form•Z in Digital Design
at the University of Waterloo

by Thomas Seebohm and John Cirka

Foundation Course

Currently, we use **form•Z** to build a strong foundation in three-dimensional, digital design and modeling with a required course in the second term of the first year in the four-year undergraduate, pre-professional program. This year we increased the emphasis on design eliminating a project, without a design component, that required modeling, interpretation and presentation of an existing house, from the recent past, featuring design excellence. As in previous years, the final term project that was an entry to the 2007 Steel Structures Education Foundation Design Competition. In addition, there were exercises intended, in each case, not only to impart basic modeling skills, but also to facilitate design skills using three-dimensional modeling.

New this year is an adaptation of John Hejduk's nine square plan design exercise adapted to three dimensions by adding two floors to make a three-dimensional grid of 27 cells. The intention of this first exercise was to ease the students into three-dimensional modeling with transformation operations only: primarily move, and navigating around the virtual model/ virtual space. Other constraints such as snapping were also included. Additionally, they were asked to output using traditional architectural drawing representations: axonometric (plan oblique), orthogonal views, cavalier projections (elevation oblique), which **form•Z** can provide (and no other three-dimensional modeling package as far as we know).

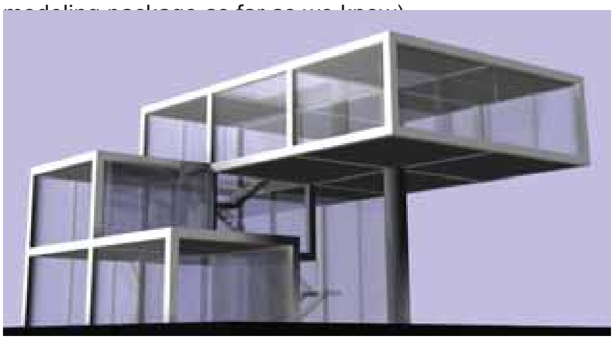


Figure 1: 3D Nine square grid design, Richard Kim.

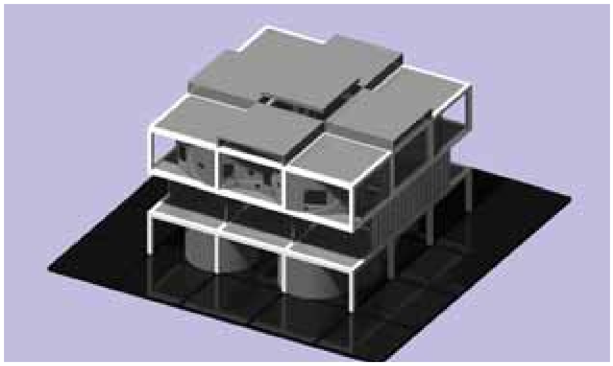


Figure 2: 3D Nine square grid design, Richard Lam.

At the same time, this exercise is a design exercise in the spirit of Hejduk's original exercise introducing students to the idea of an abstract architectural language of elements, relationships between the elements and the grid with powerful precedents in architectural discourse such as the famous essay by Rowe on the "Mathematics of the Ideal Villa" (Rowe, 1995). Although, as has since been remarked, this exercise deemphasizes material and program, these omissions can be justified in considering the limited time available in an introductory course (Love, 2003). That is not to say that other elements such as furnishings, lighting and materials cannot be added in later exercises. Some examples of the nine square grids are shown in Figures 1-3. Somewhat later in the course another exercise focuses on detailed design of a structural steel connection thereby addressing the structural issue also glossed over in the nine square grid exercise. Figures 4-6 show some examples.

Some submissions for the final term project are shown in Figures 7-10. At the level of three-dimensional modeling skills, the intention of the course is that the principles of three-dimensional modeling and dexterity in their use are sufficiently strengthened with the design exercises and the final project that the students will readily be able to learn other three-dimensional modeling software or use what they have learned to advantage on their co-op work terms that all Waterloo architectures students participate in every four months.

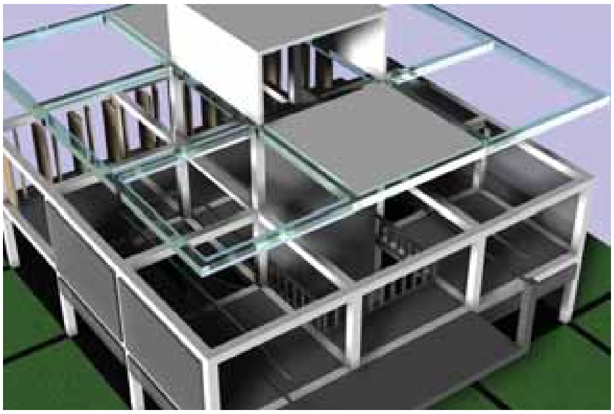


Figure 3: 3D Nine square grid design, Chris Mosiadz.

