Capabilities and Limitations of Autodesk Revit in a Construction Technology Course

Mike Christenson
University of Minnesota

Introduction

This paper describes the introduction of Autodesk Revit within a construction technology course, co-instructed by this paper's author, and offered to first-year professional M. Arch. students at the University of Minnesota in spring semester 2006.

Description of the Course

ARCH 5512 (Building Methods in Architecture) is a required three-credit course in the second semester of the first year of the University of Minnesota's M. Arch. professional degree program. The primary objective of the course is to elucidate connections between idea and construction, particularly as these connections are made visible through the production of large-scale detail drawings. ARCH 5512 is preceded in the first semester by ARCH 5511, which focuses on large-scale construction systems.

ARCH 5372 (Computer Methods II) is also a required course in the second semester of the first year. ARCH 5372 is a one-credit pass-fail course intended to introduce students to relationships between design and digital technology. In previous years, this course was integrated with design studio, or offered independently in a workshop format.

In spring 2006, the two courses (ARCH 5512 and ARCH 5372) were integrated into a single course with a common meeting time and place. The resulting course was co-taught by this paper's author, Mike Christenson, and by Renee Cheng, the Head of the Architecture Department at the University of Minnesota. Christenson wrote and delivered lectures based on the course text, and provided in-class instruction in Revit; Cheng wrote and delivered lectures on illustrative case studies presented at the beginning of the semester.

The combined course enrolled 50 students in spring 2006. The course met twice a week (on Wednesday and Friday mornings) for a total of approximately three contact hours per week. The typical course meeting consisted of a lecture delivered by one of the two instructors. On four occasions in the semester, this typical schedule was displaced in favor of in-class small-group reading discussions led concurrently by the three graduate assistants.

Students were advised at the beginning of the semester that they should expect to spend an average of six hours of outside-of-class work per week to receive a passing grade. The course had three graduate teaching assistants, one of whom was concurrently enrolled in an upper-level design studio engaged in the use of Autodesk Revit.

In addition to the lectures which consumed most of the semester contact hours, the course engaged several parallel tracks of instruction, including assigned readings, a site observation project conducted in groups, and an individual detailing project (which is the primary subject of this paper).

The assigned article and book-excerpt readings amplified issues relating to the construction site project and to relationships between the act of detailing and other aspects of design and construction. The construction site project required students to jointly observe progress at a local site for the duration of the semester. At the conclusion of the course, each group was required to produce and submit for evaluation a binder consisting of field reports, images, and a report tracking the fabrication and installation of a specific building element (such as a precast concrete ornament).

A series of cumulative exercises, requiring the use of Autodesk Revit, provided practical experience in applying lessons learned through lectures and readings, as well as a practical introduction to the use of the software. Spring 2006 was the first time in which this series of exercises was offered to students.

These parallel tracks of instruction were not strongly integrated throughout the semester. Rather, students were held responsible for identifying and acting upon connections between the various tracks. For example, students could bring issues introduced through case studies to bear upon the production of the final construction site project report. The final exam and an accompanying practice exam with annotated solutions were comprehensive and explicitly required students to draw upon knowledge from each of the various tracks.

The course used Edward Allen's *Architectural Detailing: Function, Constructibility, Aesthetics* as its primary text. Allen's text is not proscriptive. Rather, the text proposes that the act of detailing is (and has historically been) guided by patterns of assembly and of practice. In presenting Allen's text to the students through lectures, Christenson chose to classify the patterns in Allen's book either as "detailing patterns" which relate to the assembly of materials, or as "patterns of practice" which refer to general standards for professional operation.

Revit as a Medium

Revit is building information modeling (BIM) software produced by Autodesk. Its similarity to software such as AutoCAD or SketchUp exists in its ability to construct a simulated three-dimensional model of a building. But while AutoCAD and SketchUp stop at simulating the geometry of a building, Revit allows elements within a building model to be parametrically linked: the components of such a model are defined and characterized by adjustable parameters.

