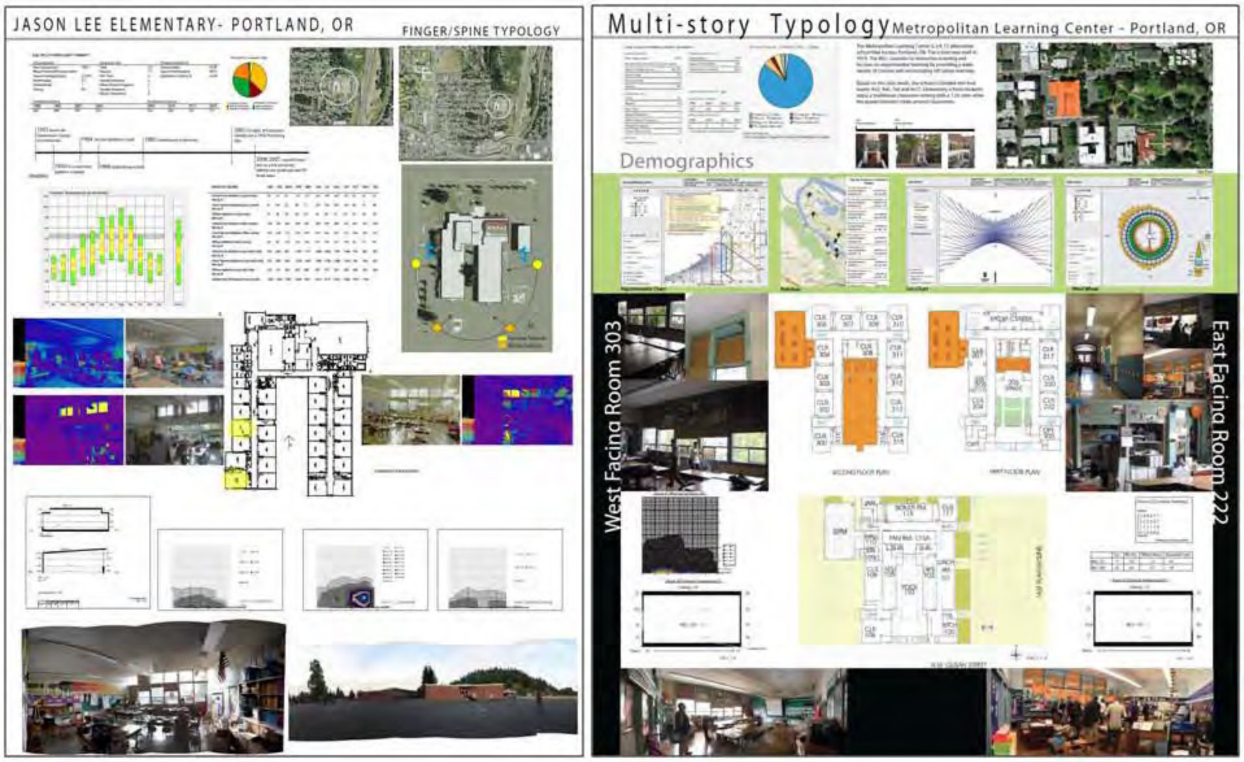

Figure 7: Analysis boards for benchmarking environmental conditions in existing schools

Acknowledgements

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Selected Publications and Media Coverage

1. Elzeyadi, I. (in press). Green Classroom Retrofit Toolbox (GCRT): Evidence-Based Design Guidelines to Adapt K-12 School Facilities for Climate Change. AIA Report on University Research 2008. Washington, DC: American Institute of Architects, AIA Knowledge Board.

2. Elzeyadi, I. (2009). Retro_Fit: Greening educational facilities for carbon neutrality and students' performance. In: ARCC 2009, ARCC 2009 - Leadership in Architectural Research, between academia and the profession, San Antonio, TX, 15-18 April 2009.

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