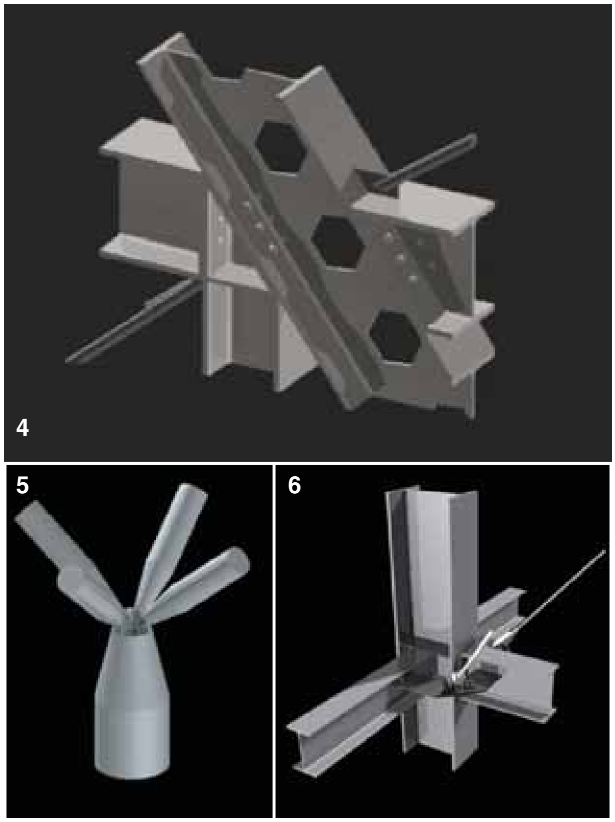
Beyond the Foundation

We realize that this one required course, though a strong foundation, is no longer sufficient to adequately train students in the diversity of digital tools that are available and new design methodologies that are being developed in academia and practice. On the one hand there is a need to simply introduce students to more software including presentation software such as advanced Photoshop, Illustrator and InDesign and other three-dimensional modeling software and rendering software, while on the other, there is a need to advance the theoretical underpinnings of digital design and new methods of design.

What are these theoretical underpinnings? As will be explored further below, fundamental is the understanding that digital design is a process of human-computer interaction based on an understanding of the human design process and how digital processes can support and expand design capability. Also fundamental is that digital design is a three-dimensional process involving the assembly of three-dimensional components rather than drawing two-dimensional representations such as plan, section and elevation. Digital design is an iterative process (as is the traditional manual process) where alternatives are generated and selection is made of the most appropriate design. Digital design opens the possibility to more complex geometrical design and hence the principles of geometric constructions, of proportion, and of constructing curvilinear shapes, including the use of scripting to form a basis of digital design. Digital design allows selection of the most appropriate design alternatives by testing with simulation software for such aspects such as lighting and energy consumption.

The solution to the dilemma of the seemingly conflicting demands to introduce more software packages and to teach the underpinnings of design is to teach both in one course using various design exercises. This solution also avoids the problem that teaching the use of new software packages is generally not considered adequate subject matter for a university course (just as learning a specific programming language is not in a computer science curriculum) because it is vendor specific and not focused on general principles underlying the software. Some examples illustrating the principles underlying three-dimensional modeling software are: polygonal model representation in terms of object, faces, edges and vertices; basic modify operations such as move, copy, mirror; solid modeling with Boolean operations; the concept of nested symbols, instances or blocks; and curvilinear modeling with Non-Uniform Rational B-Spline (NURBS) surfaces and other surfaces.

Given that digital design tools, particularly as they become more sophisticated, should be seen as untrained design assistants who have to have everything explained to them, it is clear that the more we ask these assistants to become involved in the design process the more we have to be able to articulate what the process is. The problem, therefore, is that design as currently taught in design studios is based on critiques of the final product rather than on the process. We must therefore learn to make the design process more explicit in studio teaching in order to provide the theoretical underpinnings of digital design and new methods of design.