This has several implications for design and digital modeling. First, it means that in a Revit model, a change to the position or extent of a building element will automatically update other elements to which it is linked. For example, raising the roof of a building in the model will automatically increase the height of walls whose height is parametrically linked to the underside of the roof. Or, moving a wall in the model will automatically adjust the lengths of other walls whose endpoints are linked to the first wall. Similarly, changing the location of a window in an elevation view will update the appropriate plan; changing the height of a floor in a section view will update the appropriate building elevations, and so on.

Secondly, *families* of similar elements can be defined in Revit, such that changing a component within the family will automatically change instances of that family throughout the model. For example, a single family of differently-sized windows can be defined, each sharing a common trim design and mullion profile. A change at the family level to the trim design will automatically update all windows in the project based on this family, regardless of their size.

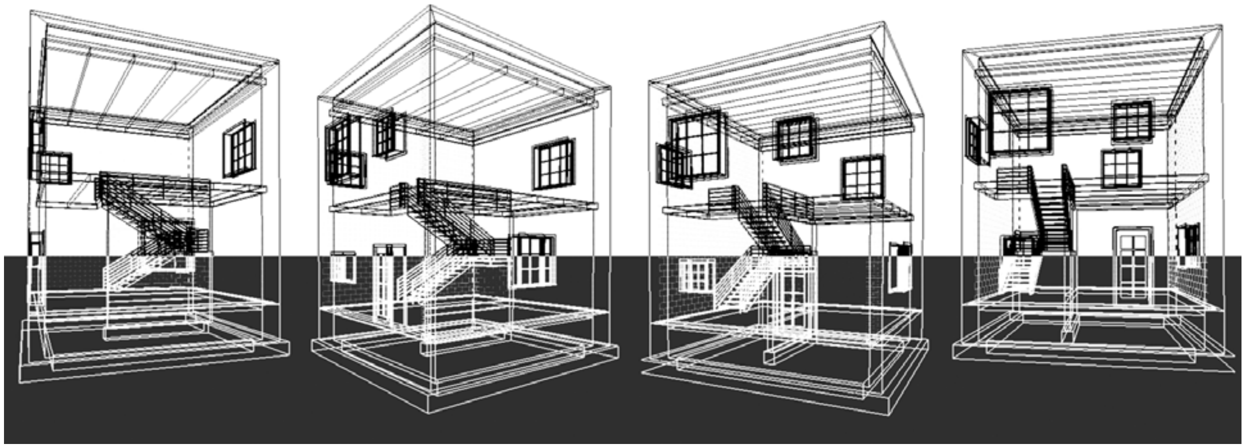

Figure 1. Completed Revit model (Student: R. Vroman).

Unlike most of the software with which incoming students were likely to be familiar (e. g. AutoCAD, Photoshop, perhaps also InDesign or Illustrator), Revit does not use layers. Instead, Revit models are organized categorically (by family and by type), and by *levels* (which correspond to datum lines within the building model, such as floor levels or window sills).

Clearly, the act of constructing a parametric building model transcends in complexity the act of constructing a three-dimensional model as in SketchUp or AutoCAD. Revit depends, as these other applications also do, upon a designer's ability to visualize and work within an on-screen simulated three-dimensional environment. But, the act of creating a parametric building model in Revit requires that a designer be able to intelligently define relationships between and within building elements. It is also true that the successful user of Revit, in addition to understanding how the software works, must understand construction technology sufficiently well in order to intelligently define such relationships.

The use of Revit in the course

Because of their experience in the prerequisite construction course taken in the immediately preceding semester, incoming students were expected to possess fundamental knowledge about typical construction assemblies. But, the students were not assumed to have any experience in digital three-dimensional modeling software (although several students did in fact have such experience, gained in undergraduate courses or in a professional workplace).