Figures 4-6: Structural steel details, by (4) Chris Mosiadz, (5) Shane Neill, and (6) Eric Tai.

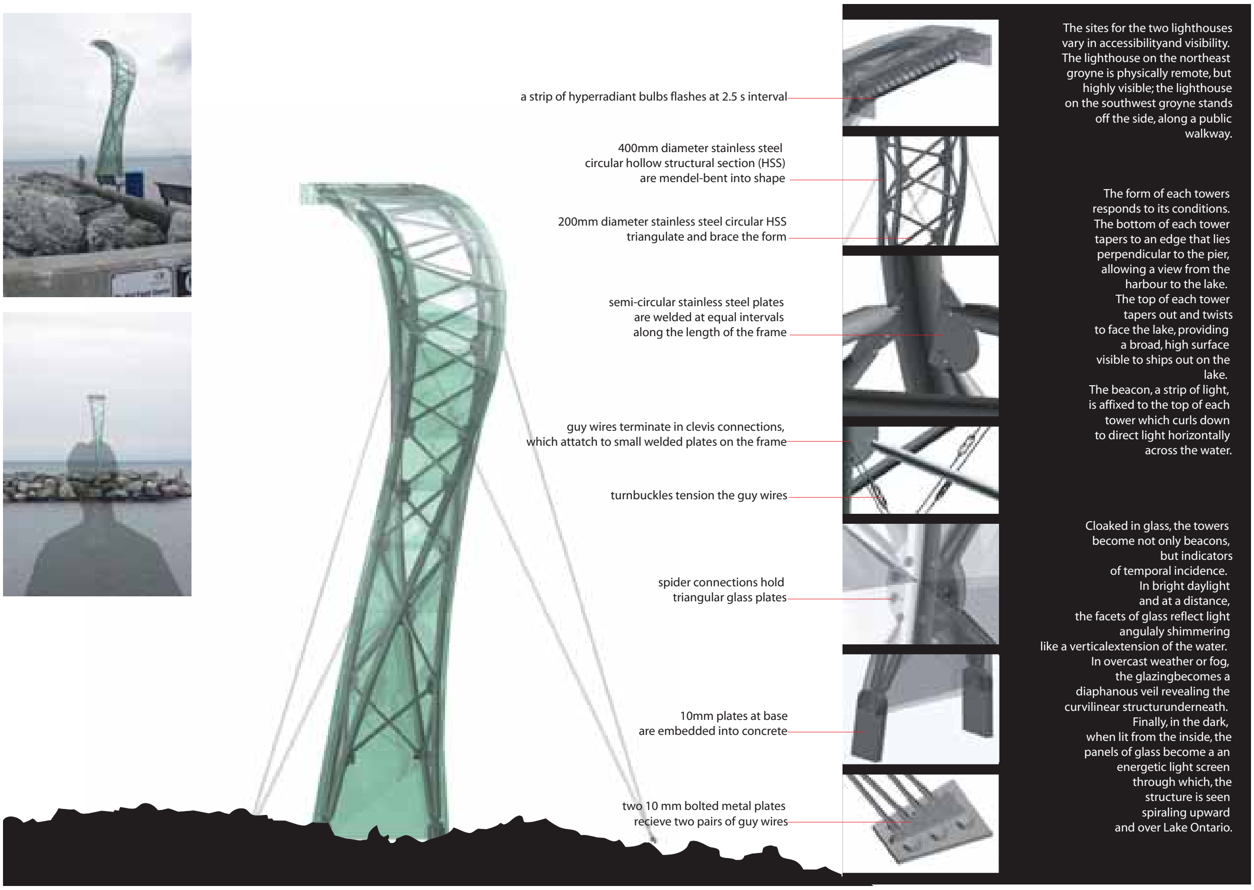


Figure 7: Final Tower Project, Neill, Bragg and Manchester.

Three areas of design teaching that can be made more explicit and supported by digital processes are: visual reasoning including the iterative design process, characterized so well by Archea as puzzlemaking in his memorable paper entitled: “Puzzlemaking: What architects do when no one is looking” (Archea, 1986, Seebohm 2007); learning of domain design content; and conceptual reasoning leading from design issues (requirements) through design concepts to the form of a design (Oxman, 1999, 2003). To clarify what each of these three areas are, consider each in turn. By describing visual reasoning as puzzle-making, what Archea essentially said is that architects proceed in a trial and error fashion, where they behave as if they are designing a puzzle in which neither the puzzle pieces (architectural components) nor the way the puzzle pieces are to fit together (the combinatorial rules describing the formal design language) are known. Architects behave this way at the outset of a design process because they do not know what solutions they are seeking, given that architectural design problems are not completely defined and allow many possible solutions. The search is for a puzzle that will have desirable effects and meets design requirements. Learning design domain content includes knowledge pertaining to the building type being designed and its context. For example, for multiple-unit housing design there are housing typologies, unit typologies, entrance lobby typologies, fire exiting requirements, social issues, sustainability issues and structural design considerations. In addition, domain content should include much knowledge that is often considered inexpressible and left to intuition but of which much can be stated explicitly and tested as Christopher Alexander has shown with “A Pattern Language” (Alexander, 1977).

Conceptual reasoning leading from design issues though design concepts and finally design form focuses on the linkage between “visual reasoning and conceptual processes” (Oxman, 1999a). These processes can be made explicit and knowable by constructing knowledge structures (diagrams of nodes and links showing relationships between issues, concepts and forms and the many stages in-between) to make explicit “the structures of knowledge employed in design thinking” (Oxman, 1999b). Oxman and collaborators are exploring digital tools to support the learning and use of knowledge structures in design.

In addition to making design processes more explicit in design teaching in order to make it possible to support these processes with digital tools currently used, being developed or yet to be invented, there are also explicit new methods that are enabled when designing digitally in three-dimensions. Among these methods is a current flourishing of parametric design alone or in combination with scripting that promises to dramatically extend the capabilities of the designer.