In-class Revit training consisted of two short workshops and question-answer sessions. At the first of these two workshops, students received a handout with annotated step-by-step instructions for the digital modeling of a small structure similar to the structure required for completion in class. The training was provided subject to a stated understanding that it would not lead to "mastery" of the software, but would instead provide sufficient exposure to the software to make it useful to the students in a fundamental way: that is, enough to permit each of them to construct a straightforward digital model of a small structure, and to subsequently modify the model and its associated details in response to a series of statements provided through five exercises.

The five exercises, of which the first three were grouped into a single submittal, tested the applicability of Revit to the act of modeling construction, and specifically to the act of detail production. The exercises were structured to simulate the act of producing a mini-set of construction documents for a simple rectangular building (Fig. 1), using a system with which students were generally familiar from the previous semester's course (brick veneer on CMU backup). While each student was required to construct their model in Revit, the mode of production for detail drawings was deliberately left open in all but one of the assignments, in which Revit was required for all aspects of production including detail drawings. In the assignments which left the mode of production open, most students chose to submit hybrid solutions combining printouts from their Revit model with AutoCAD printouts or precise hand drawings. Leaving open the possibility of alternating hybrid solutions with the required all-Revit submittal was intended to encourage students to confront and address the limitations and capabilities of Revit relative to traditional (or at least pre-Revit) media.

The difficulty in structuring the exercises was to conceive of content and processes which tested the students' evolving knowledge of detail patterns and their skill in applying these patterns to a simulated building design, while simultaneously focusing attention on the behavior of Revit software.

The initial exercise stated the conditions governing the entire set of exercises:

> "Beginning with initial conditions and proceeding through two successive revisions, students will test the ability of Revit to support the process of detail development.
>
> "The initial conditions define the physical limitations and general appearance of the structure. Successive revisions to these conditions simulate the scope of possible revisions which practicing architects may encounter in the production of contract documents for an actual structure. Revisions may include (but are not limited to) changes to the originally defined size or shape of the structure; changes to the originally defined materials; changes to the scope, number, and size of openings within the structure, and so on."

The initial three exercises defined the conditions of the structure to be modeled:

> "The structure shall be rectangular in plan, with overall exterior dimensions of 15'-0" x 30'-0". It shall include a ground level at grade, and an upper level at a height of 11'-0" above grade. Its exterior walls shall be insulated cavity walls, consisting of a single bearing wythe of 8" concrete masonry units (cmu) and a single wythe of brick veneer. It shall be constructed on a slab-on-grade with 12" perimeter foundation walls extending 4'-0" below grade. The upper level and roof shall be constructed of solid-core 8" precast concrete plank, bearing on the cmu walls. The overall above-grade height of the structure shall not exceed 22'-0". It shall have one standard 3'-0" x 7'-0" exterior door and a total of six windows. Each of the six windows shall be square in elevation. All of the windows shall have mullions, the pattern of which shall be common between the windows (e. g. division by mullions into thirds, or into halves, or into a nine-square). Each of the six windows shall be of a unique size. Include an internal steel stair, connecting the ground and upper levels."

Students were provided with a list of documents to be submitted with every successive exercise:

> "[O]ne floor plan of each level; four exterior elevations; two building sections (one through the stair); an exterior perspective view; and sufficient details to describe the typical corner condition, the typical wall-to-ground condition, the typical cornice condition, the typical wall-to-upper-floor condition, and a typical opening (head, jamb, and sill)."

Subsequent exercises tested Revit's applicability to construction modeling by proposing specific changes to the building model. The three primary purposes of these statements were (1) to simulate typical changes that detailers could expect during a document production phase; (2) to raise the issue of how a Revit model inherently facilitates certain kinds of changes, such as raising or lowering a floor level, or changing the location of a wall in plan; and (3) to consider the assembly of a building model as being a process of configuring separate yet contributing systems. Examples of changes required in the subsequent exercises include:

> “Omit the requirement for brick veneer at the exterior walls. Instead, provide field-assembled metal panels equal to CENTRIA Versawall.”
>
> “Add three standard doors to the ground floor, so that there is one door on each elevation.”
>
> “Omit two of the original windows. Instead, provide a single window, 2’-0” in height, running the length of one building elevation.”
>
> “Revise the floor plan of the structure such that it is increased in length by 10’-0”. Keep all other requirements intact.”
>
> “In place of brick, use modular stone, nominally 4” thick by 8” tall by 12” or 16” in length.”