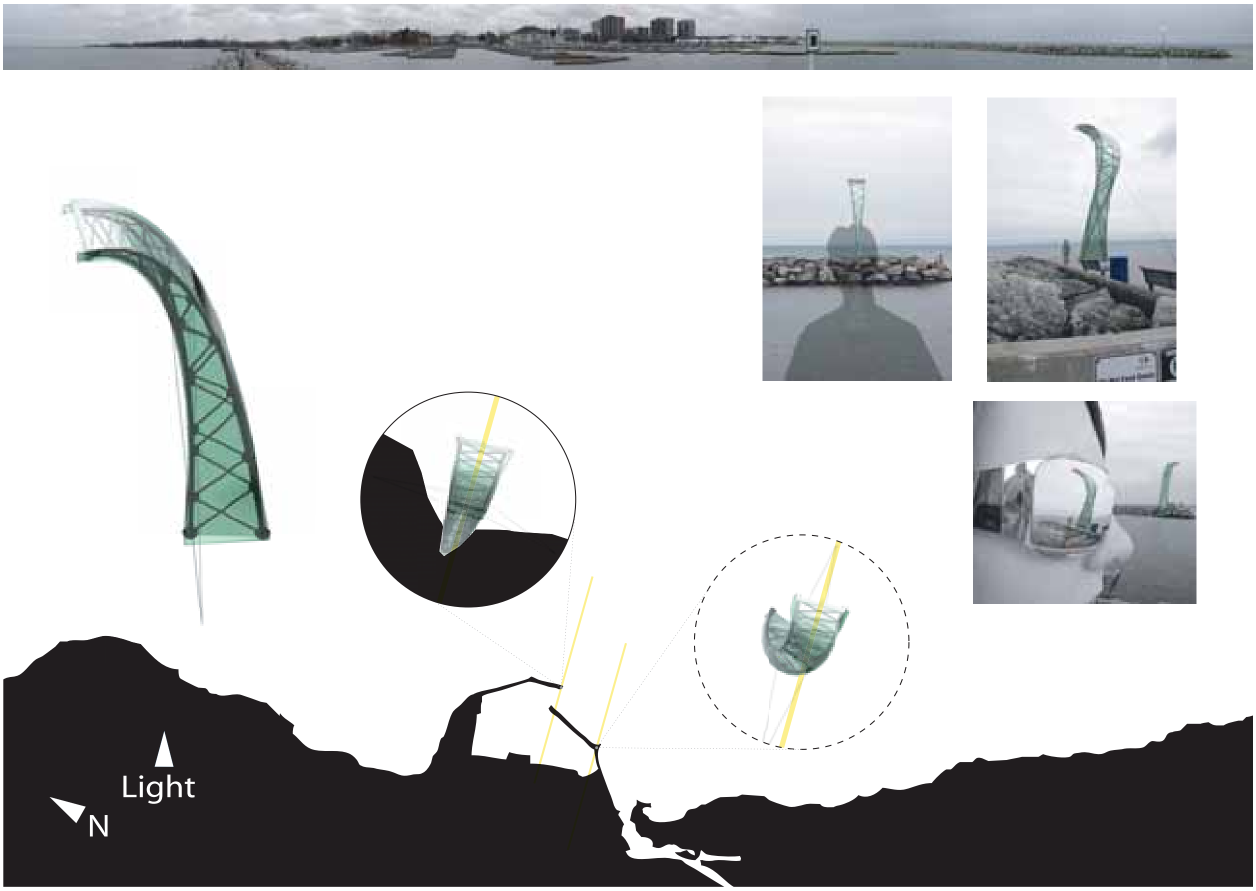


Figure 8: Final Tower Project, Neill, Bragg and Manchester.

Recent explorations in parametric design in the area of urban design by the Berlage Institute are particularly convincing (Berlage, 2007) while Generative Components from Bentley has been used to make systematic inroads on parametric curvilinear design with an innovative teaching approach based on snippets of scripts documented as patterns that are archived as web pages created with Wiki (a server program that allows users to collaborate in creating web content) with clearly stated objectives that others can learn from by adapting the scripts to their uses (Woodbury, 2007, Qian, 2007).

A Course Building on the Foundation

To extend the computing skills of all architecture students as well as going part way to providing a more explicit theoretical basis, we offer an elective course, Digital Design, that will soon become a required course (Seebohm, 2007). This course capitalizes on the strengths of digital tools for which there are no traditional hand-drawn equivalents such as an iterative, three-dimensional design process, curvilinear design and simulation of lighting performance. Moreover, the course provides digital methods that enhance traditional design approaches as in the use of color, proportion, and the use of grids.

While **form•Z** forms part of this course including providing experience in advanced curvilinear design, other software packages are also used to extend digital design experience. Some examples of other software packages and the design skills they can be used to teach are: Sketchup for quick preliminary design exploration, Carrara for fast global illumination making possible lighting studies of interiors including color studies; Ecotect in combination with Radiance for more accurate quantitative and qualitative lighting design studies of interiors; and ArchiCAD for an introduction to Building Information Modeling and its use in design development (not just construction documentation).

Conclusion

To summarize, **form•Z** is currently the foundation upon which our digital design teaching is based, but our digital design teaching is being extended by other software to complement the strengths of **form•Z**. That is, **form•Z** must now be seen in a larger evolving context of digital tools and methods. The reason **form•Z** provides such a good foundation is that it allows one to teach all the principles underlying three-dimensional modeling noted earlier (polygonal structure of objects in terms of faces, edges and vertices, solid modeling with Boolean operations, hierarchical symbols etc.), as well as rendering principles including the concept of shaders and even scripting.

Figure 9: Final Tower Project, Dong and Dabov.