Thus, each new exercise deliberately altered the dimensions, configurations, or materials of the structure, simultaneously provoking response, testing the applicability of learned detailing strategies, and encouraging students to question the appropriateness of the software to the situation. Students found that the appropriateness of Revit was particularly called into question at the moment of detail production.

The Act of Detail Production in Revit

Revit possesses an apparent advantage over AutoCAD relative to the act of preparing standardized construction documentation: *the automation of context*. The production of a detail drawing using AutoCAD generally requires the detailer to provide context through the use of external references, and consequently, a detailer’s attention is constantly refocusing between large and small. For example, if during the production of a detail drawing, a design change should occur to the large-scale floor plan or building section, the detailer must proactively bring this context forward to test its influence on the detail; neglecting to do so runs the risk of miscoordination. Revit directly impacts this process because it automates the presence of large-scale context on the production of small-scale work. When a design change occurs to a floor plan (such as the movement of a wall) or to a building section (such as a change in the elevation of a floor level relative to grade), Revit’s inherent linkages automatically bring context forward to small-scale work. Changes to small-scale components are similarly brought forward automatically to affect larger ones. In a similar spirit, Revit’s built-in interference check tool automatically finds physical conflicts between systems, and numbered detail references automatically change if a drawing is moved from one sheet to another. These built-in linkages and hierarchical definitions largely reduce (though they do not eliminate) the possibility of miscoordination.

But even within this place of advantage, there exists a moment in the production of details at which the primary mode of operation shifts from the act of establishing parametric linkages and testing large-scale manipulations into the production of 2D projections. This shift in operational focus occurs at the moment in the detailing process where a “callout” (i. e. a large-scale detail drawing) is defined from a building section or floor plan. The shift occurs because *the mode of operation required when adding information to a callout view becomes practically indistinguishable from the act of tracing an external reference in an AutoCAD drawing.* Language accompanying a Revit tutorial on detailing makes this identity clear:

> "In the callout view, you trace over the building model geometry, add detail components, and then complete the detail by adding break lines and text notes."[1]

Significantly, although detail components may be family-based and may embody parametric linkages, they are *view-specific,* meaning that they do not carry forward to other views. Positional changes or size changes to a detail component within a single callout view do not impact the position or size of this component within other callouts. In other words, the act of detail-to-detail coordination is operationally identical to the act of detail coordination in AutoCAD: in both cases, the detailer must expend thoughtful effort to manually update positions, configurations, hatch patterns, text-based information, and so on. Because moving 2D line drawings between AutoCAD and Revit is trivially easy, Revit's presumed advantage over AutoCAD is to some degree called into question.

As an example consider the ubiquitous bearing angle in a cmu-backup brick wall. Such a wall modeled in Revit possesses a set of descriptive properties or attributes; the same wall modeled or drawn in AutoCAD is fundamentally limited to geometry (i. e. the wall doesn't inherently possess descriptive properties). To indicate a bearing angle in a Revit callout, a detailer may elect to model the bearing angle as a component, then to extrude it around all or part of the building, and to parametrically link it to the wall. Alternatively, a 2D representation of the angle may simply be inserted as a component within the callout view. But in either case, the callout view which eventually finds its way to the construction document set is "finished" in a 2D drafting mode analogous to the use of AutoCAD (where the angle is drawn within the detail view as a simple 2D-drafted object).