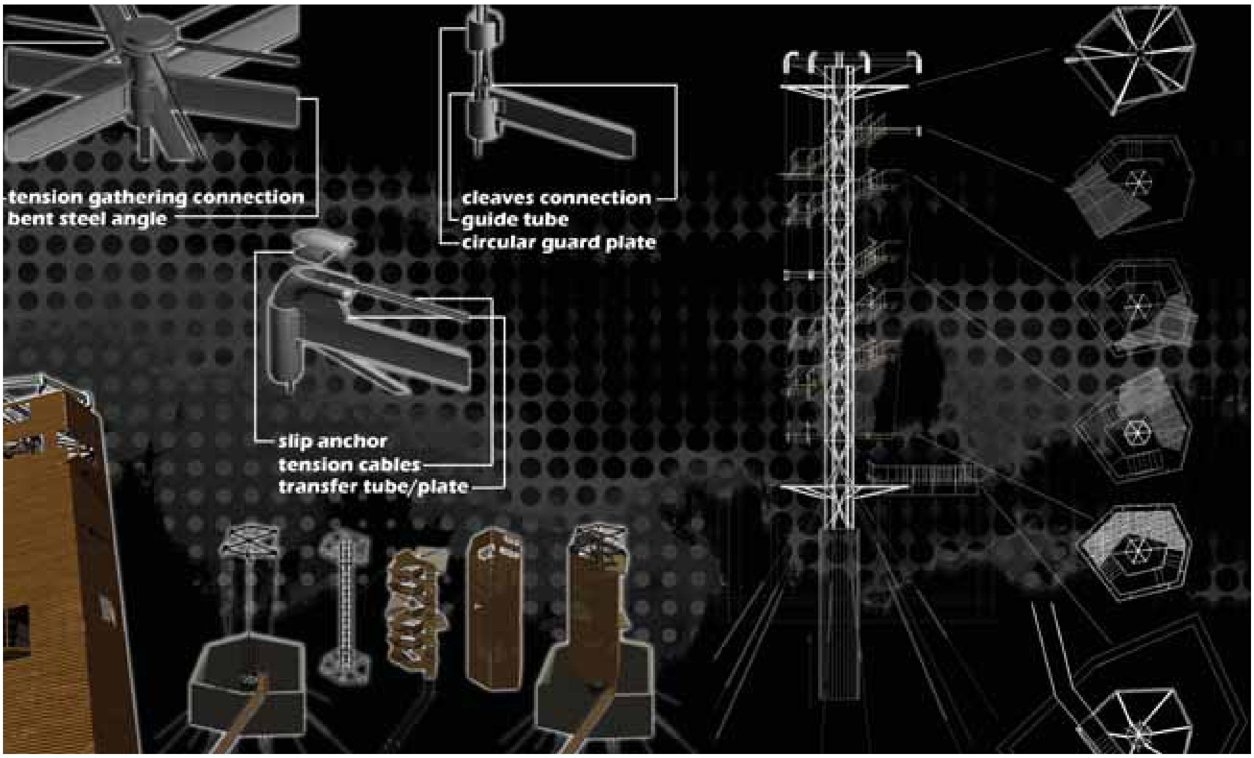


Figure 10: Final Tower Project, Dong and Dabov.

While expanding our teaching, we are formulating a theoretical armature to structure this teaching that will allow incorporation of future developments in digital design software. In this paper we have sketched out the theoretical principles in three groups. The first group consists of the principles underlying digital design, namely that digital design is a process of human-computer interaction, that digital design is primarily an iterative, three-dimensional process, that digital design is founded on rigorous geometric principles allowing complex geometric forms, that digital design allows design to be tested in many ways not possible otherwise and that it makes possible the generation of designs with scripting charting completely new territory. The second group concerns the three areas of the design process that need to be made more explicit to allow support by digital assistants, namely visual reasoning, acquisition of domain knowledge and the linking of conceptual and visual reasoning by the process of issue-concept-form (ICF) pioneered by Oxman. The third group is concerned with the principles underlying current digital design software. As this mostly concerns the use of three-dimensional modeling and simulation software, it consists of the principles underlying three-dimensional modeling software as embodied in **form•Z** and of various types of simulation software (energy, lighting, acoustics, structure etc.). To this third group one should add the principles of computer programming as the foundation for scripting in the different scripting languages offered by various three-dimensional modeling programs.

As a conclusion regarding whether of not the foundation course with **form•Z** can be considered a success, we are pleased to point out that this year's edition of the course led to an award of excellence and an award of merit in the steel tower design competition with which we started this paper, not to mention similar awards in previous years.

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Thomas Seebohm's research interests involve digital technology to design a more holistically conceived architecture and urban environment as is necessary for a more sustainable future. His current research foci are 1) digital architectural design, including digital design in academic studios and practice 2) digital lighting design using physically accurate lighting simulation and rendering software 3) rule-based form generation 4) double shell tensegrity structures including their form generation, stability, visual qualities (when supporting light filtering panels) 5) digital urban design with a special interest in the use of 3D, real time, virtual city models for designing, sustainable, livable cities with community participation. Given the importance of natural lighting in sustainable architecture, Thomas Seebohm's current focus is on designing sustainable buildings and cities using digital energy simulation software taking as input 3D digital representations of buildings and urban fabrics. Dr. Seebohm is a registered architect and professional engineer.

John Cirka is an Assistant Professor in the Department of Architectural Science, Ryerson University. He graduated from Carleton University with a B. Arch. and from Columbia University with an M.Sc. Arch. During more than two decades in architectural practice, John advanced architectural design production with the introduction of digital technologies. He has won awards for his design visualization work. His areas of teaching include digital design theory and practice, history and theory of architecture, and materiality and detail design. John's areas of research include advanced digital design techniques, building simulation and time-based studies. Of particular interest is the intersection of complex geometries, phenomena and temporal experience, and the materiality and methods of building. He is currently conducting research for his dissertation in architecture and philosophy.