Capabilities and Limitations of Revit

Seen within the primary purpose of the course, the detail assignment submittals foreground ways in which multiple tools and media can be used productively to support the act of architectural detailing. In particular, student responses to the exercises highlight Revit's success as building information management software, illustrating its ability to change information quickly at the scale of the whole building. But, the same student responses also suggest that Revit does not possess uniformly clear advantages over other media in the act of detail production. Instead, many students found that because of the ease with which 2D detail drawings can be transferred between AutoCAD and Revit, it was more efficient for them to use AutoCAD for the production of detail drawings, and Revit to support the building model and building-level changes. A limited number of students responded similarly through the use of hand-drawn details.

As discussed in the previous section, Revit possesses the capability to automate context by means of comprehensively established linkages between elements and components throughout a building model. As a consequence of the ease with which it permits changes and modifications to model elements, Revit has a strong capability to capture and hold the attention of its users. But, while clearly enhancing production, the same capability has a vaguely troubling aspect. Precisely because use of the tool focuses immediate understanding of the concrete and specific, and because changes are so easy to make, it is easy for students to come to believe that Revit models possess a sort of "truth" not available through other means. This in turn suggests that in the long term there may be

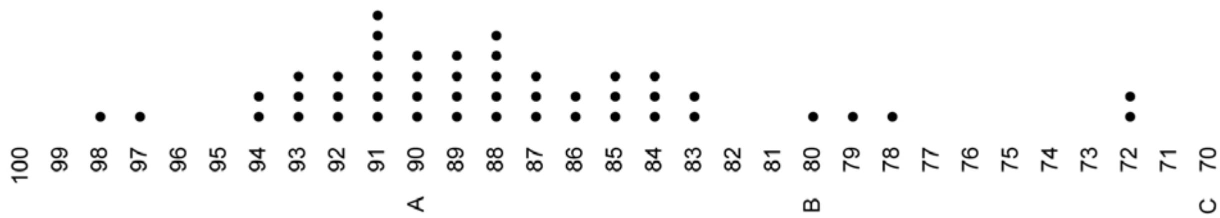

Figure 2. Chart of student performance.

a risk of students developing an overreliance on Revit at the expense of other media.

Through its multiple tracks of instruction, and particularly through the Revit assignments (which required production of content), the course implicitly raised a set of questions of recurring interest to this paper's author[2]: *what are the ways in which multiple tools and media can or should be used productively to support the act of architectural design? To what degree does the use of a particular tool or medium in a design process limit the possible outcomes?*

Conclusions and Opportunities

Student performance in the course (Fig. 2) was generally good, and student responses to the Revit assignments indicate the success of the strategy of "introduction" rather than "instruction toward mastery." There remain several opportunities for improvement in the course structure, the most obvious of which are a streamlining and integration of the multiple tracks of instruction, and expanded opportunities for Revit training.

As examples of the kind of integration between tracks which might occur in a future course offering, the construction site project could be restructured to require the students to draw details from observation, or to critique details within a provided set of drawings of the project. Or, details from the presented case studies could be made available for student critique or development based on an application of Allen's patterns.

Another approach to improved integration between multiple tracks of instruction would seek to identify commonalities between the pedagogy implied by Allen's text (instruction through patterns) and the instruction of Revit. Just as Allen posits "detail patterns" guiding the production of details, a future course could identify "Revit patterns" which guide the efficient and productive use of the software. The scale-shift discussed in an earlier section could be presented as one such pattern of use, as could the hierarchical definitions inherent in components and families.

Because students enter into the course with varying degrees of experience with three-dimensional modeling software, it would be appropriate in future course offerings to provide additional Revit training as an option to interested students. This additional training could happen in a workshop format, which could be held within class time or outside it. But, as Stephen Mamber writes:

> "[...i]f digital media courses aren't closely tied to conceptualizing the nature of the technology itself, they run the danger of becoming supervised software tutorials. .... To teach digital media, then, is to produce a new form of hybrid student who has gone beyond the parochial separations of production and theory."[3]

References:

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Notes:

[1] Excerpted from Revit tutorial titled "Creating a Detail from a Building Model", included with Revit Building 8.1.

[2] Christenson, 2005.

[3] Mamber, 1997.